SYNBIOCITY: SELF-PERPETUATING SOLAR NICHE WITHIN THE FIRST SHOCK CITY

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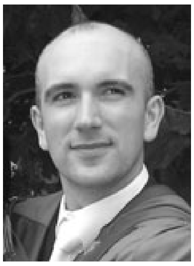

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Abstract

SynbioCity extends previous studies into solar derived form by Knowles (2000), Yoh (2001), Grooten, S. and Rankin, C. (1998), and Verheijen, M. (1998) by allowing biological expediency to inform and respond to urban contexts born out of non-solar forces. By challenging both the concept of a solar city, an oxymoron in which buildings close together shade each other and thus prevent insolation, and the solar suburbs, which are generally low density and site expensive, the work advances both the understanding of urban sustainability from a bio-analogous perspective and strengthens the architectural knowledge of urban and celestial geometries, the synergy of which are key to true solar city design.

The objectives of this research are to generate a solar community capable of sustaining an inevitable urban population within an existing and site limited Northern European city. Within natural forest systems a fractal shift of scale from the microscopic to the macro encourages specialization, mutualism, and compaction. On this evidence a hybridized hypothesis proposes an equivalent but interpretive shift of scale involving a light stratified forest community in succession and species survival strategies. It would be argued that the implications for a solar society seeking to adapt to both sun and shade environs would be profound, not only at the micro scale where selective glazing systems are now emerging, but also at meso and macro scales i.e. the street and city respectively, making for a highly distinctive and increasingly sought resolution.

Forms generated by this author and students at the Manchester School of Architecture during the SynCity Lab studio workshop display the same faceted dynamism and presence as the futuristic visions of 1930's illustrator Hugh Ferriss (1929) as well as the intense and contemporary geometries of Rem Koolhaas. By offering sustainable design a new visual language, an expressive and engaging architectural statement can now be made.

1. Introduction – Biomimetic Design

1.1 Historical Background

The aim of this ongoing research is to propose an organically creative solution to the sustainable solar city by applying natural forest growth rules to the modelling of synthetic urban solar communities (Figure 1 overleaf). The concepts and methodologies presented are biomimetic, from *bios*, meaning life, and *mimesis*, meaning to imitate. Mankind's ability to perceive and imitate organic life has technologically shifted over time leading to a regular re-evaluation of our relationship with nature and the architecture that expresses it. Classical architects saw nature as stable, balanced, and ordered. In the fifteenth century Leon Battista Alberti believed nature to be a mathematical construct with a harmony between parts and the whole. During the eighteenth century culture would be validated through its association, Abbé Laugier's 1753 illustration of the primitive hut being a principal representation.

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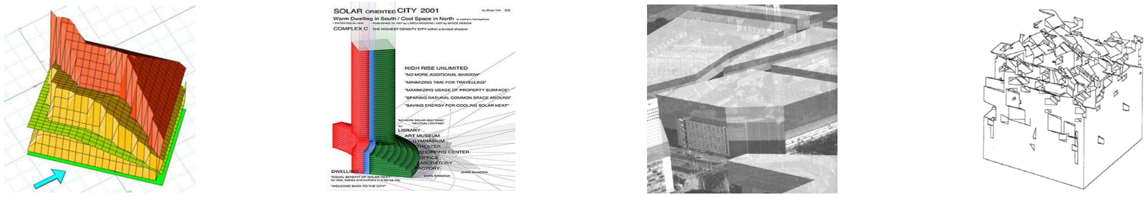


(a) (b) (c) (d)

Figure 1 Solar City form. (a) Interstitium by Ralph Knowles. Solar Envelopes form an interstitial volume between the seasons. (b) Solar Orientated City by Shoei Yoh, Toranomon-Azabudai, Tokyo. Southerly orientated dwelling zones and northerly orientated shade-tolerant zones keep private life warm, public life cool. (c) Trojan Extrusion by Mark Verheijen, MVRDV. Stratified solar blocks are superimposed over the streetscape suggesting new functions which float in a sea of new solar program. (d) Claustro City by Sven Grooten & Chris Rankin, MVRDV. Based on Dutch solar byelaws solar geometries alleviate the causes of claustrophobia in high-density urban space.

