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Design for Sustainability

ecological dimension

Module 5

Green Building and Retrofitting

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English version

ecological dimension

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1. Introduction

This Module takes a hard look at the impact of the built environment upon the Earth and how the related consumption patterns are exacerbating climate change. This is necessary given that the global average impact of the built environment and its operational uses, is estimated to use: 18% of the planet's use of fresh water; 25% of the wood consumed; 40% of fossil fuels, and, 27% of energy generated. The adoption of sustainability criteria in the built environment sector will therefore make a significant impact to contribute towards climate change mitigation and adaptation. This is particularly relevant wherein the rural to urban migration is creating significant pressure on the built environment to utilize available resources in a sustainable manner, especially with the world population expected to reach 9 billion by 2050, with an estimated 70% living in urban areas, an increase from 46% in 2015 (Source: Global Footprint Network).

This Module looks at both the 3-dimensional (3-D) vertical aspect of the built environment and also the 2-dimensional (2-D) horizontal spatial layout aspect. In other words, the form, shape and purpose of a building itself needs to be firstly designed according to sustainable design principles, but also, its spatial relationship to other buildings, the surrounding landscape and service networks. In order to address the negative impact of the built environment, the context is firstly provided from the Ecological Footprint science. Thereafter, the whole systems thinking approach is outlined before unpacking some sustainable design strategies for both new-build and retrofitting of the built environment for 3-D and 2-D applications.

From a practical perspective, the examples within this Module provide for a better understanding of how to identify the shortcomings of modern building and construction, and introduces how to design and construct or retrofit healthier, more ecologically friendly and energy efficient built environments, as well as, how to embed integrated design to achieve more functional town plans with integrated utilities.

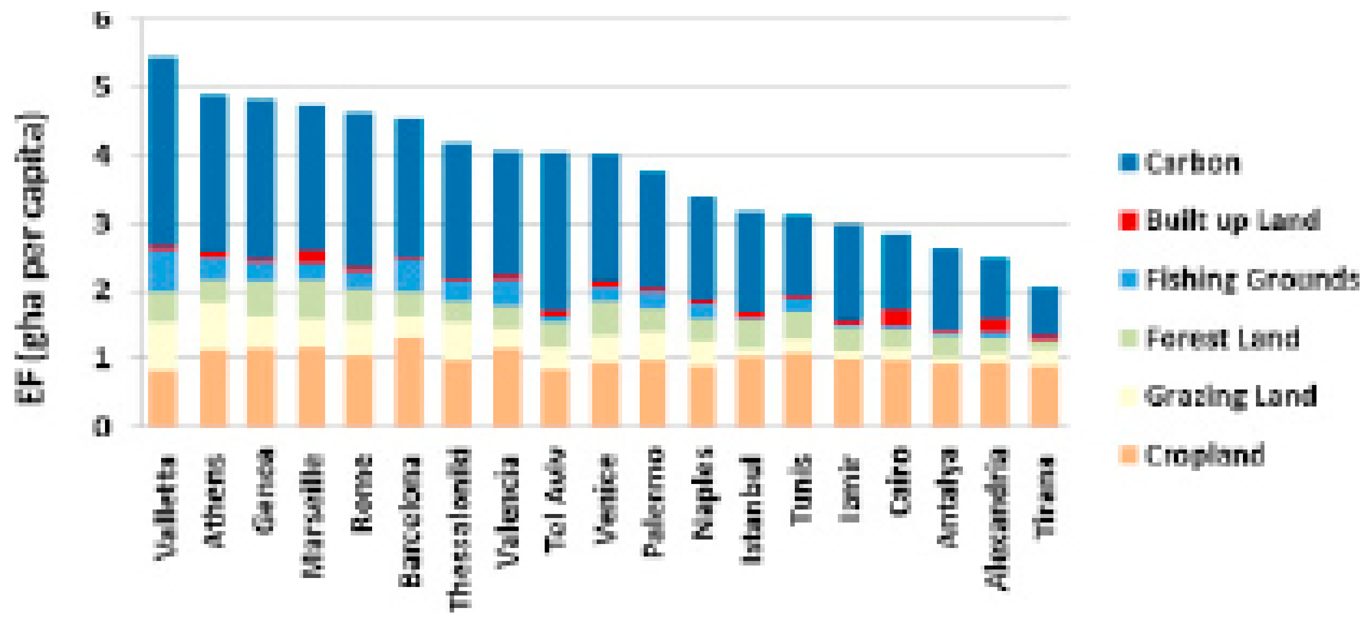
Context

There is no longer any doubt that human activity has changed the face of the Earth and is disrupting the sensitive balance of ecosystems which is driving the Holocene extinction, otherwise referred to as the sixth mass extinction or Anthropocene extinction. In fact, the Ecological Footprint of most urban areas far exceeds the biocapacity of their entire countries. For example, according to The Global Development Research Center, the ecological footprint of London alone is 120 times the area of the city itself, and basically requires the rest of the UK to support this biocapacity without any other development, and similarly, the ecological footprint of the Tokyo metropolitan area is almost three times the land area of Japan as a whole. Both these city examples are clearly unsustainable, which means that most urban areas are "borrowing" biocapacity from future generations. This is no longer feasible and urgent measures are required to arrest and reverse this dangerous trend.

Another study from the Global Footprint Network, compared the resource demand of cities in the Mediterranean region (see Figure below) and their contribution to the regional ecological deficit in order to highlight the natural resource challenges and opportunities of such urban centers in the Mediterranean region. This study identified food and transportation as the largest factors of the Ecological Footprint so that local governments can understand what their sustainable development strategies ought to focus upon.

Although it was found that the differences among the Ecological Footprint values of these Mediterranean cities was largely attributable to socio-economic factors, such as disposable income, infrastructure, and cultural habits, there was another "double dynamic" factor at play. Herein, the authors found that: "On one hand, cities concentrate investment in, and offer more access to, energy-saving modes of consumption (largely, because of institutional density and economies of scale), thus contributing to smaller per capita Footprints, all other things being equal. On the other hand, cities have also been functioning in recent history as a "social elevator," enabling residents to earn higher pay, thereby typically also increasing their consumption level". These are important dynamics to understand in order to refine sustainable development strategies and related leverage points of influence for policymakers.

The Stockholm Resilience Centre has identified nine planetary boundaries within which humanity ought to contain its impact in order to sustain its presence on the Earth.



Comparative Ecological Footprints of cities in the Mediterranean region

However, scientists from the Potsdam Institute for Climate Impact Research (PIK) concluded in 2015 that at least four of these boundaries had been transgressed, namely, climate change, loss of biosphere integrity, land-system change and altered biogeochemical cycles. It suffices to stress that human activity in urban areas has a significant impact upon these four planetary boundaries, and if left unchecked, will start eroding the remaining boundaries.

Whilst the general negative perception of urbanization is increasing pollution, lack of resources, destruction of habitats, social inequality, lack of public facilities, lack of housing opportunities, high cost of living, access to public transport, etc., there is also a positive factor regarding general efficiencies which can be derived through proper integrated planning. For this reason, the urbanisation trends for both the first and third world presents an important understanding in order to address challenges and opportunities for sustainable built environments. Herein, there are two major dimensions that need to be addressed. Firstly, one should address solutions to buildings and their immediate footprints, and secondly, the spatial context for such cluster of buildings. In other words, green building applications can be seen as "vertical or three dimensional (3-D) solutions", whilst green spatial applications can be seen as "horizontal or two dimensional (2-D) solutions" pertaining to sustainable spatial economy, infrastructure and utilities. The 3-D and 2-D solutions for the urbanisation trends of both the first and third world will have a different focus.

It can be generally surmised that the built environment for the first world is relatively well developed wherein the focus of 3-D sustainable solutions will be retrofitting of existing buildings and refinement of efficiencies within the 2-D spatial aspects. Meanwhile, the growing urbanisation within the third world, will create more opportunity for 3-D green new-build and 2-D integration and efficiencies within the spatial layout of urban areas.

The sustainable (green) building solutions are relatively easier to apply, even if through retrofitting. However, sustainable spatial solutions may be somewhat more difficult to achieve, especially since urban patterns tend to be dominated by infrastructure for transport and utilities. Herein, the sins of the city fathers in laying out such infrastructure is particularly relevant since these affect generations to come. This is particularly evident in modern sprawling cities that are modelled on individual car ownership compared to the older more compact cities established prior to the introduction of the motor car. Both 2-D and 3-D solutions are required in order to achieve genuine sustainability in the built environment. For example, all the benefits of 3-D green solutions for a building may be negated if it is located in a sprawling inefficient 2-D spatial context.

2.

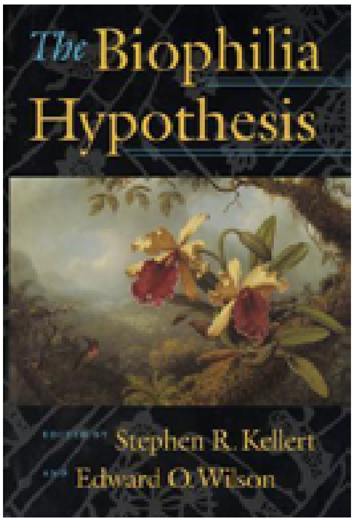
Whole Systems Thinking Approach

The familiar Whole Systems Thinking Approach, which forms the foundations of this Ecological Dimension, has several inspiring themes, namely:

- to provide ecosystem services through building performance functions;
- to achieve low impact designs with lower ecological footprints and relatively smaller buildings;
- to adopt Biophilia which includes organic design using natural materials and ecological engineering; and,
- to establish a "spirit of place" which includes vernacular design with a strong relationship to place.

In particular, The Biophilia Hypothesis, by Edward O. Wilson and Stephen R. Kellert, suggests that there is an instinctive bond between human beings and other living systems. Biophilia therefore promotes the connection between the built environment and conservation by creating more greenspaces in and around cities in order to integrate ecosystem services.

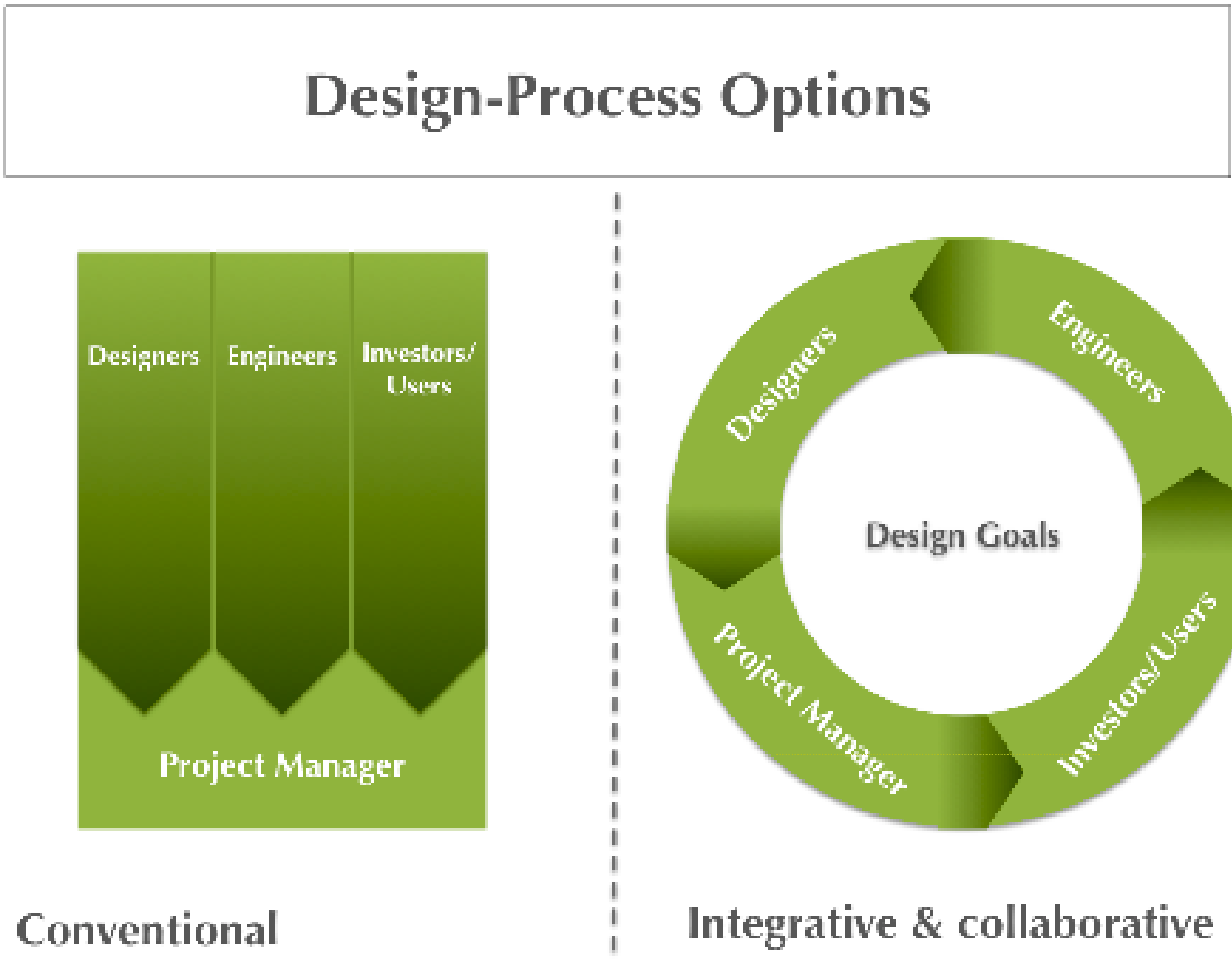
The Whole Systems Thinking Approach for the built environment is now explored further in four cross-cutting aspects which will be expanded in subsequent sections.



The Biophilia Hypothesis

Firstly, a Whole Systems Thinking Approach is a central theme of the transition to sustainable and regenerative communities, cities and bioregions. It requires design collaboration within trans-disciplinary teams of different experts and future users, compared to the dominant conventional silo mentality, as illustrated below. All stakeholders ought to embrace design collaboration in the way that engagements are made.

