

# Creating Comfortable Climatic Cities

Comfort and Climate as Instruments  
for Healthy Interior, Architectural & Urban (Re)Design

Duzan Doepel



■ Inaugural Lecture

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## Colophon

# Creating Comfortable Climatic Cities

Comfort and Climate as Instruments for  
Healthy Interior, Architectural & Urban (Re)Design

Duzan Doepel

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Inaugural Lecture Sustainable Architecture & Urban (Re)Design  
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## Summary

Sustainable design has finally entered the mainstream of the architectural service industry. For some, this can be attributed to a sincere paradigm shift and acceptance of our responsibility to rethink the manner in which we tread the earth. For others, this 'Green revolution' signifies new business that can be capitalised in a time of economic crisis. Whatever the motive, it is clear that the industry needs to develop new tools and ways of working to achieve 'more' with 'less'.

Resource efficiency, energy and climate are the main drivers that will shape the development of local and regional sustainability strategies. A social ecological approach to design is a prerequisite for translating these strategies into sustainable, liveable and attractive cities. This means taking a transdisciplinary approach and re-evaluating contextual parameters such as microclimate, energy, materials, water and waste flows. By combining existing methodologies and tools, it is possible to link form and performance to comfort, allowing one to derive the most appropriate architectural or urban response in a specific context. Climate and comfort are brought into alignment, forming valuable design instruments that link the realms of architecture, engineering and building.

## 01. A New Collective Agenda

*‘Sustainability is a societal journey, brought about by acquiring new awareness and perceptions, by generating new solutions, activating new behavioural patterns and, hence, cultural change.’ - Ezio Manzini (1997)*

There is no escaping it. Green is everywhere. Everything from supermarket products to buildings claim to be Green. It would seem that after an epoch of individualism, Green has become a new collective agenda (Maas et al., 2010). We may claim that a common agenda has emerged and sustainability has become mainstream, but it would be jumping the gun to claim that the paradigm of mass consumption has shifted. A true paradigm shift is inextricably linked with behavioural change on a massive scale; this is clearly not yet the case. History has shown that a good dose of moral concern for the ecological and social conditions on our planet is not enough to change mass behaviour. It took the Middle East oil crisis in the early 1970s to mobilise collective thinking about the state of the planet, biodiversity and other environmental issues. Although the design activists that emerged from this period laid the foundations for the sustainability agenda of today, their impact at the time was limited. As oil prices dropped, so too did the perceived collective need to act. But two global concerns have since emerged that make this moment in time different from the early 1970s. The double whammy of peak oil and climate change has levelled the playing field, creating the economic and social conditions for real change (Faud-Luke, 2009). Even if the conditions for a paradigm shift have emerged, the current market is not yet adept at tackling these challenges. Innovation in all fields of life is needed to make this transition to a new Green reality.

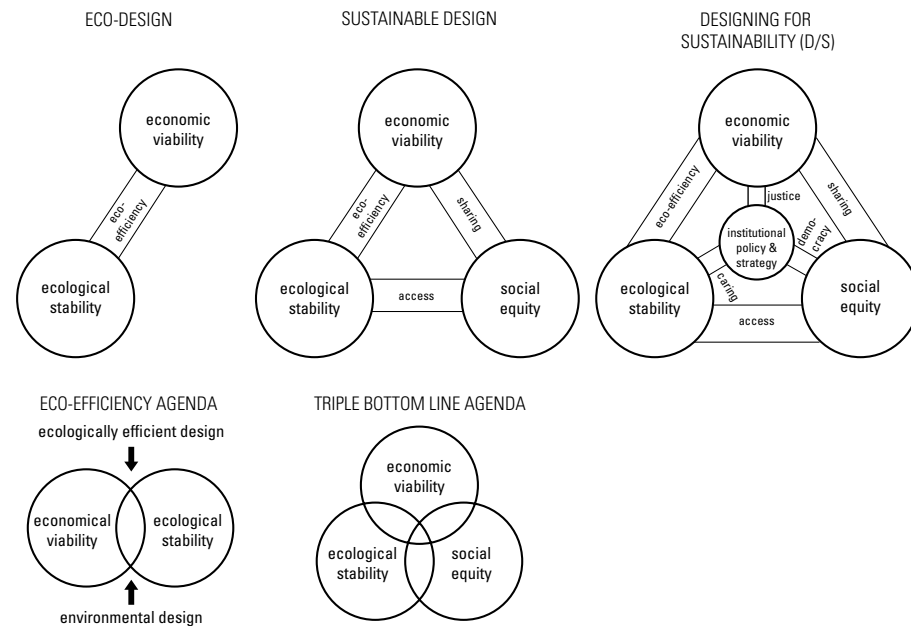
Sustainability is the pre-eminent challenge of the 21<sup>st</sup> century, although it remains a contentious concept. In view of this, Janis Birkeland (2008) prefers to talk about ‘positive’ rather than ‘sustainable’ development in the context of urban planning and design:

*‘Positive development refers to physical development that achieves net positive impacts during its life cycle over pre-development conditions by increasing economic, social and ecological capital.’*

This definition specifies the direction of development and how it should affect economic, social and ecological capital. Design can have a positive impact on these capitals and over the past three decades has already evolved on a small scale towards meeting the sustainability challenge (Faud-Luke, 2009). It is not surprising that most sustainable architectural proposals focus on the physical, spatial and ecological aspects of design. For this reason the majority of Green architecture can be positioned on the eco-efficiency axis of sustainability (see Figure 1). But architecture and urban design can have more impact than this. Achieving the right balance or symbiotic solution for each situation demands a broader sustainability base to design and a transdisciplinary approach to problem solving that draws on other, more complex aspects of the sustainability toolkit: systems thinking, network theory and life cycle analysis. 'Integral Sustainability' goes beyond the merely physical aspects of sustainability. It involves bringing together as many aspects of sustainability, on a systems level, within a spatial and temporal context (Bosschaert and Gladek, 2010).

Figure 1.

Eco-design, sustainable design, designing for sustainability - the sustainability prism (Faud-Luke, 2009) [Doepel Strijkers, 2012]



The three elements - the ecological, the economic and the social - are used in Venn diagrams to represent eco-design and sustainable design, with their eco-efficiency and triple bottom line (TBL) agendas - people, planet and profit. The Agenda 21 framework for action that emerged from the 1992 Earth Summit in Rio de Janeiro added important considerations to the sustainability debate: participation, open government and the role of institutions. The institutional element introduced a further level of complexity and gave rise to the sustainability prism, which links the social, ecological, economic and institutional dimensions.

The sustainability prism is a more holistic framework for balancing the different dimensions and revealing opportunities and threats (Faud-Luke, 2009).

This integrated definition and approach to design has not yet fully found its way into the mainstream of design education and practice. In the worst case, sustainability in architecture is no more than a superficial layer of Green, camouflaging poor architectural design (Maas et al., 2010). What started on the drawing boards of smart marketing companies has found its way into architecture. 'Greenwashing', as it is derogatorily called, is omnipresent in contemporary architectural design proposals all over the world. This process continually repeats itself. As Stephen Bayley so eloquently put it, the biggest source of inspiration for architects are other architects.

*'Where do architects and designers get their ideas?*

*The answer, of course, is mainly from other architects and designers, so is it mere casuistry to distinguish between tradition and plagiarism?' - Stephen Bayley (1989)*