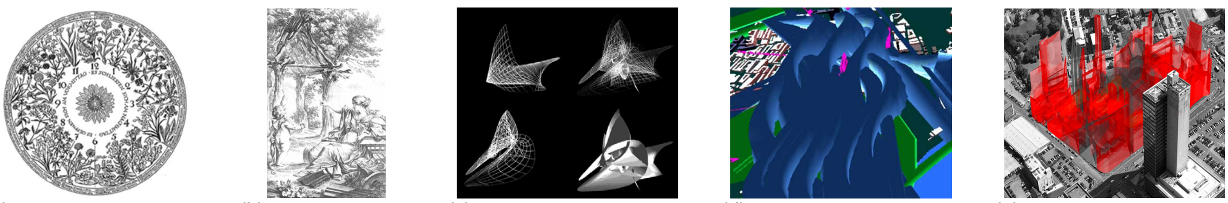
This comprehendible concept of a reducible nature would maintain a static architecture into the twentieth century. Nature interpreted as machine served as a universal entity, devoid of climatical differences and specialisation. A nature now dominated was to be constructed and reassembled to suite an architectural method. Moholy-Nagy, while teaching at the Bauhaus, wrote that if architecture pursued functionalism in the correct way, that is, with a complete understanding of task, tools and materials, then designs even without studying a natural model would nevertheless be confirmed as agreeing with natures own creations.

Perceiving nature to be a proven and workable concept, Neutra (1954) proposed Biorealism, a science based architecture that sought integration between 'Bio', the biology of humankind, and 'Realism', behavioural and environmental rhythms. Later advances toward nature-inspired solutions now known as Biomimetics derive and technologically interpret organic rules, concepts, and physical structures. Extending this methodology Benyus (1997) defined Biomimicry as a Model, Mentor, and a Measure in proposing an era based not on what we can extract from the natural world, but on what we can learn from it.

Today, nature is understood to be highly complex, dynamic, and chaotic, challenging the traditional clockwork and immobile view. Frazer (1995) imitated this non-linear nature by accelerating evolution and creating virtual architectural models that respond to changing environments, culminating with an urban organism that receives, collects, and feeds back information.

1.2 City as Forest

The natural forest is a highly compact, self-regulating, and solar diverse community that has apparent connotations with model urban sustainability. Forest growth would serve as an analogy leading to the development of an animated solar city model entitled Phenotypic Plasti-City (Figure 2e). From the outset a level of interpretation was necessary, cities are not forests, nor are buildings trees; it would be the algorithmic solar process of forest community, typology, and surface that had the potential to be bio-mimetically advanced through computer urban modeling.



(a) (b) (c) (d) (e)

Figure 2 Nature perceived, dominated, cultivated, and mimicked. (a) Flower clock by Linnaeus (1751), indicative of mans predictable and mechanistic view of nature. (b) Illustration of the Marc Antoine Laugier's Primitive Hut (1753) describing the quest for architectures natural beginnings. (c) Evolutionary Form by John Frazer (1993). (d) Softscraper, Rotterdam, by Lars Spuybroek, an architecture that transforms its own geometry organically in response to information from the Web. (e) Phenotypic Plasti-City by Martin and Keeffe (2007). A biomimetically derived solar city masterplan inspired a phenomenon that allows a genotype to adjust to varied light conditions.