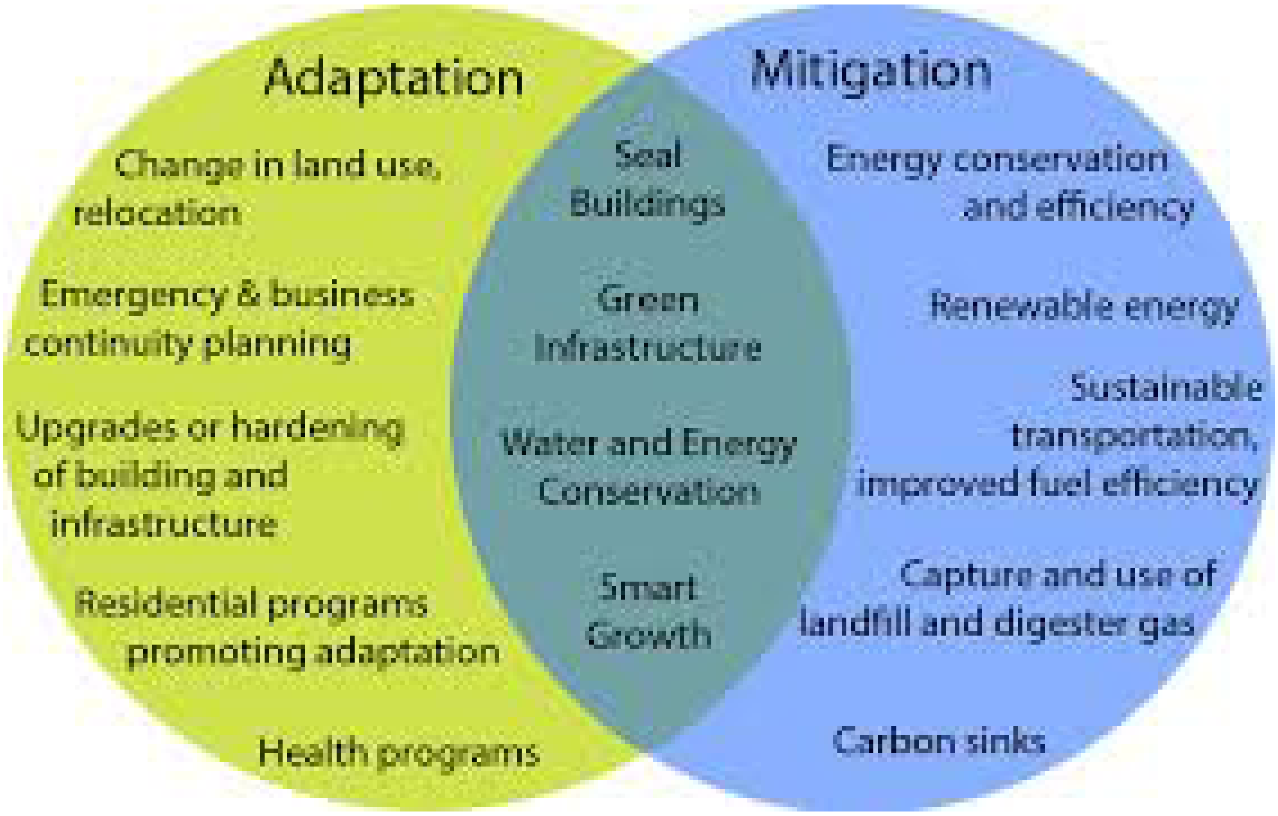
Secondly, a positive enabling environment is required with appropriate policies for sustainable development which facilitates the development of appropriate strategies for Climate Change Adaptation and Mitigation for both the public and private sectors, as depicted in Figure 5.3. Generally, Climate Mitigating actions have a global impact whilst Climate Adapting actions have a local impact. Herein, the policies and strategies should



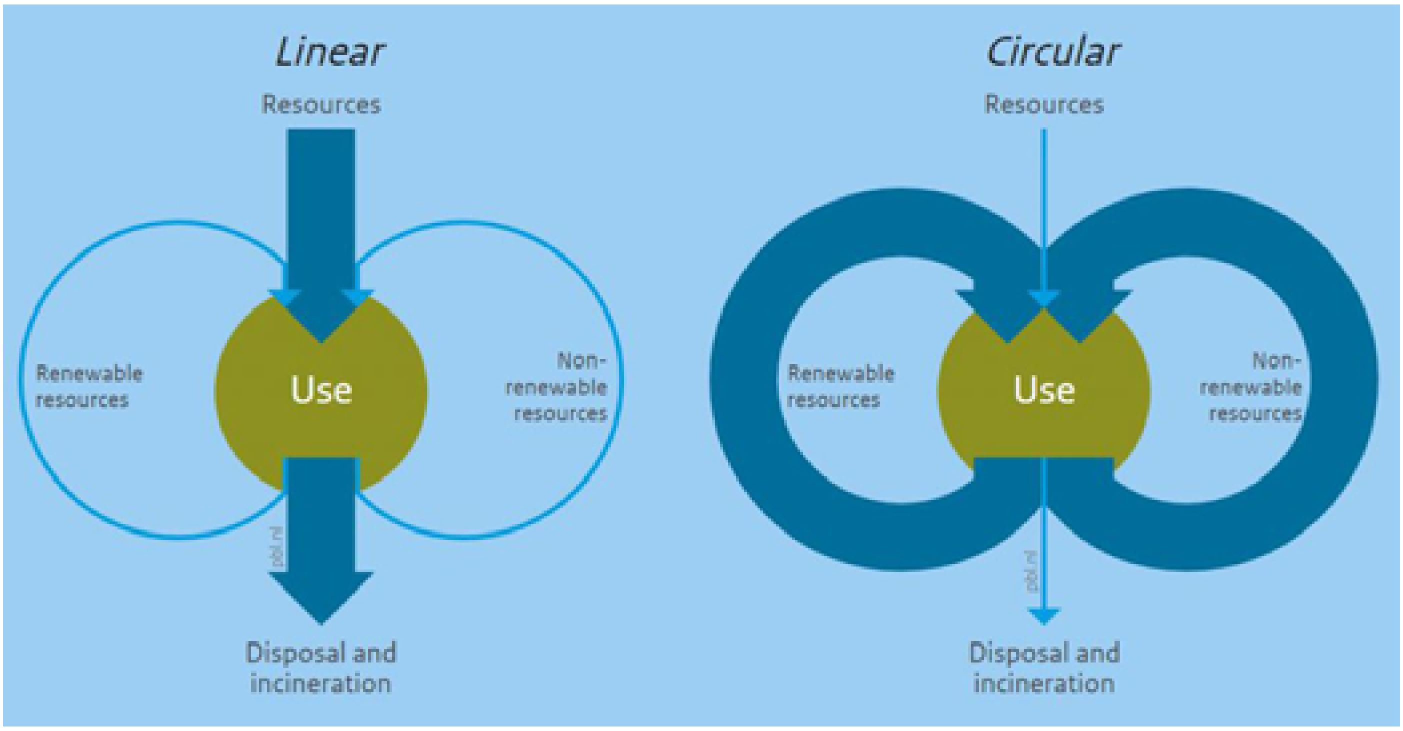
Design Processes, Rocky Mountain Institute

focus on the categories of human impact, especially for urban areas, such as, the built environment, utilities, transport, energy and food production. Thirdly, a Whole Systems Thinking Approach based on closed loop / cyclical systems provides the central 3-D theme for new-build and retrofitting solutions for the built environment, as shown in Figure 'Buildings that function as ecosystem'. More specifically, sustainable design will attempt to connect the different elements of a building system into cyclical mutually reinforcing relationships that avoid waste, capture and use energy sustainably, and maintain or improve the quality of water, air and soil, whilst mitigating expensive operational and maintenance costs.

Fourthly , the 2-D design integration of a city-wide integrated infrastructure system is essential in order to achieve sustainable design along spatial perspectives, especially for large scale development projects. Herein, the argument of centralised versus decentralised spatial patterns and associated infrastructure and services has been at the forefront of the debate for enhancing the sustainability of the built environment. The concept of strengthening local internal linkages are considered to be a more resilient strategy than relying on external global dependent linkages, as introduced in Module 1.

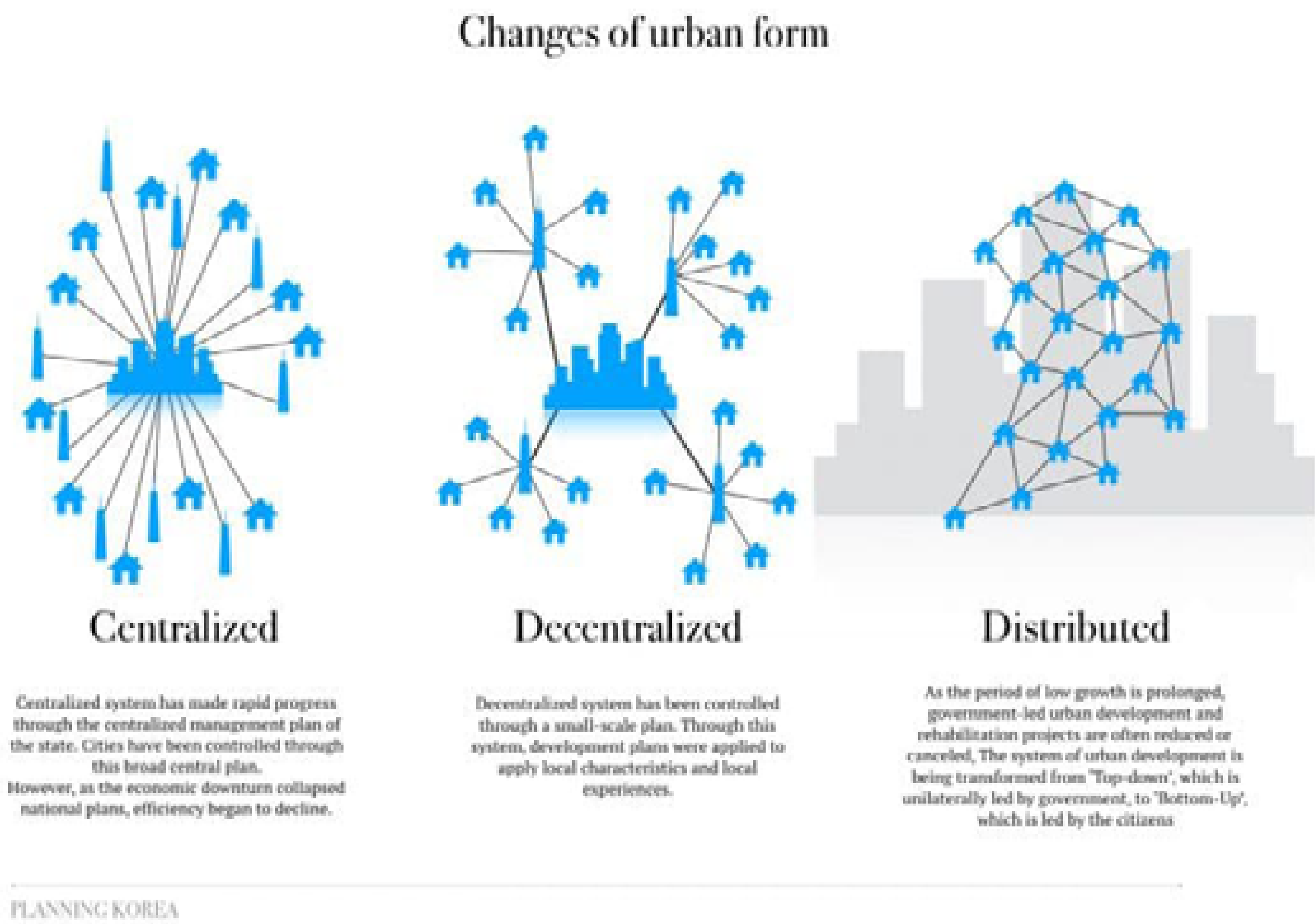


[Climate change mitigation and adaptation policy/strategies]



[Buildings that function like ecosystems]

However, there is a growing realisation that since the last economic world recession in 2008, there has been very little, if any, economic growth in real terms. One of the reasons for this phenomenon given by the Transition Town movement, is that the relative cost of energy has risen, and this is now hampering an economic revival which had before 2008 always relied upon relatively cheap energy to kickstart an economic upturn. The days of cheap energy are over, especially with the transition cost to renewable energy. In turn, this is starting to reshape our design thinking for the built environment. This appears to be a long-term emerging trend that is changing the form of the city as illustrated in Figure below, which shows that as economic growth slows down, government-led "top-down" urban development projects are being scaled back to "bottom-up" development led by the citizens. This trend is also facilitating the era of Degrowth, which is a movement that promotes the scaling back of consumerism and resource depletion in keeping within biocapacity limitations.



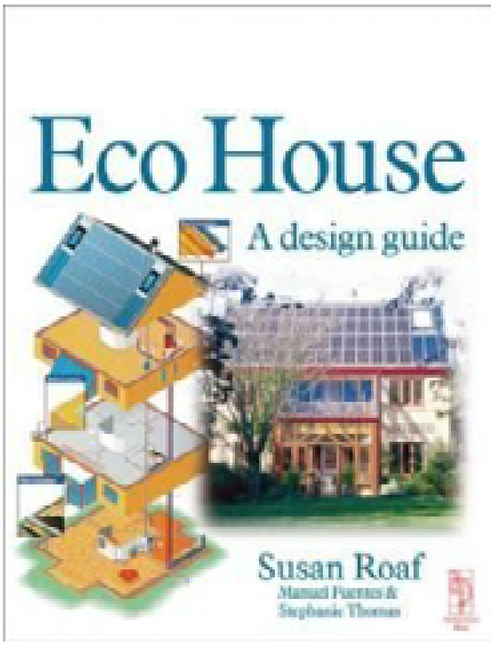
Changes in the urban form

3.

Sustainable Building Design Strategies

The aforementioned 3-D whole systems thinking approach, is now further explored as Sustainable Building Design Strategies (also referred to as "Green Building") for both new-build and retrofitting of buildings within an urban and architectural design framework, as shown in Figure in the next page, where in five categories of design strategies are unpacked for better understanding, namely:

- **Bioclimatic strategies – intelligent design;**
- **Conservation – mainly around green building materials;**
- **Energy – aiming at carbon neutrality;**
- **Waste management – recycling solids and water as far as feasible;**
- **Social strategies – designed for community involvement as well as smart controls of technologies, broadband services and security.**



Eco House - A design guide

Several of the drawings used in this section are from the book Ecohouse by Susan Roaf, Manuel Fuentes and Stephanie Thomas (2007), or inspirations derived therefrom. A short summary presentation of the Ecohouse project in Oxford, England can be found here. Another source of inspiration is Green Building magazine to help one design and build sustainable, healthy and ecological buildings. A further reference source is The Passive House Institute (PHI), which is "an independent research institute that has played an especially crucial role in the development of the Passive House concept - the only internationally recognised, performance-based energy standard in construction"