Images of superficial Green design in glossy magazines inspire copycat behaviour. The problem is deeply rooted. Our consumerist society attributes meaning to artefacts in terms of 'style' and the associated status that brings. This has always been the case. Even the social agenda of the early Modernist movement was lost as it became commodified by the International Style at the beginning of the previous century. This 'international style' was soon appropriated by transnational corporations, which used it as a flagship to showcase their modern aspirations (Faud-Luke, 2009). In the decades that followed, glass, steel and concrete structures sprung up all over the world, irrespective of the local climate and culture. Architects and mechanical engineers became dependent on installations to manage the indoor climate of their buildings and create comfortable conditions for their users. In a world where cheap fossil energy was abundant and the paradigm of mass consumption was dominant, there was no imperative or incentive to act otherwise. This trend took off exponentially towards the end of the last century. The telecommunications revolution fuelled globalisation and the current culture of regional competitiveness and city branding. Urban developments became inextricably linked to the 'image buildings' spawned by this urban marketing. 'Form' and 'image' prevailed over 'sense' and 'sensitivity'. Never before in the history of mankind has the schism between architectural form and genius loci been so huge.

The first group of people that need to change their behaviour are designers themselves. Given the copycat culture, it is imperative that they produce good examples of integrated design with positive social, economic and ecological effects as models for

change. Most examples of Green architecture focus on the eco-efficiency aspects of sustainability. Few manage to blend sociocultural or socioeconomic sustainability with eco-efficiency and a powerful design aesthetic. A fine example of the latter is the Jean-Marie Tjibaou Cultural Centre by Renzo Piano (Faud-Luke, 2009) (see Image 1).

Image 1.

Jean-Marie Tjibaou Cultural Centre in Nouméa, New Caledonia. {Renzo Piano, 1998} [wikipedia.org]



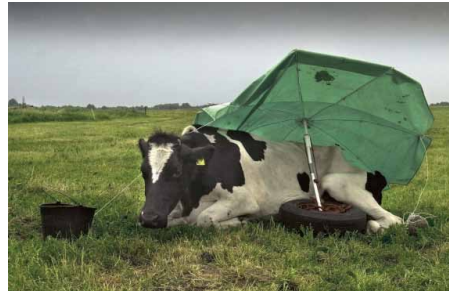
Located on the narrow Tinu Peninsula, the Jean-Marie Tjibaou Cultural Centre celebrates the vernacular Kanak culture of New Caledonia, amidst much political controversy over the independent status sought by the Kanaks from French colonial rule. The vernacular Kanak building traditions, use of materials and optimisation of the microclimate inspired Piano to create an integrally sustainable building in a contemporary idiom. The formal curved axial layout, 250 metres long on the top of the ridge, contains ten large conical cases or pavilions (all of different dimensions) patterned on the traditional Kanak Grand Hut design.

The architectural service industry is in dire need of tools and strategies for integral design to accelerate the process of change and assimilation. Innovation and experimentation are necessary to achieve this, but given the current economic crisis it is unrealistic to expect this to come solely from the market. The most effective approach for acceleration is to bring research, education and practice together in concrete pilot projects to test and demonstrate innovative design and development strategies, and to measure their effects on user behaviour and social, economic and environmental capital.



**Image 2.**

Heat stress in the Dutch polder [Anninga-GPD, 2008]

**Image 3.**

Hot summer day in the city of Rotterdam [JB\_NL, 2012]

**Image 4.**

Flooding of the Westersingel, Rotterdam, 2009 [DCMR Environmental Protection Agency, 2009]



## 02. Contemporary Sustainability Issues and Opportunities

To develop strategies for 'positive development' we need a broad understanding of the key issues that will continue to shape the landscape of design. Our global environment, the human condition and the natural world are undergoing extensive changes at an astounding rate. Trying to balance the earth's ability to provide biological sustenance with a growing human population, and to simultaneously nurture a 'better life' for humans, is a truly daunting task. This task is made immeasurably more difficult against the background of climate change (Faud-Luke, 2009).

### Climate change

In 2006, Al Gore captured the imagination of the world with his epic documentary *An Inconvenient Truth*. The basis of his discourse revolves around the fact that most governments do not include the true costs of climate change in their models of economic development. At the same time, Sir Nicholas Stern (2006) published a report for the UK government predicting that if we take immediate action, it will take 1 - 2% of global GDP to avert the worst consequences of climate change, compared with 15 - 20% if we do nothing. Although design activists had been voicing these concerns for at least thirty years, Gore and Stern finally captured the attention of leaders all over the world (Faud-Luke, 2009).