2. Introduction – The Synergy Crystal

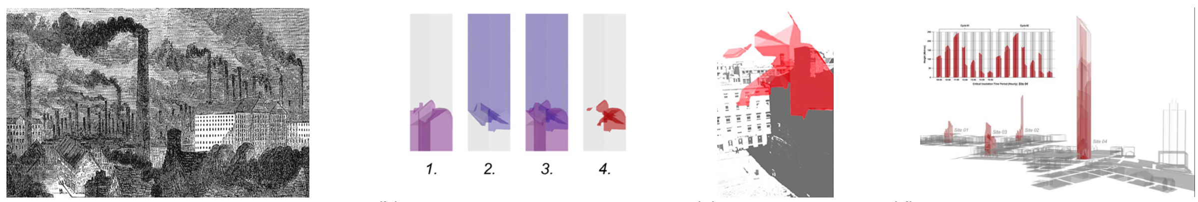
2.1 Historical Context

Manchester, England (53.7°N 2.1°W) was to become the world's first unplanned and chaotically arranged industrial city (Figure 2.1a). The city plan and the built forms that still dominate are essentially Victorian and Edwardian due to its transformation from medieval settlement to an industrial Cottonopolis during the nineteenth century. Indeed, the rate of change in the architectural, cultural, political, social, scientific, and medical fields was so great that Manchester would later be regarded as the world's first *Shock City*. Despite the introduction of a Model Series of Bylaws in the years that followed, which restricted building height for reasons of health and sanitation, there would be no specific solar influence in Manchester's planning. Composed of variously oriented gridirons, Manchester streets have acquired subtle changes in angle. Contained within this framework are blocks that vary in size and shape allowing for numerous routes across the city.

2.2 Synergy & Mutualism

Despite massive redevelopment Manchester remains an unchanging gridded context, its low-rise form, latitude, climate, and organically compact urban grain continuing to conflict with the principles of passive solar design. The need to address overshadowing, inevitable for most of year, became the main argument of CAD generated Synergy Crystal form, and the reason why Manchester continues to serve as a location for current research.

Research concluded that solar aperture in Northern Europe was an important form generator. By constructing a Perfect Passive Solar Envelope (P.P.S.E.) a volume unshaded by existing buildings, then intersecting this with the Solar Envelope, a form originally developed by Knowles (1981), a Synergy Crystal could be created that had solar aperture, yet did not shade existing buildings. The Synergy Crystal would be a highly animated mutualistic urban solar niche that visually indicated the energy conversion potential of a site for specific seasonal and diurnal time periods (Figure 3).



(a) (b) (c) (d)

Figure 3 Shock City. (a) 'Manchester, Getting Up The Steam', unprecedented urban growth illustrated in 'The Builder' (1853). (b) An elevational study of Synergy Crystal generation, Newton Street, Manchester (1. Solar Envelope, 2. P.P.S.E, 3. Synthesis, 4. Synergy Crystal). (c) Synergy Crystal in urban context (Newton Street, Manchester). (d) An aspect society of Synergy Crystals displaying organic solar dynamism across the Mancunian skyline.

3. SynCity: The Quest for Solar Generated Niche within the Urban Forest

(Bioclimatic Labs, Event Workshop 2008 – MSA)

3.1 Background

The annual SynCity Workshop facilitated a mapping of city and nature in order to grow a mutualistic solar response. With initial reference to the Synergy Crystal and Phenotypic Plasti-City (a heuristic solar model developed by this author through PhD research) students would be asked to demonstrate an understanding of the similarities between the natural forest and sustainable city. Analogies developed culminating with flexible passive niche strategies for various urban brownfield locals in Manchester and Liverpool.

3.2 Aims & Objectives

The intention of the workshop was to engage undergraduate architecture students at the Manchester School with sustainable solutions on a more expressive platform. Architectures challenge has always been to creatively transform data, contextual or otherwise, into form. Though quantitative energy analysis is an essential factor and continues to be undertaken, participants were encouraged to be form creative.

The knowledge and understanding of solar geometries (latitude, azimuth, and altitude angle) and urbangeometries (grid and density) would be critical throughout, as the 3D CAD modelling of both would present a futuristic vision of post-industrial solar form. From the outset students were presented with various scaled forest phenomena e.g. forest gap dynamics, tree/leaf strategies, and chloroplast responses, enabling a biomimetic dialogue to run concurrently with modelling. A central aim was to advance the understanding of active and passive solar technologies along with their potential provision within the proposed masterplan.