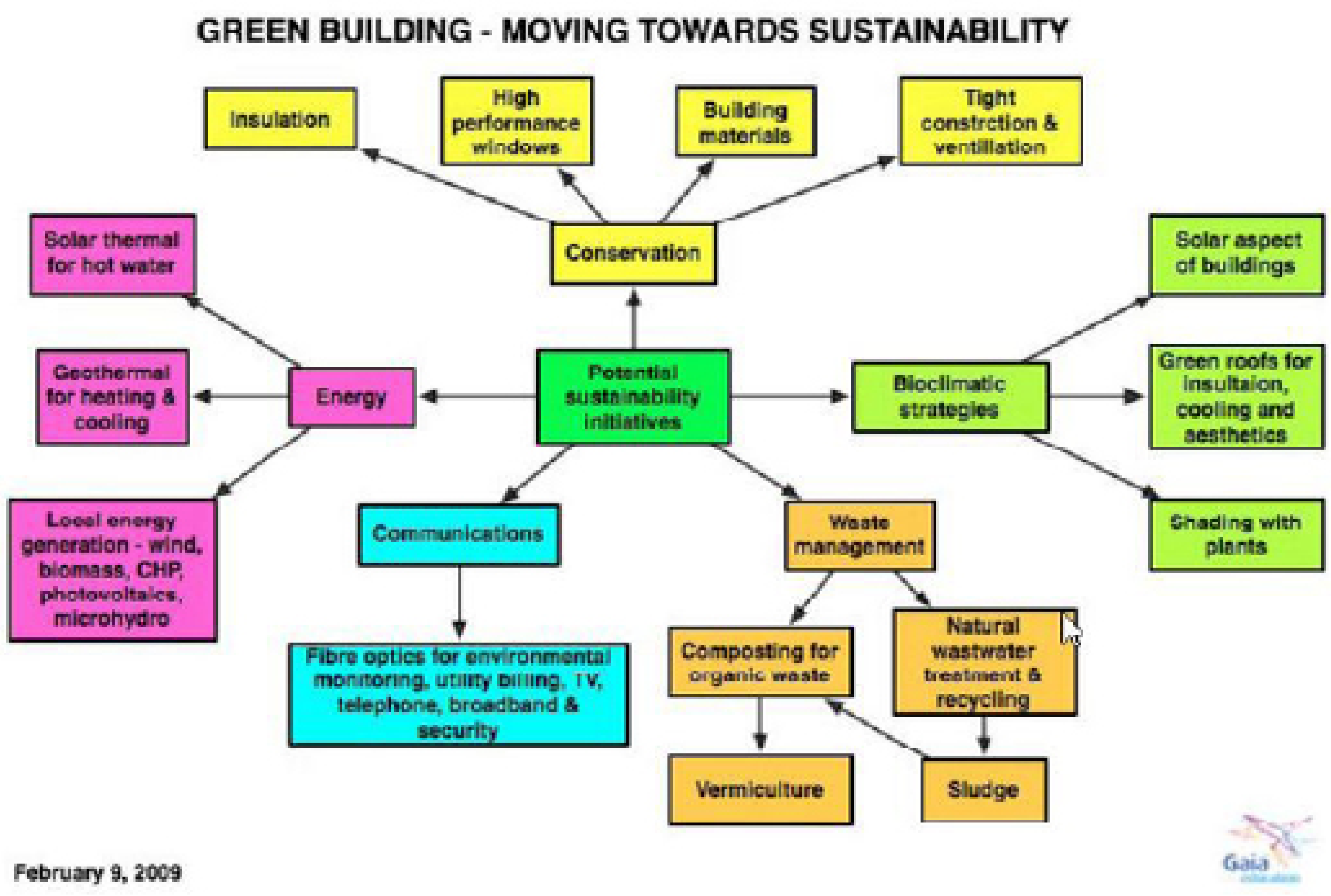


Figure 5.6: Sustainable Building Design Strategies

Bring it to Life!

Think about the place you call home: you may own or rent, alone or share with others.

- **What is the house orientation?**
- **What are the materials is it built of?**
- **How are the rooms distributed?**
- **Are the rooms and furniture appropriate and/or adapted to the functions of those-rooms?**

Looking at figure above, are there any of those strategies useful for your reality?

Can you think of other strategies that may be appropriate to the place you live?

Post your ideas in the forum.

3.1 Bioclimatic Strategies

Bioclimatic strategies are a key element of designing sustainable houses. The aspect (relative position) of the building to the arc of the sun along with attention to specific site conditions is paramount in order to create an ecologically intelligent design. Where heating is a key issue, a passive solar design will determine the aspect of the building to the sun. Where cooling is an important consideration, landscaping can provide shading and the wind natural ventilation. More specifically;

- **Sensitive site design** attempts to minimize environmental disturbance by taking cognizance of; weather influences of sun, wind and rain; niche microclimates; site hydrology, topography and geology; and, site flora and fauna.

- **Solar aspect of buildings or passive design** is all about building aspect to maximise solar gains as illustrated in the 2 figures below whilst the following one shows some solar harvesting designs using thermal mass of masonry and rock beds, as well as, air flow gaps. Active solar heating can be achieved by building thermal mass into the structure. Thermal mass combined with thermal insulation in a building buffers changes in the outside environment, thereby creating more even and comfortable conditions inside the structure. These processes can be enhanced with active systems, using fans and pumps.

- **Green roofs for insulation**, cooling and aesthetics can provide extra insulation as well as aesthetics to a design. Many green roofs absorb the sun's energy as opposed to reflection and can reduce the ambient temperature within an urban district.
  A good option for green roof plants is sedum or to allow the natural surrounding grasses to establish themselves. However, regular maintenance of the green roof is essential in order to remove any shrubs or tree seedlings which take root. A typical green roof design shows
  the various layers that make up a good design detail which ensures that the roof structure remains waterproof. The green roof design around the verges and gutters is usually quite challenging, but again, the details must ensure that excess rainwater is adequately drained away at all times.

- **Shading with plants** is landscaping with deciduous trees and extended roof lines to provide shading for summer cooling, whilst low sun in winter through bare trees can provide passive solar heating. Similarly, pergolas with vines over verandas can provide much needed summer shading whilst in winter the leaves will fall and allow winter sunlight for warmth, as illustrated in.

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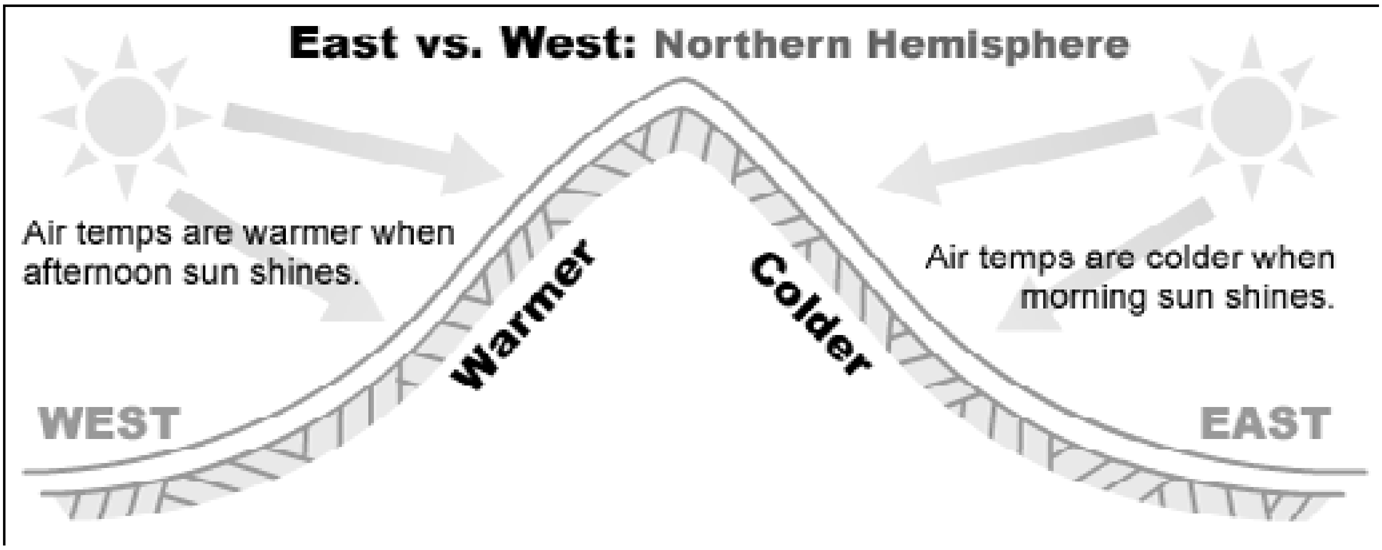
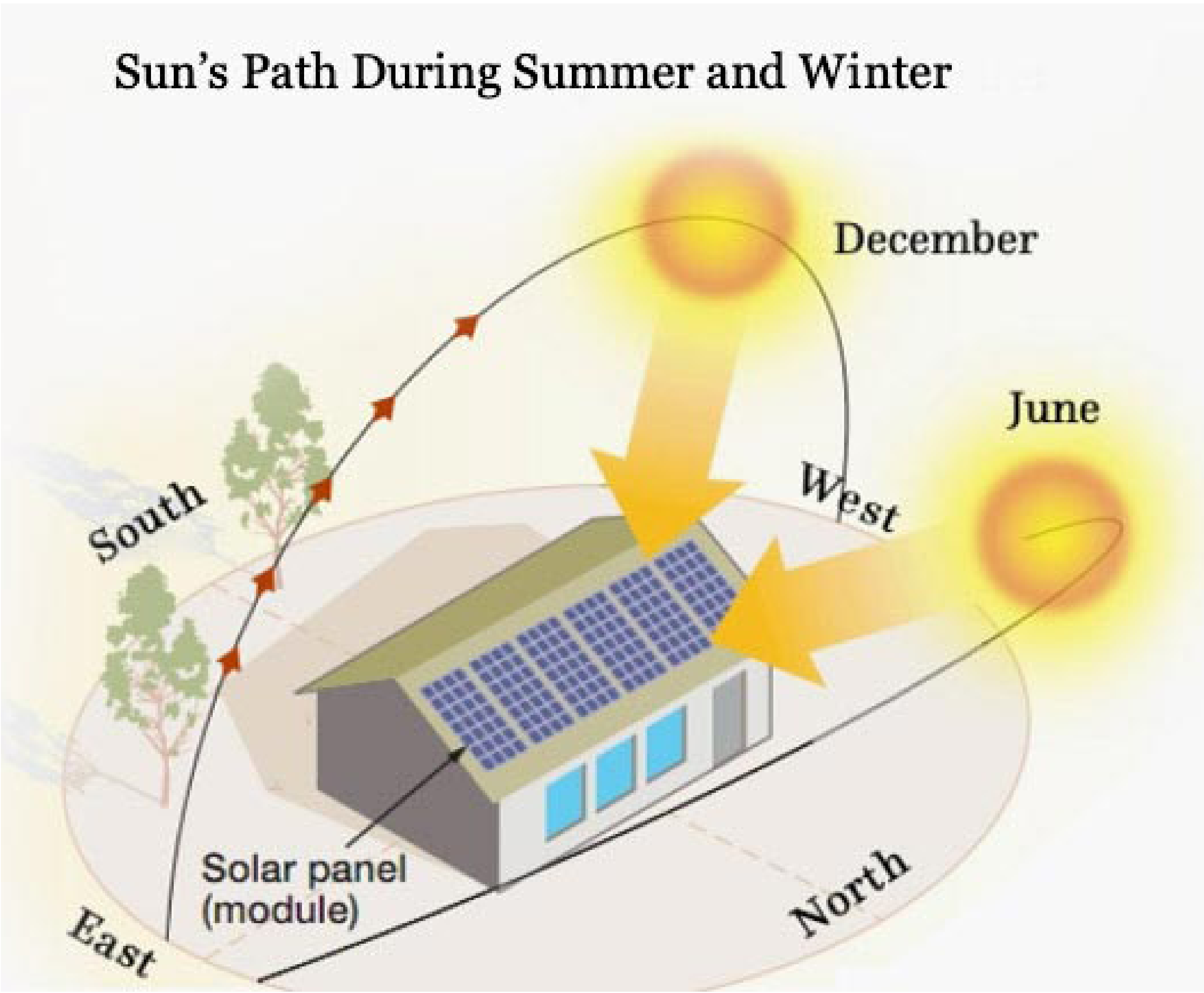
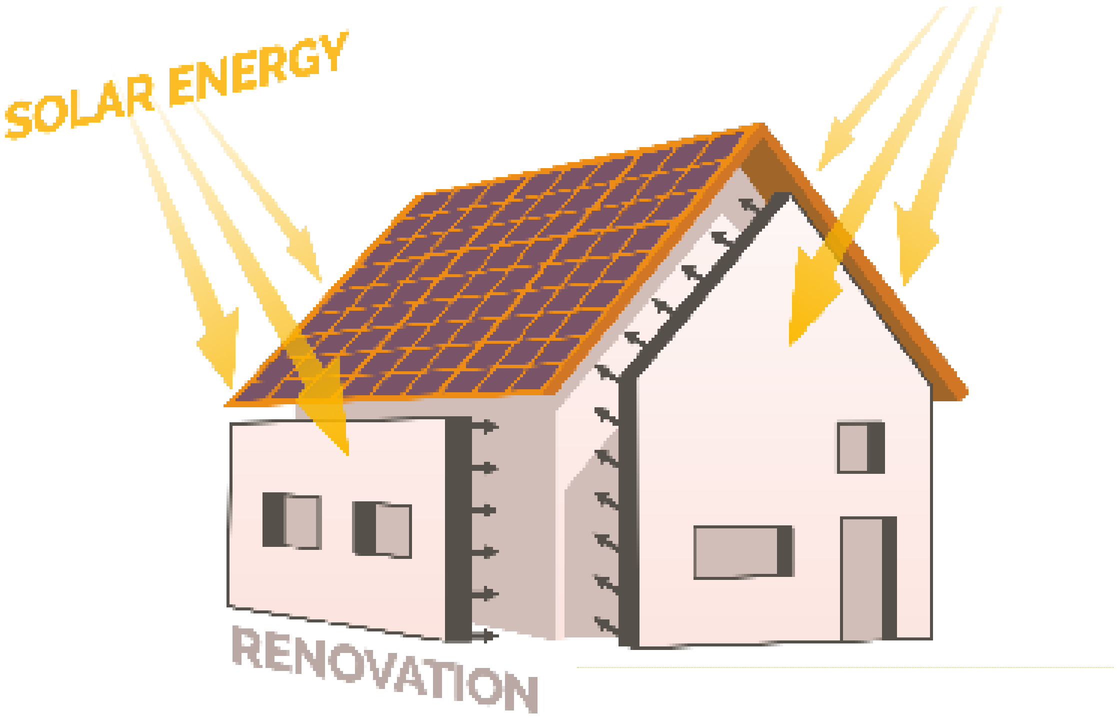