3.3 Form & Vision

Forms generated during the workshop display the same faceted dynamism and presence as the futuristic visions of 1930's illustrator Hugh Ferriss and the intense contemporary geometries of Rem Koolhaas. The similarities end when the internal programs of each of the illustrated precedents are evaluated (Figure 4). All are essentially shade-tolerant, they do not require direct sunlight and would be largely unaffected by continuous shade. Essentially programs such as office skyscraper, auditoria, library, and TV studio are shade-tolerant; they require diffuse daylight and as a necessity take steps to prevent solar penetration. A strategy not repeated by forms generated in the SynCity workshop which actively seek solar radiation. Figures 5 and 6 represent a selected few workshop outputs, each demonstrating how form would be dependent on site context, solar rules, process, and solar positional data (hourly and seasonal

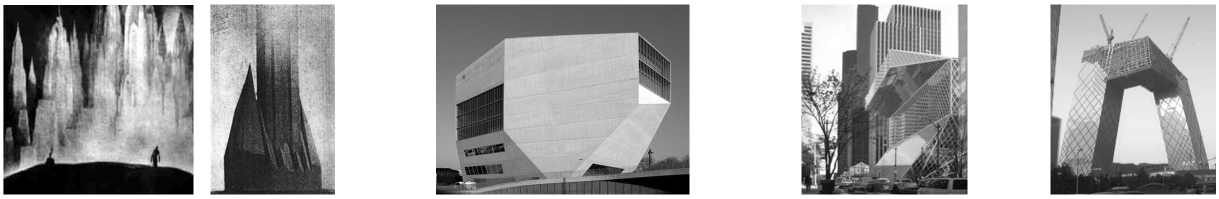


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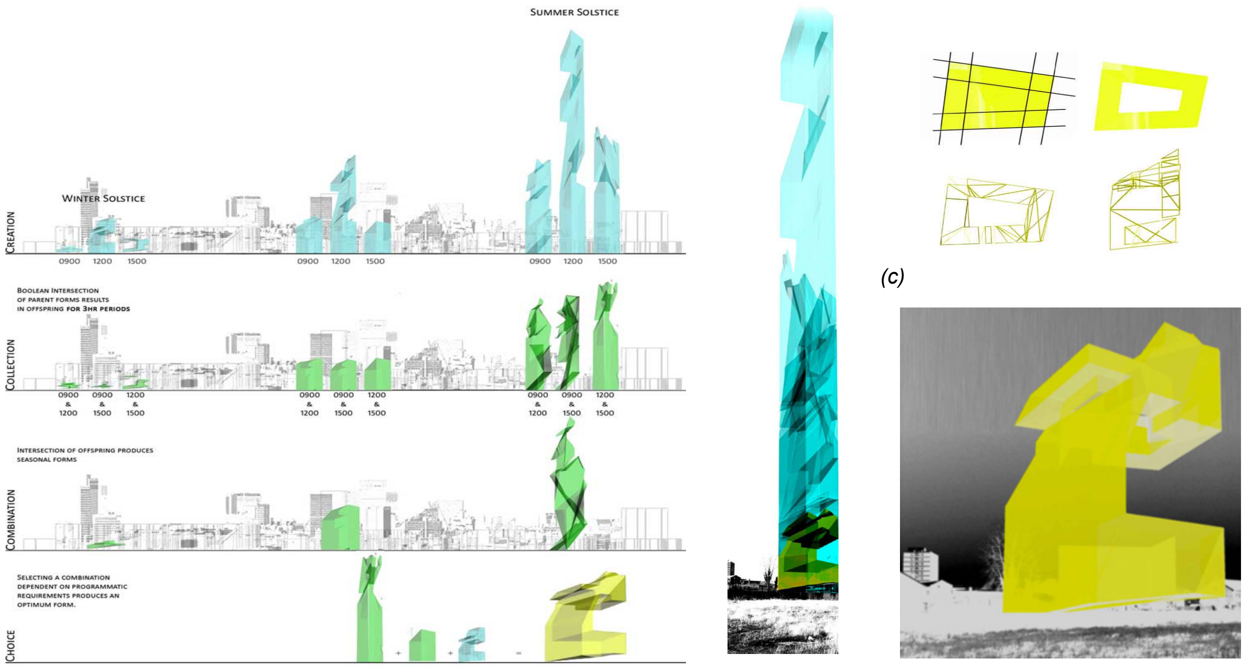
Figure 4 Unconventional faceted urban forms by Hugh Ferriss and Rem Koolhaus (OMA). (a) Sketches of Ferriss' vision of the futuristic city (1929). (b) Casa da Música, Porto, Portugal, a spatially distinct and sculptured 1300 seat grand auditorium. (c) The Seattle Central Library (USA), a public building incorporating numerous low energy impact strategies including rainwater collection, selective triple glazing, and energy management systems. (d) CCTV, TV Station HQ, Beijing, a towering 'loop' of interconnected programs.



(a) (b) (d)

Figure 5 SYNCITY WORKSHOP 2008, MSA, Alex Shovelton (Yr 3 student), site: Manchester City Centre, UK. (a) Seasonal and hourly geometries generate faceted tower and block niche. (b) Superimposition of form visually describes cyclical relationship of site and sun. An optimum volume is revealed that satisfies all environmental conditions and critical periods of mutual solar access. (c) The methodology is extended to include passive and non-passive zones, the form further sculptured to reveal a 6 metre perimeter niche capable of being naturally ventilated and illuminated. (d) Contextualisation of final optimum form.

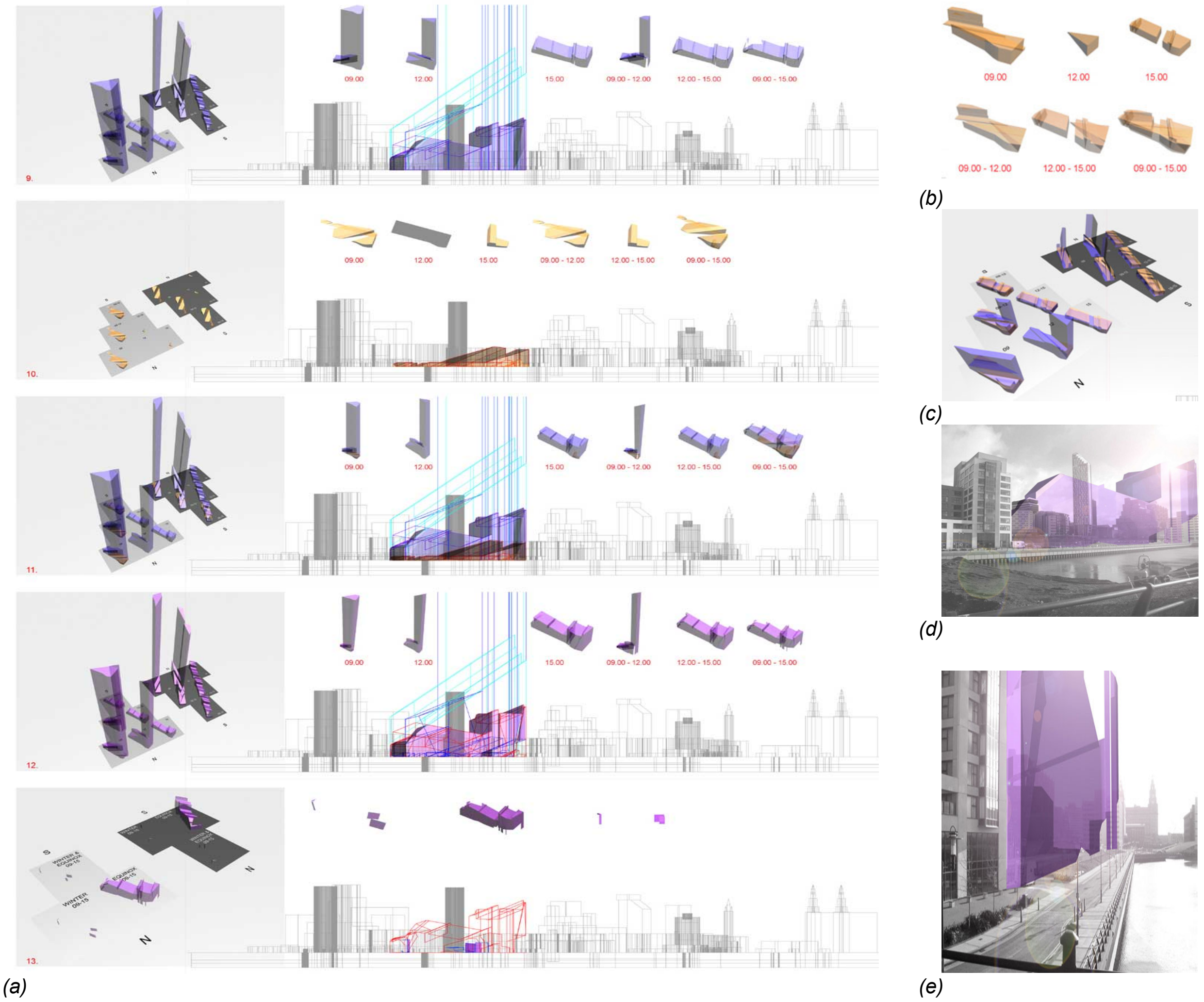


Figure 6 SYNERGY CITY WORKSHOP 2008, MSA, Mike Groves, John Roberts, and Ricky Tam (Yr 3 students), site: Princes Dock, Liverpool, UK. (a) Solar forms for Equinox collated, Boolean interested, and evaluated on a pyramidal grid relating to hourly and seasonal periods of solar and shade access. (b) Winter shade niche de-contextualised within hourly periods of access. (c) Winter shade zones and Solar Envelopes aligned. (d) & (e) Contextualisation of final optimum form in Princes Dock, Liverpool.

4. Forest Analogy

4.1 Forest & City Metabolism

The analogy between the operational patterns of natural ecosystems and those belonging to sustainable development is an obvious but significant one to make. Forest systems increasingly partition energy to maintenance and respiration rather than growth and production as they successionally advance toward a climax community; a phenomenon that Dumreicher et al. (2000) make reference to in their critique of current unsustainable cities. As stabilising mechanisms fail to operate, carrying capacity limits are exceeded once a city reaches climax. This leads to overproduction, a distinguishing and decisive factor that separates current cities from forest systems, and currently threatens the very existence of synthetic and natural communities.

4.2 Light Stratified Superorganism

Within each layer of a stratified temperate forest light is a limiting factor. Direct sunlight creates a shade environment, which through natural selection or more specifically, coevolution shade-tolerant species are able to survive. Tolerance, a significant factor in any life strategy, is a form of compromise between species that normally compete for the same resource. This specialization between species ensures that interspecific competition (when two or more species populations adversely affect the growth and survival of each other in an effort to gain a limited resource) is muted as forest species retreat to their own particular habitat or ecological niche.

4.4 A Self-perpetuating Solar Model