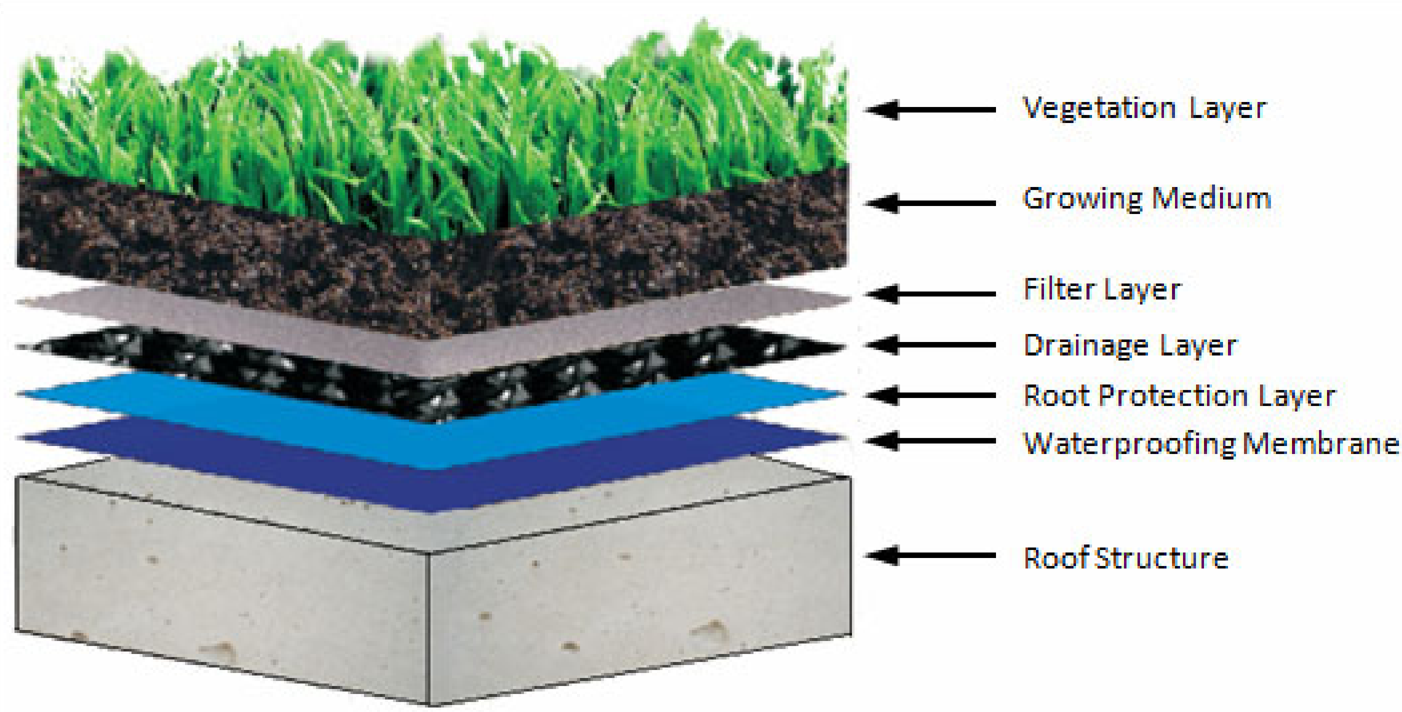
[Northern Hemisphere solar aspects]

Northern Hemisphere, reproduced from diagram by Neufert E and Neufert P (Neufert E et al. 2012)

[Functional Planning for Solar Gain]



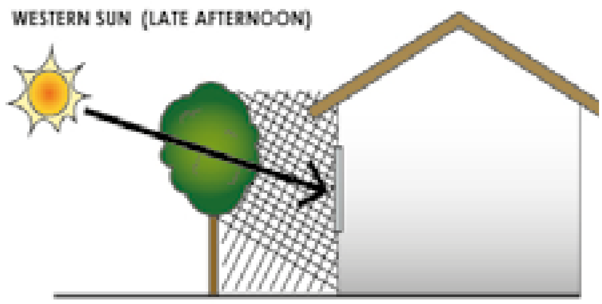
[Design for Solar Gain]



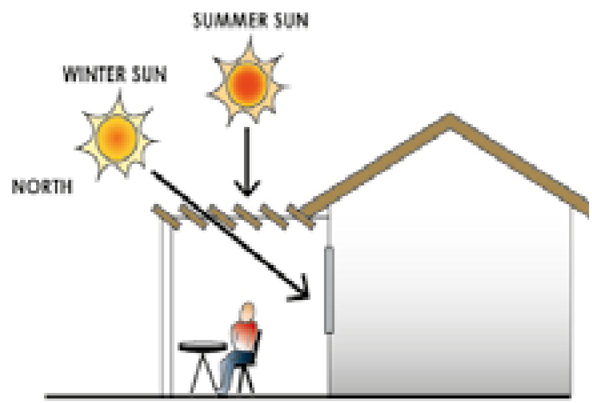
Rooftop Landscapes incorporate a system of layers of engineered linings

[Rooftop Landscapes]

- **Natural ventilation** is where it is necessary to have forced air ventilation for bathrooms and kitchens. There are also useful techniques for passive or natural ventilation, for example termite ventilation (video), which can be applied depending on the specific site and climate.



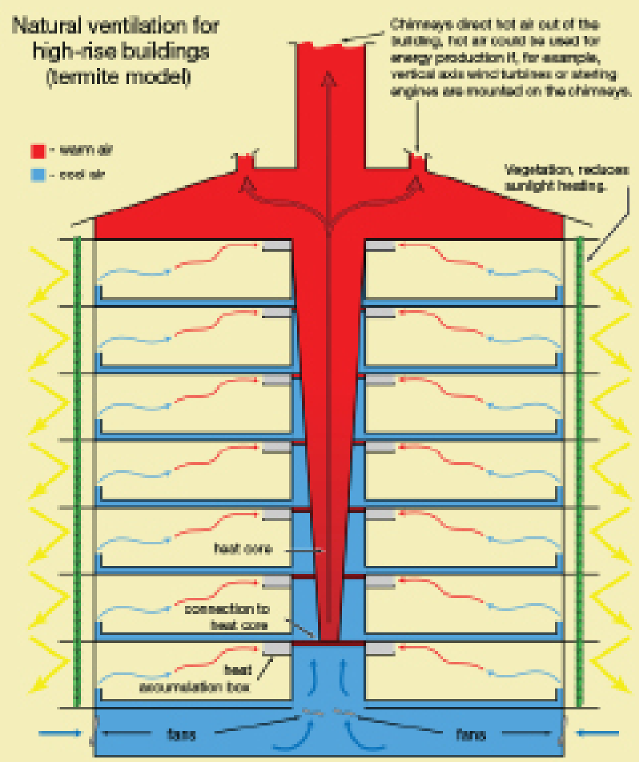
Strategic tree planting around your home can help protect windows from late afternoon western summer sun.



Shading devices fitted to external verandahs & pergolas can allow winter sun to penetrate internal living areas while blocking the harsh summer sun

[Shading with plants]

Case study 1: Biomimicry in Ecological Building Design



A schematic shows the air movement within Eastgate Centre.
Image: Mick Pearce

The Eastgate Centre in Harare, Zimbabwe, typifies the best of green architecture and ecologically sensitive adaptation. The country's largest office and shopping complex is an architectural marvel in its use of biomimicry principles. The mid-rise building, designed by architect Mick Pearce, in collaboration with Arup engineers, has no conventional air conditioning or heating, yet stays regulated year round with dramatically less energy consumption using design methods inspired by indigenous Zimbabwean masonry and the self-cooling mounds of African termites! (Source: Inhabitat)

The Eastgate Centre uses 35% less total energy than the average consumption of six other conventional buildings with full HVAC (heating, ventilation, and air conditioning) in Harare. The saving on capital cost compared with HVAC was 10% of total building cost. During the frequent shut down of mains power, or of HVAC due to poor maintenance in other buildings, Eastgate continues to operate within acceptable confort levels with its system running by natural convection.

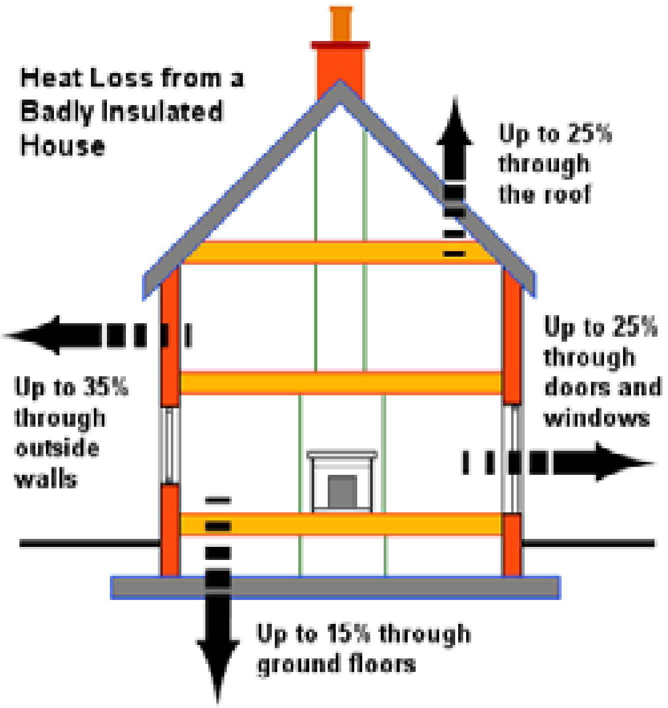
"Whether a building has begun to attain a life of its own since occupation is a matter of judgement. This was an attempt to design a building based on the metaphor od a living system more like a termitary. An ecosystem, not a "machine for living in"

Mick Pearce

3.2 Conservation Strategies

Insulation is one of the most critical building design details in order to mitigate the ingress of moisture and dampness into a building. There are many places in a building which are prone to dampness and should therefore be addressed through proper insulation as illustrated in Figure below.

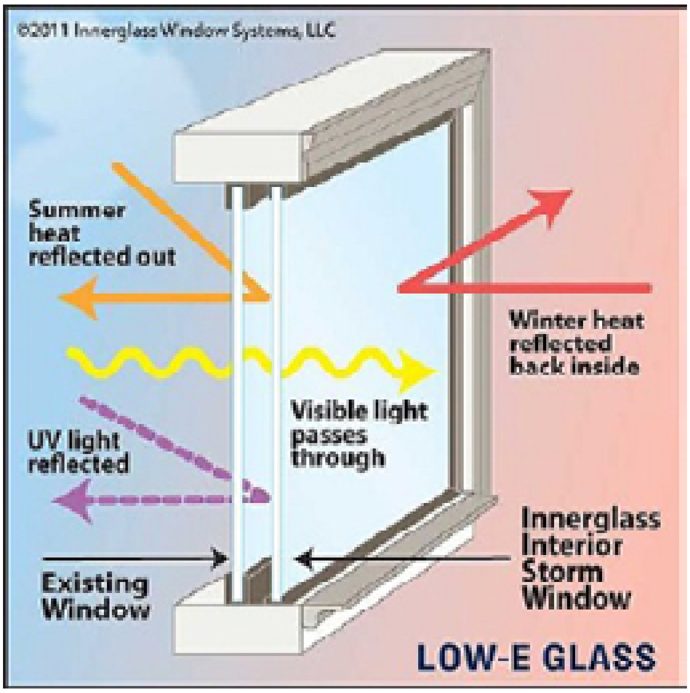
High performance windows are an important design feature considering the relative window to wall ratio and the density of glass to various walling solutions. The relatively low glass density makes for a greater transfer of temperature difference between the external and internal components of a building compared to most walling densities. However, with double or triple glazing with inert gas seals, the air gap reduces heat transfer by conduction and convection, since air is a poor conductor and the air gap is too narrow for convection currents, respectively. However, with double or triple glazing with inert gas seals, the air gap reduces heat transfer by conduction (since air is a poor conductor) and convection (since the air gap is too narrow for convection currents). Furthermore, with Low-E, or low-emissivity glass, the amount of infrared and ultraviolet light that comes through glass is minimized without minimizing the amount of light that enters the building. Low-E glass windows have a microscopically thin coating, usually on the external face of the internal double glazing, which is transparent and reflects heat. The combination of double, triple glazing, Low-E glass and plant shading, all offers various combinations to reduce energy consumption of heating and cooling of buildings, as illustrated in the windows Figure in next page.



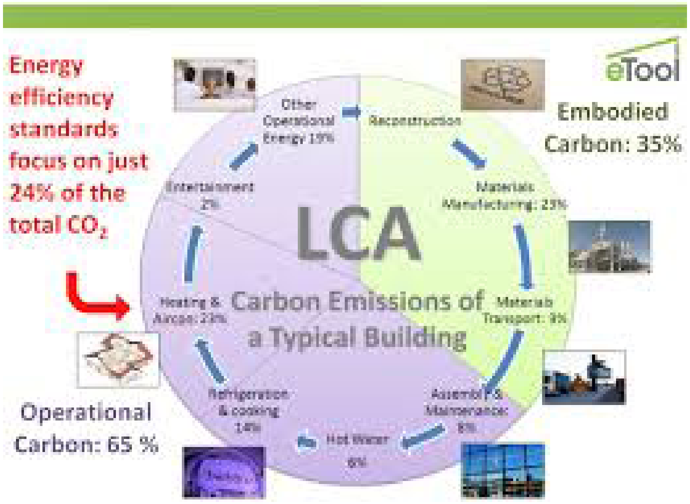
General heat losses in a building

Building materials is the choice of materials with low emergy (embodied energy/carbon footprint, both initial and ongoing – see LCA Figure) as a means to reduce the ecological impact of a building by doing a life-cycle analysis (LCA). The LCA in this figure shows that, generally, the total emergy of a building, is approximately 35% during the initial implementation and 65% during the ongoing lifetime operational and maintenance of the building. One should therefore design to minimize the impact for both during and post implementation.

Given that many buildings exhibit high ecological footprints, it becomes imperative to reduce this impact through the choice of various building materials. Using local materials from within the bioregion of a



Combination of double glazing and low -E glass windows

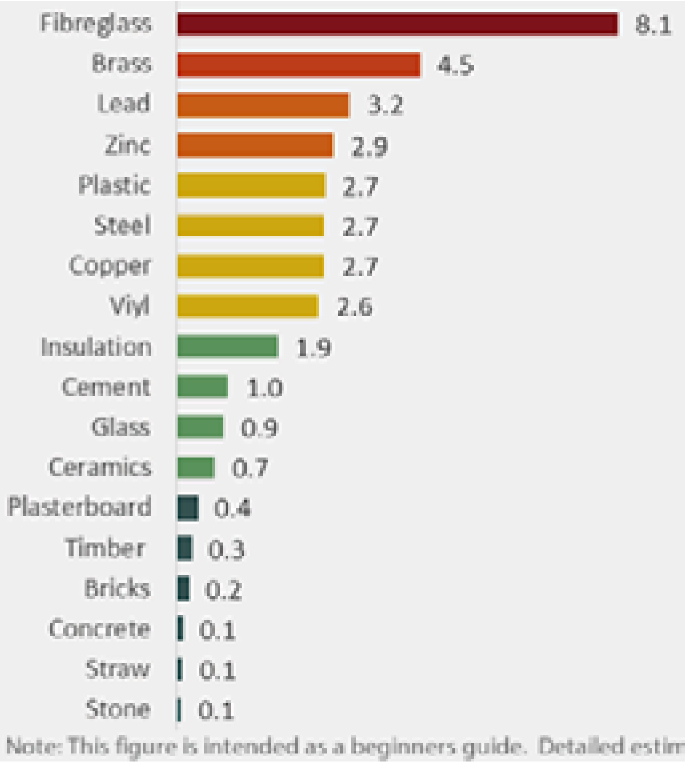


Life Cycle Analysis (LCA) – Embodied Energy ("Emergy")

building project will contribute significantly towards reducing emergy values, especially through relatively low emergy materials such as: local wood, unfired clay bricks, rammed earth, cob, adobe bricks, stone masonry, local ceramics and tiles, local insulation (which might be sheep's wool, recycled paper, straw, hemp). See collage of "Building with Earth". Meanwhile, materials with high emergy include concrete, aluminium, steel, highly manufactured items, and, bulky materials sourced from great distances. The choice of building materials (Embodied carbon Figure) is therefore an important factor in designing for carbon neutral buildings.