A forest self-perpetuates at all scales. Of particular interest to this study is the intermediate meso scale where species interactions and gap dynamics occur. The following two types of gap regeneration became significant biomimetic precedents. The first, the Phasic Series published by Watt (1947) relates to any new gap created by the fall of a single tree. Under this dynamic a single shade-intolerant tree would follow four phases; pioneer, building, mature, and degenerate. The second, Sernander-type dynamics published by Sernander (1936) is only initiated with disturbances larger than a single tree fall. Forests of narrow-crowned trees require this large gap to self-perpetuate, if insufficient in size this shade-intolerant community would tend towards a self-replacing climax of shade-tolerant tree species.

In an attempt to make an interpretive move from the biological to the synthetic it became clear that Synergy Crystal research did not extend to a community-scaled self-perpetuating solar model. Unlike the Solar Envelope, developed for the expansive gridiron of Los Angeles, the Synergy Crystal responded to singular urban pockets contained within an established, organically compact conurbation. If a biomimetic solar city based on forest algorithms were to succeed, it would have to respond to disturbances greater than the fall of a single building i.e. a solar city following Sernander-type forest patch dynamics.

4.5 Interspecific Competition

Natural interspecific competition occurs when two or more species populations adversely affect the growth and survival of each other in an effort to gain a limited resource i.e. direct sunlight. In nature specialisation between species ensures that interspecific competition is muted as species retreat to their own particular habitat or ecological niche. The Synergy Crystal, an ecological niche inhabited by shade-intolerant species, visually identified specific periods of solar access. However, with no effort to minimise interspecific competition, the methodology failed to consider an ecological niche capable of sustaining shade-tolerant species, and consequently could not utilize the same environmental mechanisms open to a forest system.

As the toleration of shade is critical within any light stratified forest system, the aim of the methodology was to embrace the physical compaction of cities and therefore the volumes of shade that will inevitably result. The objective now was to grow a community of solar related forms that visually indicate regions where both shadow and sunlight occur at critical times of the day and season without compromising community solar access. Further, a solar resolution was sought that offered a compacted and contextually receptive alternative to expansive solar developments formulated by the oblique winter midday sun angle.

5. Growth Methodology

5.1 Overview

Using a process of synthetic natural selection, city elements such as dwellings (shade-intolerant species), offices and commercial premises (shade-tolerant species) are able to interact daily and seasonally in a symbiotic way. In addition, a synthetic silvicultural process of seeding an urban grid enabled specific solar communities to be grown sequentially.

5.2 Growth Rules

Solar growth began with the formulation of a contextualized urban grid, the random numbering of each grid subdivision continuing the heuristic nature of this study. Through the implementation of various growth rules a community of solar-related volumes emerged that diurnally and seasonally apportioned periods of solar access to both existing and future urban form.

Rules relate to periods of solar access, existing building/plot use, and present/future energy potential. For example when an existing façade becomes a generator of new form due to its solar adjacency to the site being grown its area of glazing is evaluated. A façade with greater than 25% glazing can only be overshadowed from the ground upwards by 33% during specified solar access hours, whereas facades that serve as firewalls or other vertical surfaces with limited glazing may be totally overshadowed by new solar form. Niche volumes are designed not to overshadow the roof of any existing building, a move protecting the future potential of passive and active solar technologies. In summary, the methodology for the growth development of Northern European brownfield sites adheres to the following sequence (Figure 7 overleaf):

1. Divide site into grid, then subdivisions.
2. Decide on growth order of each subdivision. This can be random or controlled e.g. numbers allocated north to south or south to north.
3. Use solar azimuth and altitude for each hour on Equinox to create Solar Envelope.
4. Identify shade-tolerant layer beneath.
5. Commence a Boolean intersection of forms based on hourly periods of sun and shade.
6. Visualise shade-intolerant niche and a shade-tolerant niche.
7. To grow next subdivision repeat steps 3 to 6.

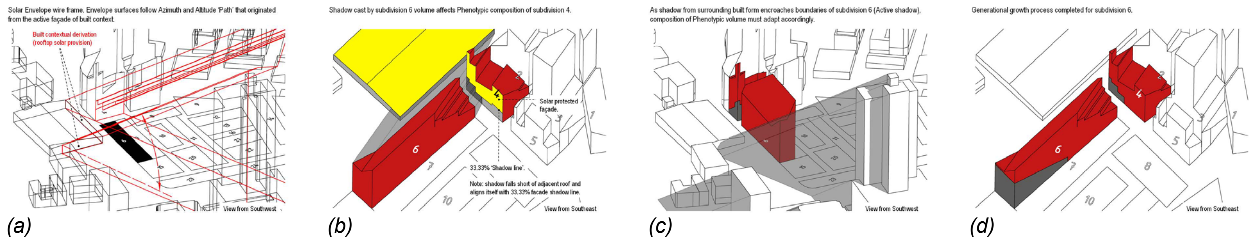


Figure 7 Self-perpetuating solar city methodology. Selected slides describing the sequential technique used during the growth of a dual shade-intolerant and shade-tolerant volume i.e. a volume partly overshadowed by both surrounding built context and previously generated solar forms.

5.2 Stasis Community

The initial methodology was to quantify and express visually biomimetic growth at hourly solar time-checks i.e. 09.00, 12.00, and 15.00hrs. An extension of this led to the possibility of forest inspired solar community that considers prolonged periods of solar and shade access. Through a process of Boolean modelling this hourly cyclical solar city would be transformed into a state of suspended animation or stasis, enabling the modelling of a biomimetically stratified community more in tune with natural forest biorhythms and structure. As durational periods of solar and shade access are immediately realised a visual survey has confirmed that periods of solar insolation lengthen within the overstorey and the upper regions of the stasis canopy, while periods of shadow progressively increase nearer the understorey and ground (Figure 8).