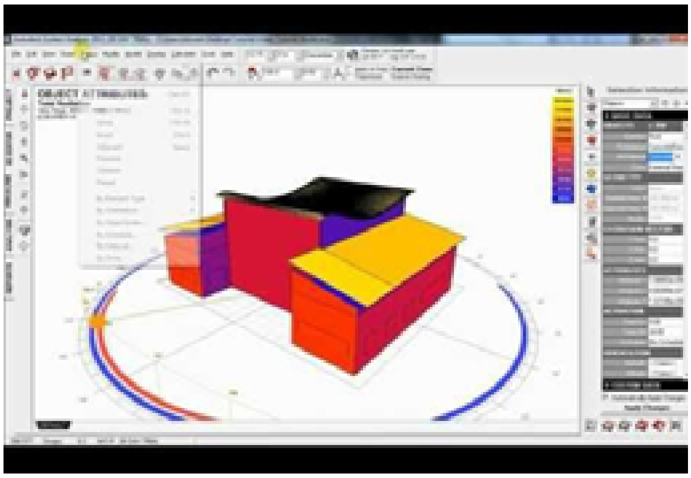
Tight construction and ventilation are a feature of construction details which requires attention to detail to ensure air tightness where heating is necessary, which makes a large difference to the energy budget. However, it is also necessary to have forced air ventilation for bathrooms and kitchens. There are also useful

Source: One Community Global



Embodied carbon of some building materials

techniques for passive or natural ventilation, as per the termite ventilation described before. The form and shape of a building is also an important factor to consider when detailing construction joints and ventilation. A typical useful software design tool that can identify potential weakness in building design is "Autodesk Ecotect Analysis", which



Autotect Ecotect Software

is an environmental analysis tool that allows designers to simulate building performance from the earliest stages of conceptual design. It combines analysis functions with an interactive display that presents analytical results directly within the context of the building model", as shown in Figure above and in a video demonstration.

Natural lighting or daylighting is the efficient design to bring natural light into a building by using exterior glazing (such as, windows, skylights, etc.), thereby reducing artificial lighting requirements and saving energy, as illustrated in Figure below.

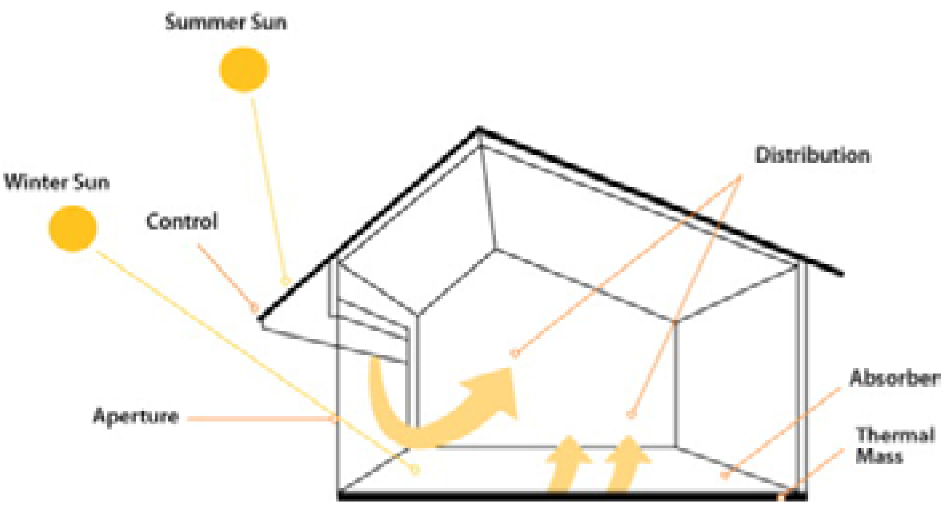
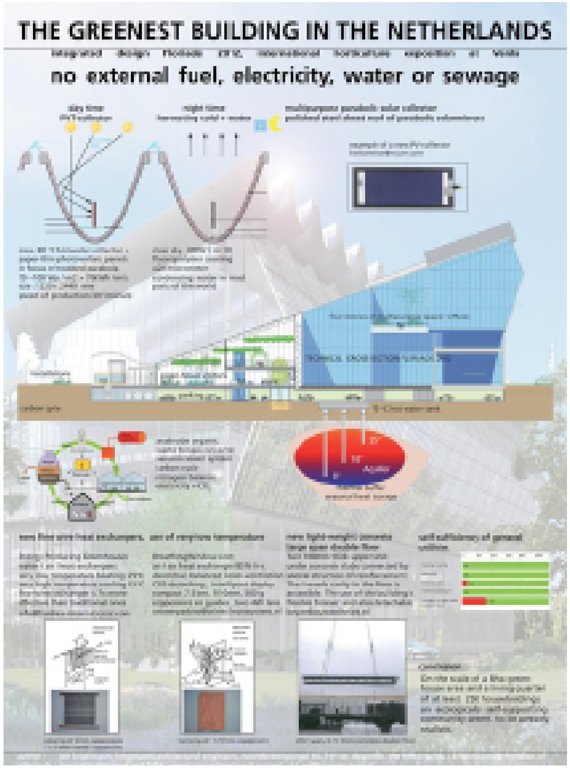


Illustration of natural lighting into a building

3.3 Energy Strategies

This is covered in more detail in Module 4, but reference is made to the Figure beside which illustrates a cyclical ecological design thinking for both new-build and retrofitting of buildings for energy conservation. Herein, several building systems are integrated in order to maximise sustainability of the building. More specifically, energy supply is from wind, solar thermal, photovoltaic, biogas; water supply from municipal source, but augmented with rainwater harvesting and wastewater treatment; and, an ecological sanitation system that recycles waste nutrients as compost and provides biomass for the biogas digestor. This ecological design reduces the negative waste impact and also the operational cost of utilities, such as, water, sewage, electricity and solid waste removal.

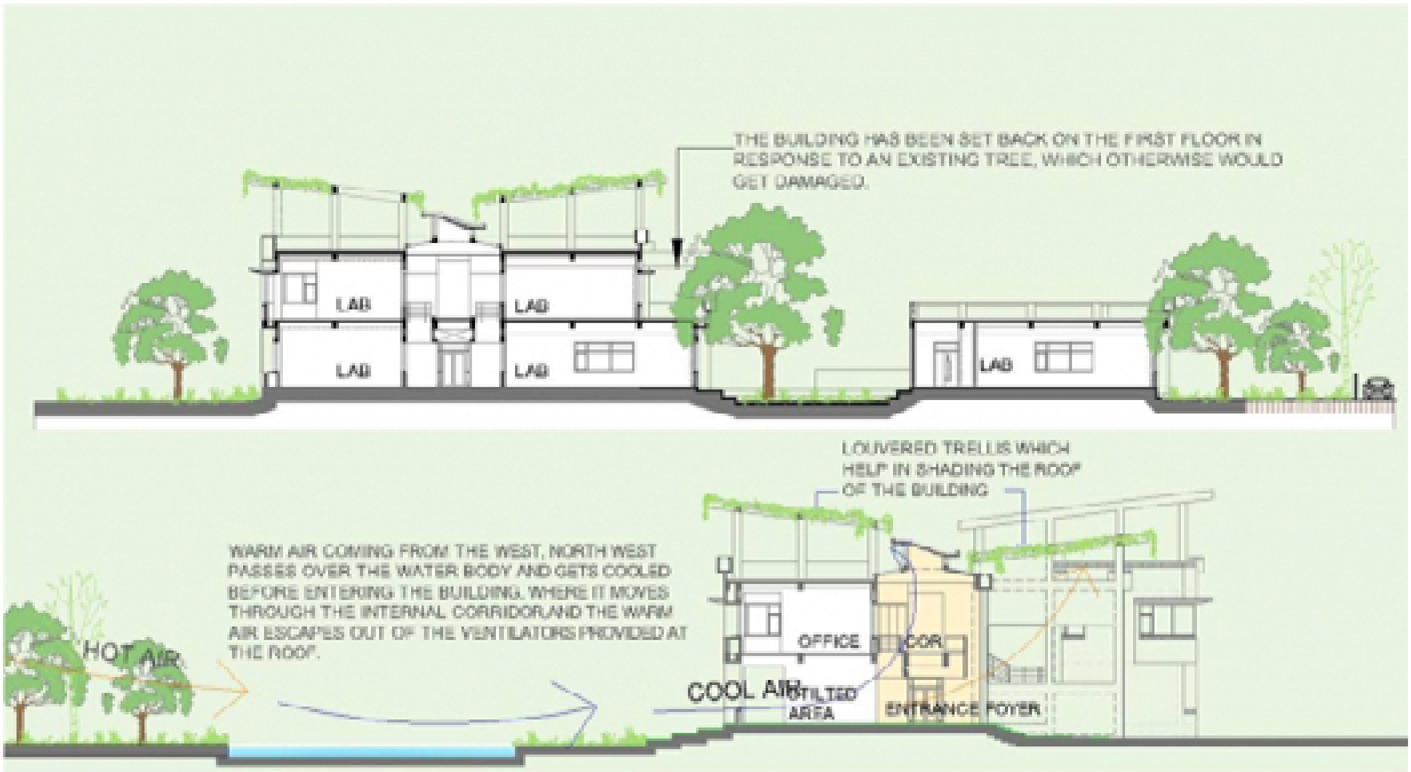


The greenest building in the Netherlands

3.4 Waste management Strategies

T **topic is covered** in part in Modules 2 and 3, but reference is made to Figure 5.18 which includes wastewater treatment for reuse as grey water and also green waste recycling through the composting process of a biogas digester. In addition, rainwater harvesting is a relatively simple design feature which should be integrated with stormwater management included within any building project. An example of how rainwater harvesting, stormwater management, a biogas digestor, renewable energy and a school food garden is integrated in order to add value to a school building project is shown in the case study below.

Case study 1: Biomimicry in Ecological Building Design

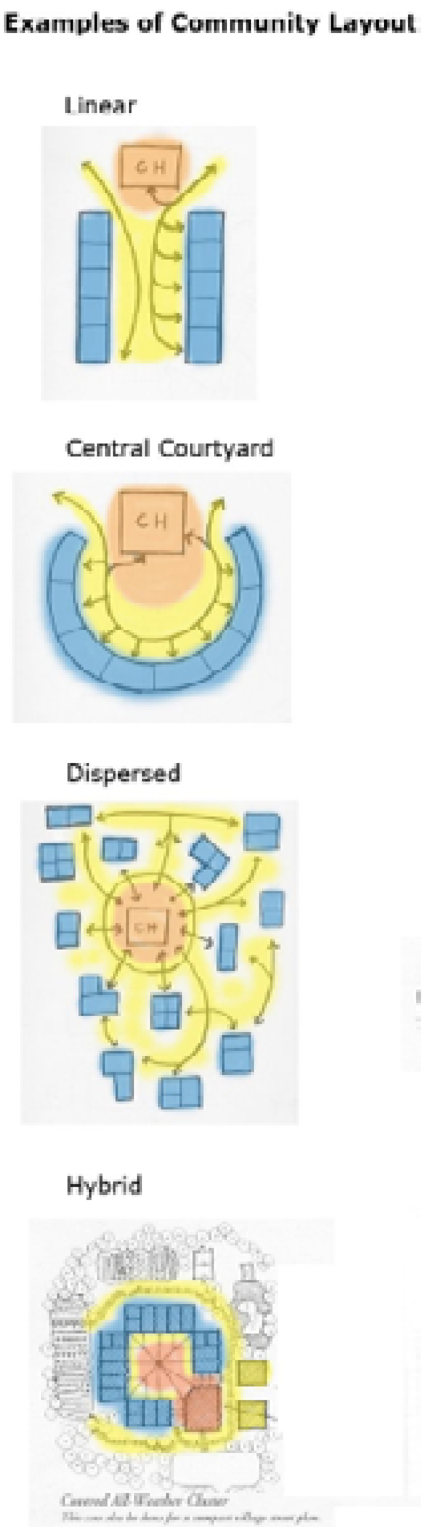


Case Study 2: Sustainable Site Planning Practices

3.5 Social Strategies

Design to enable personal fulfilment and social capital can be facilitated through Cohousing/ Ecovillage developments wherein the form and shape of facilities are spatially arranged to maximize social interactions and a community ethos along like-minded sustainable lifestyles. Furthermore, social interactions are planned among stakeholders as a collaborative design process with an emphasis on community governance and design integration of form and functional spaces (An insight into this collaborative design process can be explored at this weblink). This lays the foundation for Cohousing as a socially sustainable model which helps to build social cohesion and community capacity. It also empowers individuals, households and communities to address social, environmental and economic needs. Social strategies inform both the 3-D aspect as in the form and shape of Cohousing, and also, the 2-D aspect in the spatial layout form.

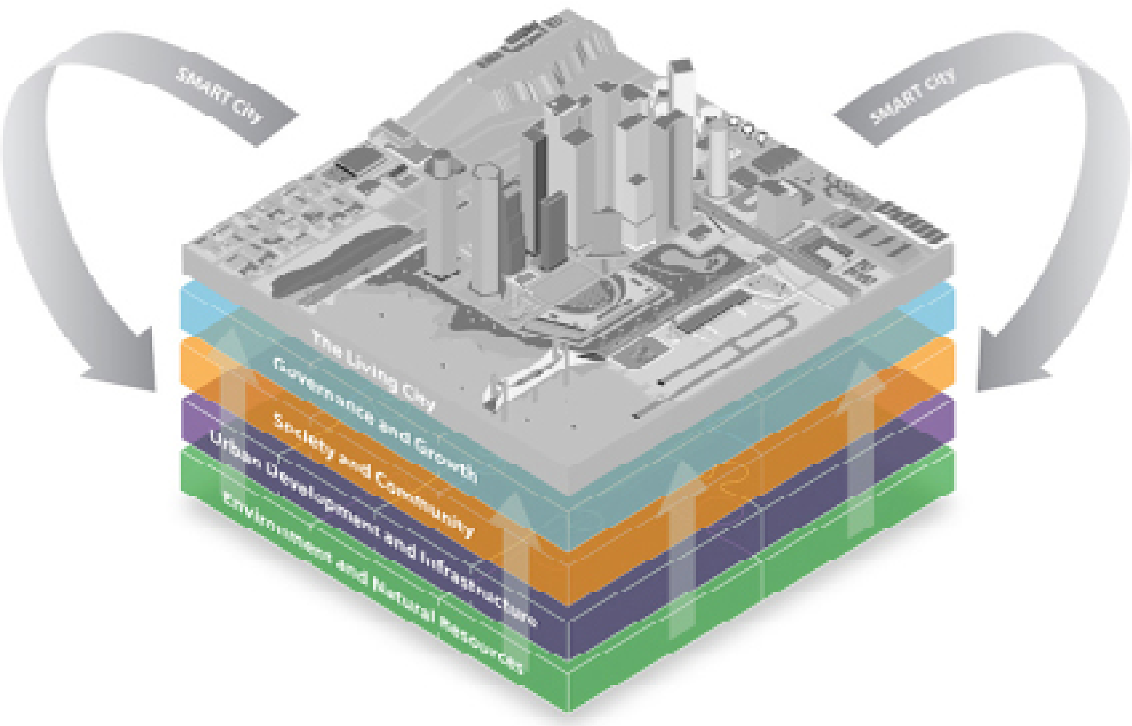
As a sustainability strategy, the Cohousing model can be seen as a microcosm of a future sustainable society wherein it can help transform design approaches for housing and urban development. The aspirations of Cohousing residents are social and not material-consumerist, and they are usually pro-actively involved in environmental action. Consequently, Cohousing residents generally live in smaller dwellings than 'normal'; they share household and other consumer goods; they grow their own organic food in significant quantities; and, they also manage waste and recycling particularly well.