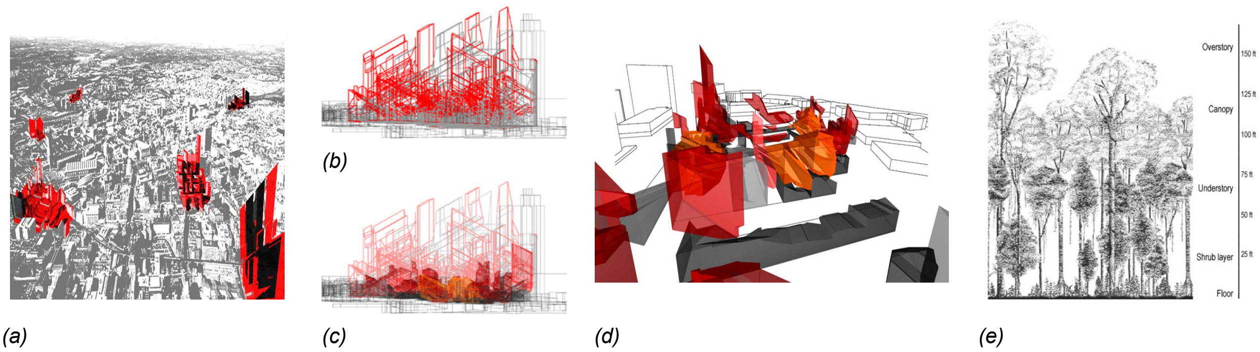


Figure 8 Generation of forest-Inspired solar stasis. (a) A polyclimax of cyclic solar communities become inter-seasonal energy hubs migrating across the Manchester skyline (b) A Cyclic community: 09.00hrs + 12.00hrs + 15.00hrs. (c) Stasis community niche identified by Boolean intersections. (c) Light stratified system of forest-inspired growth in stasis. (d) Light stratified system of forest-inspired growth in stasis, each volumetric niche offering varying periods of sun and shade. (e) The five strata forest, the overstorey containing emergent tree crowns that rise above the rest of the canopy.

6. Conclusion – Biomimetic Transfer (Macro, Meso, & Micro Scale)

6.1 Macro Scale (Community)

A biomimetic solar society has been presented that is capable of invading post-industrial cities. Envisage a solar metropolis that displays both light and shade avoidance strategies, akin to leaf chloroplasts at the microscopic scale that relocate in an attempt to receive shading from the inner face of mesophyll cells and themselves. By employing an opportunistic strategy aspect societies of biomimitic development rapidly exploit light gaps within the urban overstorey, canopy, and understorey. The city is now inter-seasonal and expands like a snow buttercup during each equinox and summer to intercept the sun’s warmth, later releasing heat through district heat stores.

6.2 Meso Scale (Typology)

Within this synergised landscape interspecific competition would be muted as mixed-use programs retreat to their own sunlight and shade niche, the result, a positive mutualistic community in which solar energy acquired by shade-intolerants via passive or active means is symbiotically relayed to shade-demanding office and retail organisms, their faceted surfaces displaying leaf heliotropisms. In a diaheliotropic response shade-intolerant form expose vertical planes toward the sun, and in a paraheliotropic action niche canopies incline into the suns’ rays allowing neighbouring buildings and solar forms insolation.

6.3 Micro Scale (Surface)

Shade-intolerant buildings often require selective layered façades to mitigate diurnal and seasonal solar variation, a strategy not dissimilar to that displayed by shade-intolerant Multilayer trees and Sun Leaves which increase their photosynthetic rate through the separation of leaf and chloroplastic layers. In a conscious effort to maximize species biodiversity, biomimetic offices do not now require the double-skin to prevent external solar heat gain and glare, now their view of the sun has now been intentionally obstructed by sunlight-demanding species. This implied single-skin strategy having direct associations with shade-tolerant Monolayer trees and Shade Leaves that arrange their leaves and chloroplasts into a single surface.

6.4 Sun, City, Nature, & Form

The aim of this paper was to present a city scaled strategy that took inspiration from the processes and design of natural phenomena. Over evolutionary time nature has consistently demonstrated a benchmark to which our design efforts must now reach in order to combat climate change. In a reciprocal action nature is once again valued and appreciated in architecture, in stark contrast to one that continues to be cultivated, dominated, and exploited.

The ancients showed great technological ingenuity in their solar derived communities. Quantitative solar data would be visually expressed by rhythm and ritual within extreme environmental conditions. The solar forms presented here echo this appreciation in an era of energy uncertainty. Future city form may be reliant on the ability to be sustained by an ecological solar niche derived by daily and seasonal environmental forces and rhythms.

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