Generic concept plans for Cohousing layouts

Site design for user interaction can be facilitated through Cohousing / Ecovillage developments that provide a balance between private, social and workspaces, whilst simultaneously reducing ones building footprint through sharing of facilities. The sustainability benefits of Cohousing demonstrate efficient land use through the clustering of dwellings and sharing of facilities, which in turn, frees up land for other purposes, such as, children's playlot, small business workshop facilities, circulation space, food garden, etc. The sharing principles of Cohousing reduces the need for car ownership and associated parking spaces since a smaller pool of vehicles, albeit with a wider functionality, such as, motorbikes, small cars, delivery van, combi-bus, etc., can better service the community transport needs. Some of the generic concept plans for Cohousing layouts which create spatial opportunities for social interaction are shown in previous Figure.

Communications via WiFi, fibre optics and broadband are an emerging feature in "smart city" solutions wherein hyper-connectivity is becoming the norm. The European Commission defines smart cities as: "A smart city is a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business. A smart city goes beyond the use of information and communication technologies (ICT) for better resource use and less emissions. It means smarter urban transport networks, upgraded



The relationship between Smart Cities and the Living City. Image by Buro Happold water supply and waste disposal facilities and more efficient ways to light and heat buildings. It also means a more interactive and responsive city administration, safer public spaces and meeting the needs of an ageing population".

However, "some experts believe that the notion of smart cities has been overly driven by hi-tech companies", for various reasons. These experts go on to say that, "Given this situation and the belief by some that the planning, design and construction of future cities requires an integrated approach to achieve successful outcomes, alternative terminology has been suggested. The term 'The Living City' refers to an approach in which technology plays an important but nevertheless supporting role (Ref Buro Happold : The Living City)".

Architectural design for the soul appeals to something beyond vernacular design and a sense of place, but also designing for a whole quality of life wherein the environment nourishes the soul. In his book, "Spirit and Place (2002, page187)", Christopher Day states this more poignantly as: "For wholeness – the basis of health – we need nourishment at every level. The complex and dynamic organization of the physical body underpins our relationship to spatial qualities. Life enhancing qualities around us support our life energies. Colour, harmony, multi-sensory delight supports our feeling life, particular moods redressing personal and situational imbalances. Buildings built upon these principles are buildings to nurture the whole human being".

This echoed by David Pearson, founder of the Ecological Design Association in the UK and co-founder of Gaia International, an innovative group of ecologically responsible and inspired architects, believes that "far from expensive technological dreams, we need a down to earth vision – a future home integrated into a sustainable lifestyle for all of us.

He argues: "Whether old or new, future housing will need to employ life-supporting systems. Materials, and spatial designs that meet the health, conservation and spiritual criteria" (Pearson, 1998, p.57) listed in the 'Gaia House Charter'. The box below is list of criteria for holistic sustainable building was drawn up by the members of Gaia International. Many such houses have already been built and many old existing structures have been converted with these principles in mind. These are the beginnings of a complete transformation of the existing building stock to meet the long-term requirements of sustainable living.

The Gaia House Charter for Healthy and Sustainable Building (Reproduced and adapted from Pearson, 1998,p.57)

Designing for Harmony with the Planet:

- Site, orient, and shelter the home to make best and conserving use of renewable resources. Use the sun, wind, and water for all or most of your energy needs and rely less on supplementary non-renewable energy
- Use green materials and products – non-toxic, non-polluting, sustainable, and renewable, produced with low energy and low environmental costs, and biodegradable or easily reused and recycled.
- Design the house to be intelligent in its use of resources and complement natural mechanisms, if necessary, with efficient control systems to regulate, heating, cooling, water, airflow and lighting.
- Integrate the house with the local ecosystem, by planting indigenous tree and flower species.
- Compost organic wastes, garden organically, and use natural pest control – no pesticides.
- Recycle greywater and use low-flush or waterless toilets. Collect, store, and use rainwater.
- Design systems to prevent export of pollution to the air, water, and soil.

Designing for Peace and Spirit:

- Make the home harmonious with its environment – blending in with the community, the building styles, scale and materials around it.
- Participate with others at every scale, using personal ideas and skills of all in order to seek a holistic living design
- Use proportions, forms and shapes that are harmonious, creating beauty and tranquillity.
- Use colours and textures of natural materials and natural dyes, paints, stains to create a personal and therapeutic colour environment.
- Site and design the house to be life enhancing, and increase the wellbeing or vital force chi, of its occupants.
- Connect the home with Gaia and the natural world and the rhythms and cycles of the Earth, its seasons, and its days.
- Make the home a healing environment in which the mind and the spirit can be free and flourish.

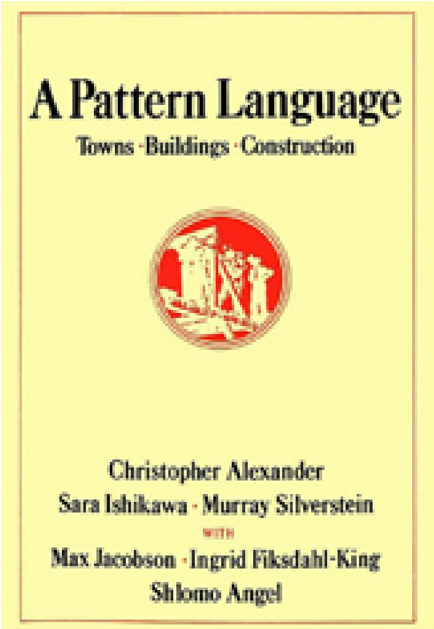
Designing for Health of the Body:

- Create a healthy indoor climate by allowing the house to breathe, and use natural materials and processes to regulate temperature, airflow and quality.
- Site the home away from harmful EM [electro-magnetic] radiation from power lines and also away from negative ground radiation. Design to prevent the build-up of static and EMF [electro-magnetic fields] from domestic equipment, and to avoid interference with beneficial cosmic and terrestrial radiation.
- Provide safe and healthy air and water, free from pollutants (radon especially), with good humidity, negative-ion balance, and pleasant fragrance from herbs, materials, and polishes. Use natural airflow and ventilation.
- Create a quiet home, protect and insulate from external and internal noise, and a pleasant, sound- healthy environment.
- Design to allow sunlight and daylight to penetrate, and thus rely less on artificial lighting.

3.6 Sustainable Spacial Strategies

This section explores some 2-D Sustainable Spatial Strategies for the built environment that support and enhance the 3-D Green Building Strategies. The 2-D spatial plane involves the town planning for the built environment land use parcels (housing, public realm, commercial, industrial, environmental and all servitudes); provision of utility services (water, sewage, solid waste and energy), transport (rail, road, water and air) and intermodal ports (harbours, transport terminals and warehouse logistics). It is an important concept to grasp that sustainable design for the built environment occurs both in a 3-D vertical space and also in a horizontal 2-D spatial plane. In other words, the built environment provides a continuum from town planning, landscape design, urban design and architecture, from a 2-D to a 3-D aspect, respectively. In order to achieve sustainable design in this built environment continuum, a whole systems thinking approach and design integration at all levels is imperative. This section will thus explore the following concepts:

- A Pattern Language
- Integrated Infrastructure Systems
- Sustainable Drainage Systems
- Green Urbanism



Source: Pattern Language

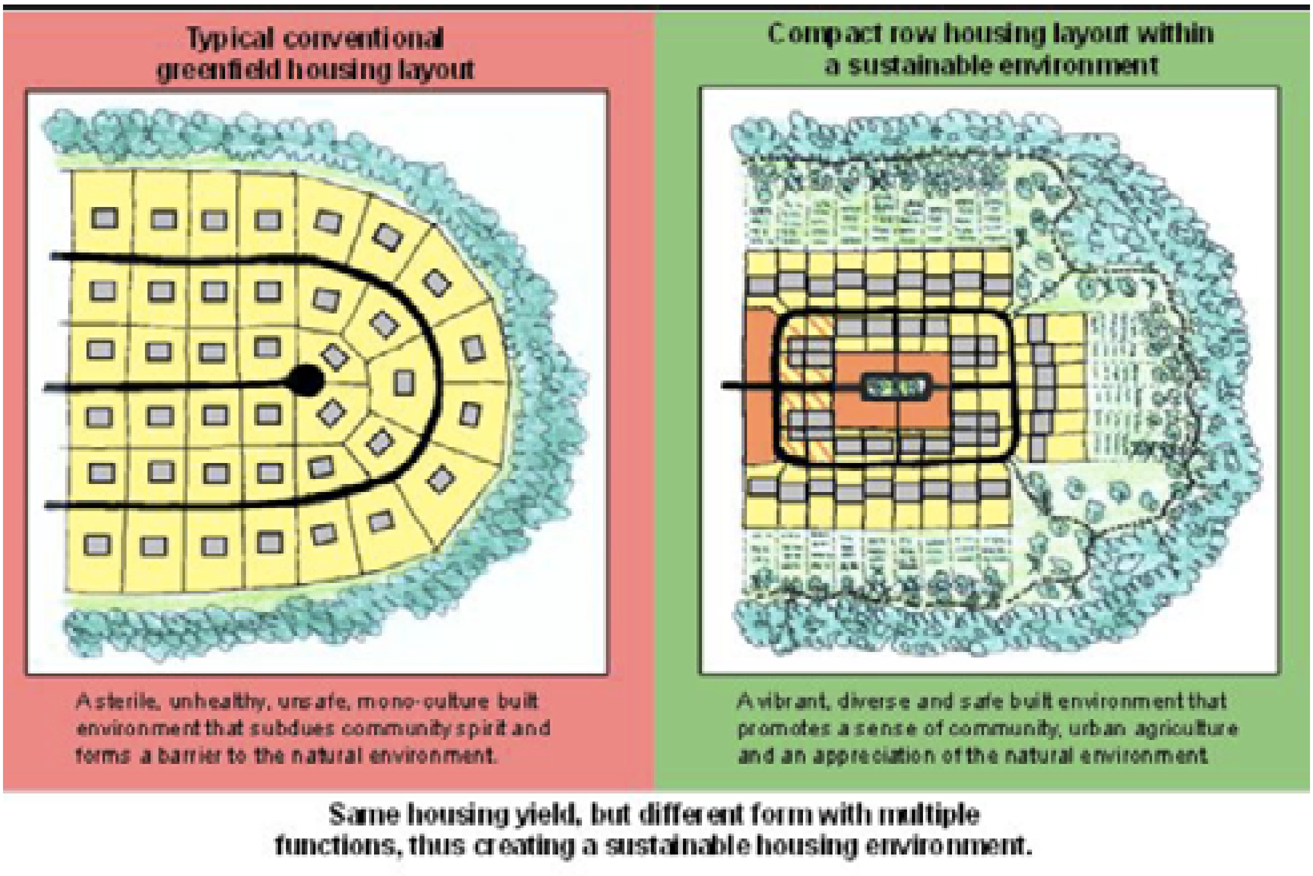
A Pattern Language

One of the sources of inspiration for the design integration of the built environment, is the book, "A Pattern Language: Towns, Buildings, Construction", by Christopher Alexander et al. A website has been developed in order to expand the teachings from this book into a design language which shows the pattern relationships of the built environment. The following excerpt from this website provides the backdrop to the built environment design integration continuum:

"Back in 1977, the book first introduced the concept of people designing buildings for themselves, and guaranteeing the comfort and functionality of the buildings they designed, because the elements of the language are "patterns", elements which are a collective memory of things which work in our surroundings. The language begins with patterns that define towns and communities. These patterns can never be designed or built in one fell swoop - but patient piecemeal growth, designed in such a way that every individual act is always helping to create or generate these larger global patterns, will, slowly and surely, over the years, make a community that has these global patterns in it.

The next part of the language gives shape to groups of buildings, and individual buildings, on the land, in three dimensions. These are the patterns which can be "designed" or "built" – the patterns which define the individual buildings and the space between buildings; where we are dealing for the first time with Patterns that are under the control of individuals or small groups of individuals, who are able to build the patterns all at once. The next, and last part of the language tells how to make a buildable building directly from this rough scheme of spaces and tells you how to build it in detail."

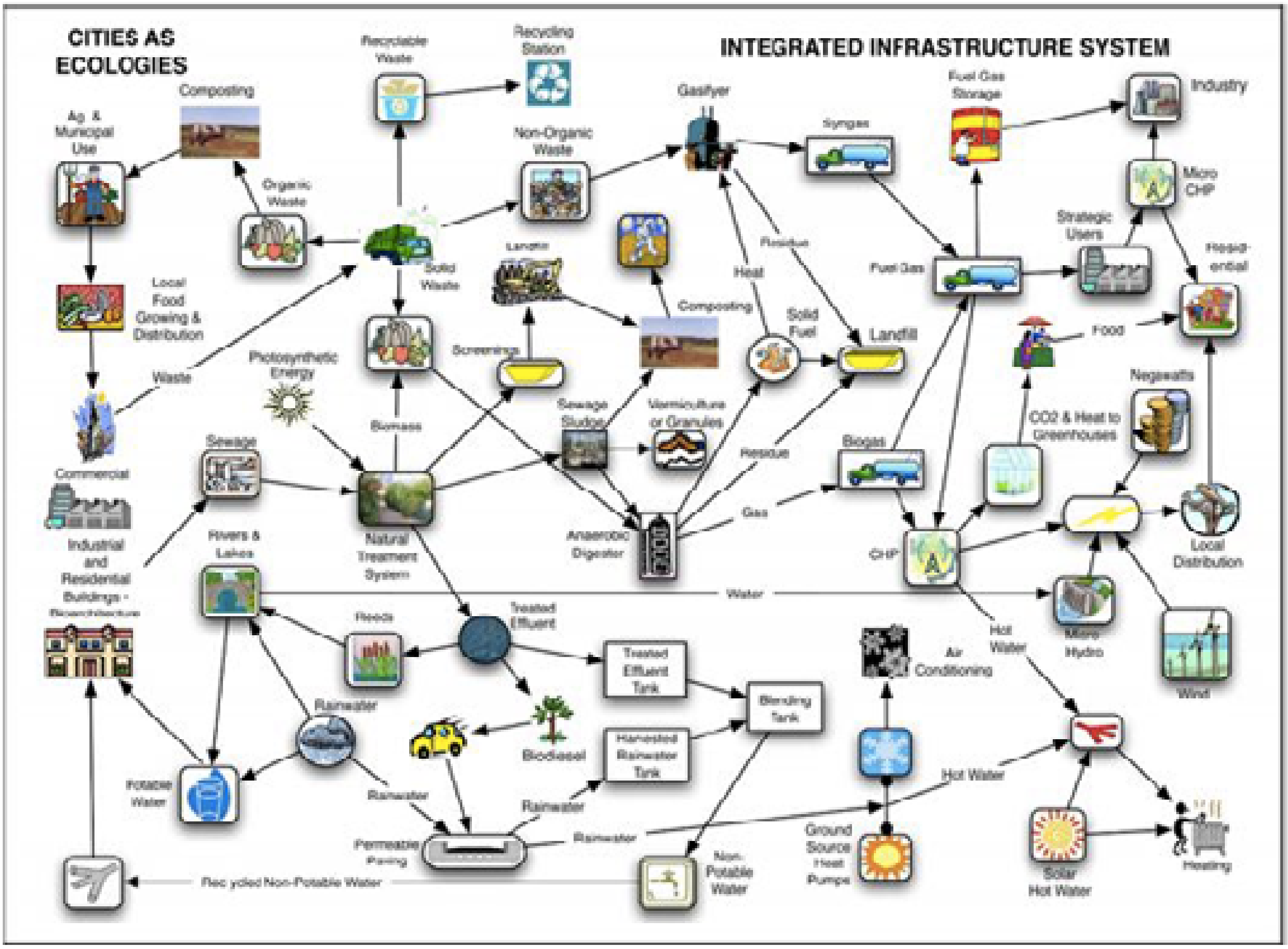
Alas, there is no perfect sustainable built environment, but nevertheless, there are many very good examples across the world where best practices have been developed and are being transferred to other regions. This section explores some of these approaches whose focus is on design integration. A typical introduction to the "Pattern Language" way of thinking is embodied in the Figure below that compares a conventional layout with a more wholistic integrated layout which both have the same number of housing units, but with much different characteristics.



Comparison of two housing layouts - conventional versus sustainable

3.7 Integrated Infrastructure Systems

A concept example of an integrated infrastructure system is shown in Figure below for a proposed development for Harlow North (UK). Herein, the overarching design protocol was simply to not abstract from aquifers more than half of the daily 90 litre per person water consumption quota. This design imperative resulted in a major closed loop design for the ensuing rainwater harvesting, stormwater drainage, wastewater treatment, sewage, composting, biogas, etc., wherein the "waste" of one process is the "food" for another process.

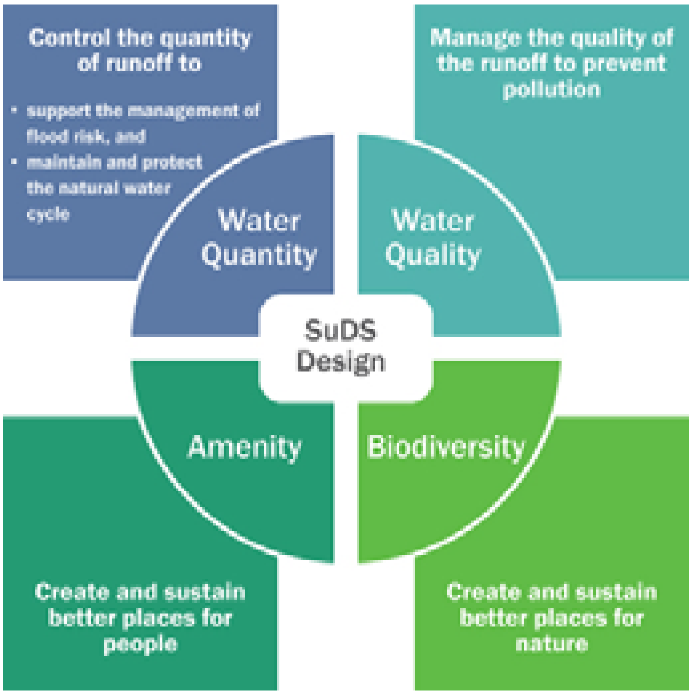


An example of an integrated infrastructure system for a proposed development for Harlow North (UK)

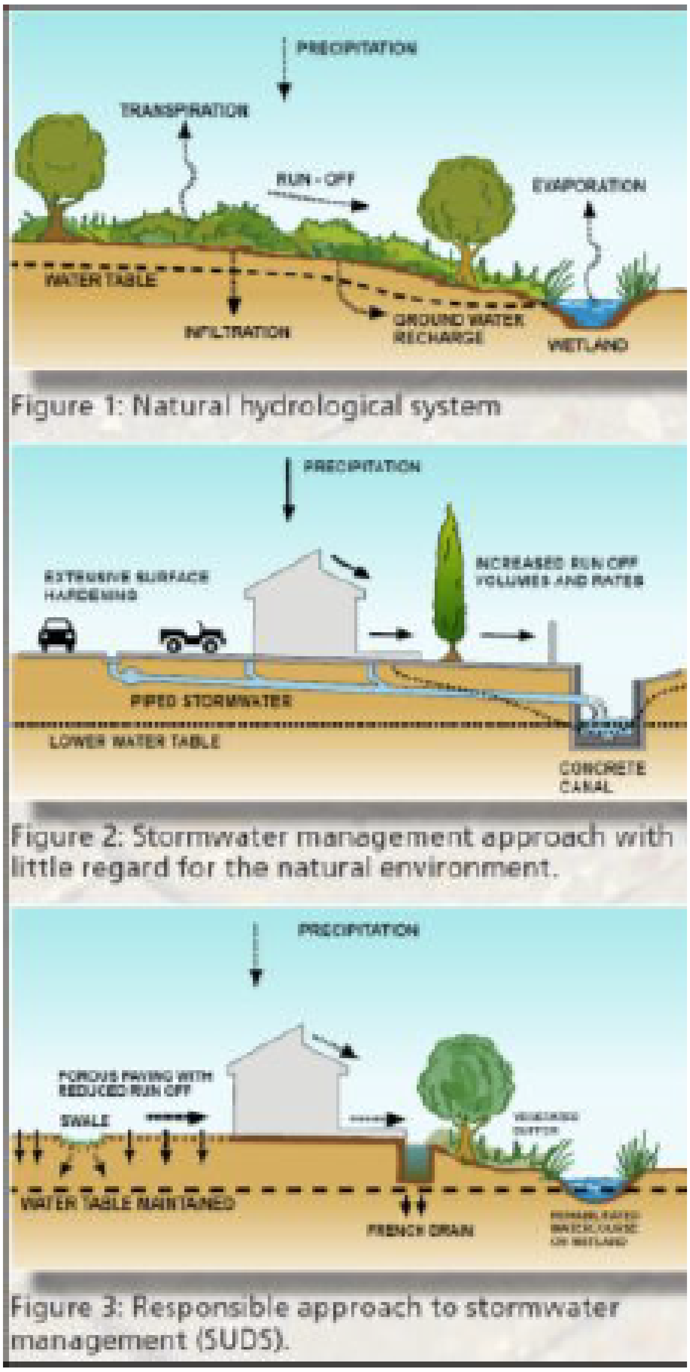
3.8 Sustainable Drainage Systems

A sustainable drainage system (SuDs, SuDS, SUDS) is designed to reduce the potential impact of stormwater surface discharges, especially severe rainstorms, for both new developments, as well as, the retrofitting of existing developments, as outlined in the SUDS design approach in Figure below.

SUDS is a closed loop system that slows down, spreads and sinks stormwater discharges, unlike conventional stormwater management which paves, pipes and pollutes stormwater runoff. This concept is illustrated in the Figure on the right which compares the natural hydrological system, a conventional engineered stormwater management approach, and, a responsible approach for stormwater

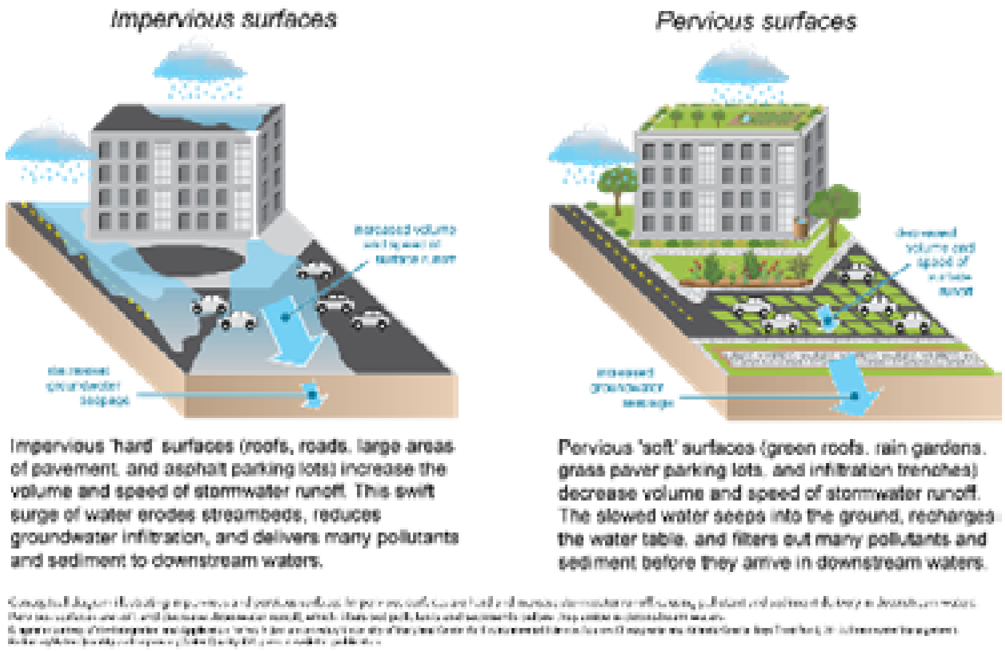


SUDS Design Approach



SUDS comparative example

management as in SUDS. Another comparative concept for impervious and pervious surfaces is shown in Figure that follows.

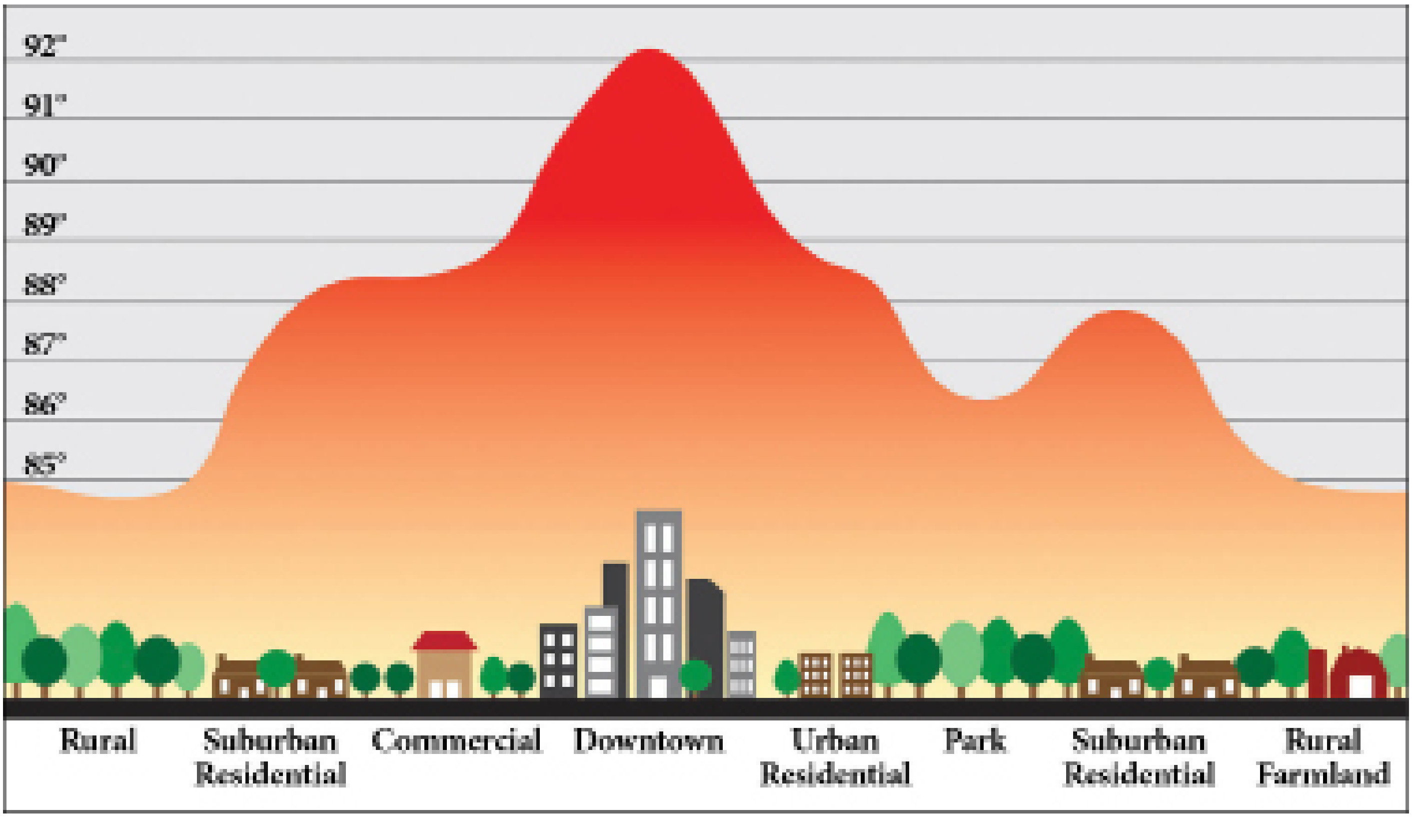


SUDS comparison of impervious and pervious surfaces

3.9. Green Urbanism

Green Urbanism is an interdisciplinary collaborative response from built environment professionals, such as, town planners, landscape architects, environmental engineers, transport planners, urban designers and architects, as well as, support professionals, such as, psychologists, sociologists and economists, in order to create more sustainable and harmonious relationships among spaces, communities and lifestyles (Source: Wikipedia). This response has acknowledged that the rural to urban migration is creating huge pressure on existing urban centres, many of which are not coping to keep up with the provision of extensive networks of utilities, transport, housing and public facilities. A huge negative impact upon these urban centres is the growing pollution and consequential heat island, which is contributing to global warming, as shown in first following Figure.

Green urbanism is therefore a positive response designed to mitigate urban heat islands through mass greening of sidewalks, roadways, roofs, vertical walls, additional parks and conservation areas, which impact of tree-scapes is shown in Figure left part of the second following image.
Green urbanism also integrates SUDS and waterways as can be seen in right part of the Figure in the massive project which transformed Seoul. An inherent challenge of most cities is the pollution of its stormwater and waterways. Cleaning up these waterways presents big challenges, but the concept of floating islands with wetland-type plants provides the ideal habitat for micro-organisms to populate the plant roots trailing in the water and thus clean up these waterways. This video from Biomatrix Water "living water cities" demonstrates these opportunities.



Urban heat island effect

Green urbanism through restoration of waterways, Cheonggyecheon River,Seoul, Korea

4. Sustainable Design Integration

Thus far, this Module has presented sustainable building (3-D) and sustainable spatial strategies (2-D), which are now presented in the form of some case study examples to highlight the application of whole systems thinking for the built environment under the following topics;

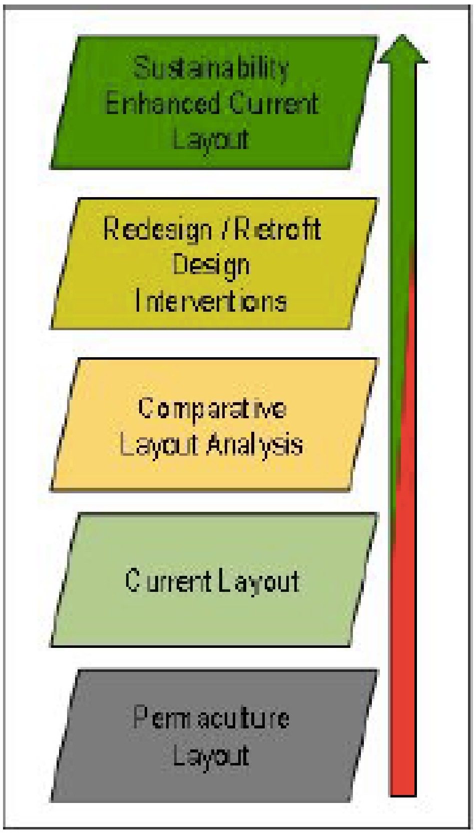
- Permaculture design in the built environment
- Ecological Economics applied to the built environment
- Retrofitting Suburbia

Permaculture design in the built environment

The Permaculture design principles are not only limited to agriculture but can also be extended over the built environment. In particular, the canvas of Permaculture Zones can extended from a typical homestead across a whole village and town as expressed in Case Study No.3, A Permaculture inspired town planning concept, Marikana, South Africa. In particular, Zone 5 was designed as a meandering stream (maximizing edge) that would collect the water drained from the centre of a water-logged development area in such a manner that the earthworks dug out for the stream would in turn establish an earth mound with natural vegetation, thereby screening the unsightly mine dumps (the problem is the solution). The draining of the site would make way for the other inner zones comprising passive open space (Zone 4), agricultural allotments (Zone 3), dwellings and homestead gardens (Zone 2), social self-sufficiency, commercial, public and entertainment facilities (Zone 1), and, a village green and town centre (Zone 0) for the people of this community (Zone 00). The Zone 1 area would form an activity corridor providing access and integration with an adjacent developed area.

Case study 3: A Permaculture inspired town planning concept, Marikana, South Africa

Another application of Permaculture in combination with Yeomans' Scale of Permanence (also known as Keyline Design) was used for the Ndumo case study project as shown in Case Study No.4. This case study was compiled in order to facilitate debate towards a more sustainable town plan, and also, to validate that sufficient water could be harvested from the landscape to supply all the town's needs instead of the more expensive planned bulk water supply from 30kms away. The debate for a more sustainable town plan was done by juxtaposing an ideal concept layout plan, as derived from Permaculture principles, against the current development reality (see Figure beside). The ideal layout plan conceived a robust framework by following the Keyline design process of rainwater harvesting, access roads and forest belts, which in turn, delineated the Permaculture zones for the town development. A closer scrutiny of this comparison was done to facilitate debate to re-align, re-design and retrofit the current reality towards a more sustainable layout plan for the overall development. Moreover, the landscape-based rainwater harvesting plan was calculated to be sufficient to meet the town's future estimated population of 2 000 homes or 12 000 people instead of relying on a 30km bulk water supply, which source was questionable.

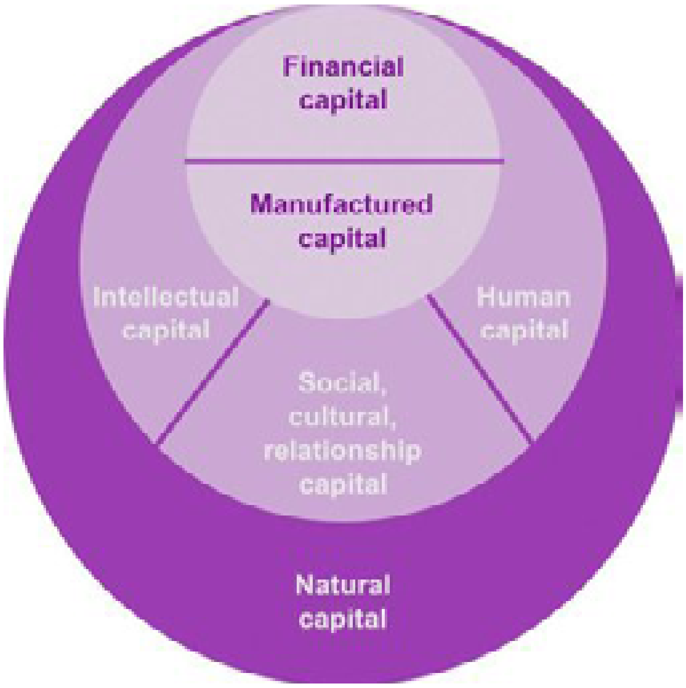


Redesign / Retro it me-thodology towards a more sustainable layout

4.1 Ecological Economics applied to the building environment

Ecological Economics it balances the 4-Capitals, comprising the Natural-, Built-, Human- and Social Capitals, in an integrated manner to achieve sustainable solutions for the built environment as illustrated in Figure beside. More specifically, the Natural Capital should lead the design integration process by harnessing the unique natural forms and patterns of the landscape. The Built Capital is then integrated within the Natural Capital by prioritizing design elements according to Yeoman's Scale of Permanence, and also, by allowing building function to determine building form. The Human Capital comprises individual knowledge, skill and expertise to deploy human resources to harness the Natural Capital and shape the Built Capital. The Human Capital collectively forms the Social Capital, also known as the glue, that forms the Community, which establishes governance systems to thrive sustainably.

All the aforementioned case studies have elements of the 4-Capitals, although the Human- and Social Capitals may be somewhat lacking or not yet developed. Meanwhile, the Shack Re-Blocking example in Case Study No.5 shows how all 4-Capitals have been integrated, even though the Natural Capital is very limited due to the specific circumstances. This shack reblocking process has been formulated into policy by the City of Cape Town as part of its "smart cities drive".

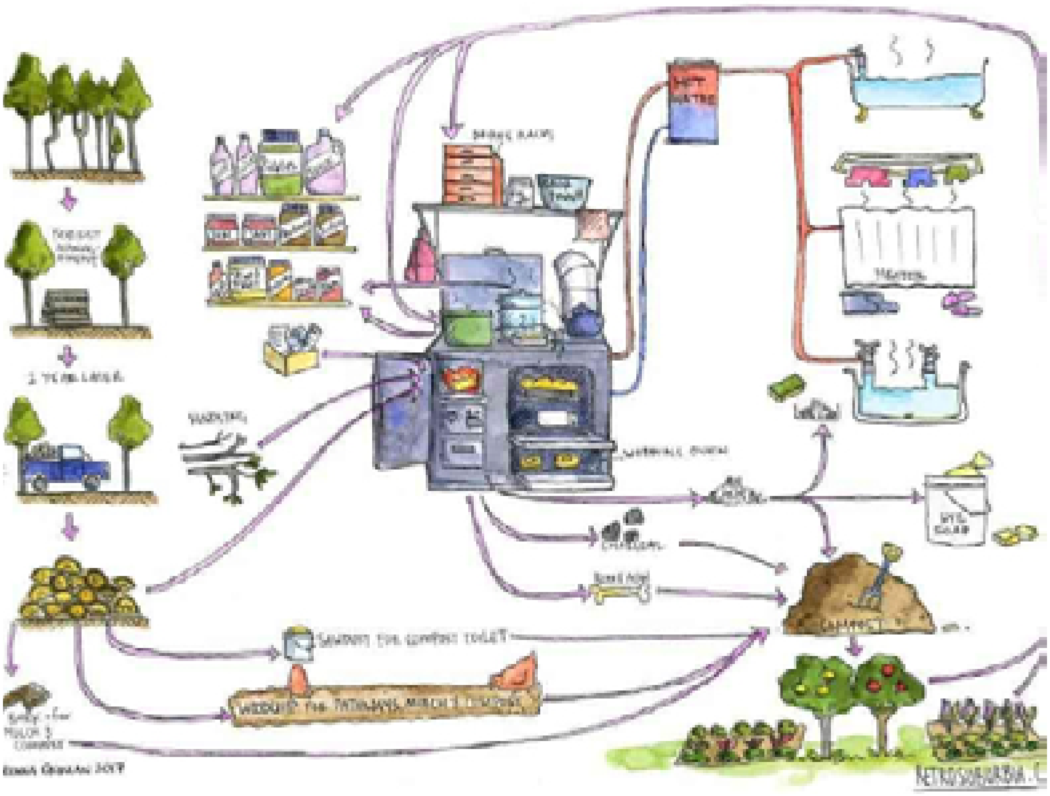


Ecological Economics - the 4-Capitals

Case study 5: Highlights from a Shack Reblocking process, Cape Town, South Africa

4.2 Retrofitting Suburbia

The co-founder of Permaculture, David Holmgren, has taken the Transition Movement to a very practical level in Retrofitting Suburbia (the website, book and roadshow) by demonstrating "how Australian suburbs can be transformed to become productive and resilient in an energy descent future. It focuses on what can be done by an individual at the household level (rather than community or government levels)". It shows how to live more sustainably by retrofitting one's home, establishing edible gardens, and, for communities to be more self-organised, sustainable and resilient. This is another application of how the 4-Capitals can be deployed within the built environment, as depicted in the collage below from images of the retrofitting suburbia website.



5. Sustainable Eco-Home and Ecovillage Designs

This section firstly looks at some sustainable Eco-Home model examples and then expands these concepts into broad sustainable Ecovillage design principles. The rationale for first presenting the Eco-Home examples is that these incorporate the occupant's initial desire for sustainable living and then how it can be expanded into an Ecovillage environment.

Sustainable Eco-Homes

This section looks at a few sustainable Eco-Home models which demonstrate a wide range of design integration, particularly for rural off-grid type developments which are integrated within their surroundings. These are just a few, among many other good models, in order to demonstrate what is possible across some diverse climes. Moreover, some of these examples tested the local authorities with planning permission, often at great cost to their proponents, but in the end, their perseverance has opened up avenues for similar development approvals for others to follow without the same hardships. However, as a general guideline for sustainable eco-homes, 50% of the success can be attributed to architecture, 25% to good and efficient systems and equipment, and 25% to the attitude of the occupants. Only if inhabitants understand the energy and water saving features of their homes will they know how to operate them appropriately and will be motivated to do so.

The first example is about the inventor of the earthship model, alternative architect, Mike Reynolds, whose documentary Garbage Warrior ,traces his life experience in building his earthship and the challenges with the authorities in New Mexico, USA. Reynolds is a pioneer of how to facilitate approval for alternative building construction codes with authorities, which have often proved immensely difficult. He has also established an Earthship Biotecture Academy to demonstrate how to build off-grid homes with recycled, low emergy materials which have low operational and maintenance costs. Whilst these solutions appear suitable for rural off-grid type developments, they can also find themselves useful among the growing informal developments in fast growing urban areas where government supported public housing is found wanting. The illustration in Figure 5.31 is a classic cross-section example of an off-grid, low footprint earthship.

Earthship example from Mike Reynolds, the Garbage

The second example is That-Roundhouse by Tony Wrench in Wales, UK, which fought a long standing development approval battle with the authorities to eventually be left in peace. That-Roundhouse is a low impact "ecohome of wood frame, cobwood and recycled window walls, straw-insulated turf roof; with solar power and wind turbine for electricity, compost toilet and reed beds for grey water" (see video). The significant aspect of this ecohome, is that besides the solar power, wind turbine and odd metal items, the house will disintegrate to nature at no cost should it be dismantled. That-Roundhouse also blends into its surrounding landscape which is established according to Permaculture principles. Tony Wrench has gone on to establish training courses and assist other folk to acquire development approvals for similar type ecohomes.

The third example is The Nature House of the Hjertefølger Family in the Arctic area of Northern Norway. The Hjertefølger's constructed a geodesic dome in order to create a micro-climate for a cob-built house with its small food garden and outdoor living area (see the video). The geodesic dome provides for its water supply through rainwater harvesting and capture of condensation, whilst through its greenhouse effect, it moderates the internal climate to reduce heating requirements and grow food that usually cannot be grown in the Arctic. The geodesic dome provides complete weather protection from the harsh Arctic climate, and also reduces ultraviolet radiation to minimise negative impact on the internal building.

That-Roundhouse by Toby Wrench, Wales, UK

The Nature House of the Hjertefølger Family, Norway

5. Sustainable Eco-Home and Ecovillage Designs

5.1 Sustainable Ecovillage Design Principles

If inhabitants of single dwellings appreciate sustainable cyclical design principles that reduce operational and maintenance requirements, then it will be easier to extend these principles outwards into an Ecovillage community. To this end, a community in formation of some 30 odd families, could well co-develop the following "green design brief" to help them evolve towards planning and establishing an Ecovillage:

- A simple shared design theme fitting into the local vernacular
- Relatively small houses, making for economy and small ecological footprint
- Passive solar space & water heating (see energy section)
- Bioarchitecture - cooling with landscaping and roof overhangs for shading and natural ventilation
- Using local materials where possible with low embedded energy
- Carbon neutral settlement in operations, which means no fossil fuels, or at least built to a "Gold Standard" of 4 to 6 kgCO 2 pa/m 2
- Using Permaculture as a key design principle within the settlement
- Small scale food production, with protected crop horticulture
- Cooking and supplemental heating using biomass, including district heating systems
- Rainwater collection and grey water irrigation
- Local sewage treatment and treated effluent re-use, including composting toilets
- Composting of organic wastes
- Shared facilities - gardens, common house, outdoor kitchen, wood-fired hot tub and/or sauna, greenhouse, chicken tractors, laundry & bike shed
- Cohousing and land trust ownership model
- Car sharing and biodiesel production

The above "green design brief" lays out the Fundamentals for Ecovillage Developments which is emulated in many established Ecovillages.

Fundamentals for Ecovillage Developments

For Greenfield developments, the wholistic village layout designed according to Permaculture principles is the most important fundamental which lays out the framework for the development, failing which, the development will forever deal with retrofitting process to enhance operational sustainability.

mental Some of the above concepts are shown in the collage below from the well-established Green School in Bali, Indonesia, which shows bamboo built structures with a permaculture garden, whilst the Wongsanit Ashram, Thailand, shows structures built with local materials on stilts, cooled by water and shade.which

6. Conclusion

This Module on building systems explores how to redesign and retrofit the built environment in ways that mimic the healthy functions of ecosystems. In designing eco-buildings, ecovillages and sustainable communities, one can well to ask: "In what way does one's building function like a tree, and, in what way does one's community function like a forest?" Learning from natural systems and working with the specific climatic and ecological conditions of the places one inhabits, using ambient energy (passive solar gain and thermal mass, natural ventilation) are equally part of green building systems as are attempts to reduce the ecological, water, and carbon footprint of buildings and related infrastructure by employing regionally regenerative low-embodied energy materials that do not affect human or ecosystems health negatively.

Winston Churchill said: "First we shape our buildings, and then our buildings shape us." Building and retrofitting green infrastructures that support healthy individuals andhealthy communities to have a regenerative impact on the ecosystems they inhabit and depend upon, are very important aspects of the transition to diversely adapted regenerative cultures and sustainable communities. Whole systems design can help to create synergies between the social, ecological, economic and worldview dimension of design for sustainable communities. Whilst this Module may not make instant built environment professionals, it empowers one to better understand the negative implications of and capacitate a more informed level of advocacy towards regenerative solutions.

Bring it to life!

What is your reaction to the whole system solutions presented?

Can you see some applicable to your community?

To your life and reality?

How are they appropriate to the economic, social and cultural realities of where you live?

Can you think of transitional whole systems solutions that may be applicable to what is already in existence in your community or life?

Share your ideas in the forum.