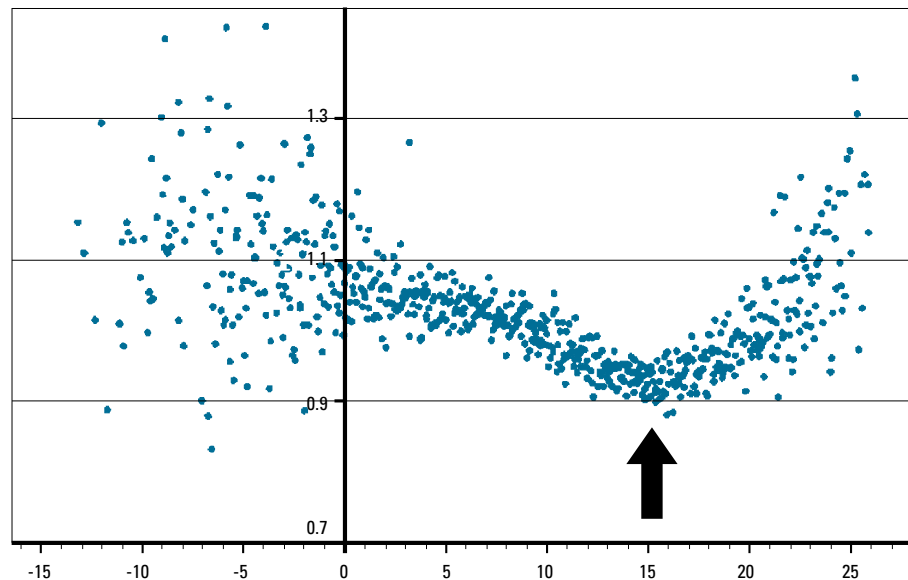
In the very same year, the KNMI (Royal Netherlands Meteorological Institute) predicted the possible effects of climate change for the Netherlands using simulation models and climate scenarios. In the most pessimistic scenario, the effects on the low-lying delta cities will be immense. The amount of water cities will have to deal with, in the form of rising sea level, increased precipitation and freshwater from the mountains in bordering countries, will increase radically. Besides the effects on urban water, the region will be affected by an average increase in temperature of 2°C by 2050 and up to 3°C this century, resulting in a similar climate to modern day Lyon in the south of France (van den Dobbelsteen et al., 2011) (see Image 2, 3 and 4). The KNMI expects more climatic variation: winters are expected to be milder and wetter due to increasing westerly winds, while summers are expected to become hotter and dryer due to increasing easterly winds. The effect of the latter will be that cities will dry out even more, making seasonal buffering more important in the future. In 2007, the UN's Intergovernmental Panel on Climate Change (IPCC) predicted a global temperature rise of 6.4°C by 2100. The effects of climate change will undoubtedly impact heavily on urban transformation in the 21<sup>st</sup> century.

In the summer of 2011, a record high temperature difference of +7°C was measured between the inner city of Rotterdam and the surrounding countryside. This phenomenon, known as the heat island effect, is caused by thermal accumulation, heat emitted by vehicles, buildings and industry, and insufficient urban green. Factors that influence this are the absorption and retention of heat by the urban

mass (hard surfaces, stone-like materials, asphalt, bitumen), the quality of the buildings (compactness and insulation values), the movement of air (urban axes, street patterns), and evaporative cooling from surface water and urban green (van den Dobbelsteen et al., 2011). Most of the existing housing stock in the Netherlands is not designed to cope with long periods of extreme heat. Although hotter summers can be seen as a blessing in a temperate climate like the Netherlands, research by Huynen et al. in 2001 shows a clear correlation between the number of mortalities and a small temperature rise of a few degrees (see Figure 2). When placed in this perspective, the social benefits of improving the energy performance of the existing building stock could outweigh the environmental ones.

Figure 2.

Temperature and mortality rates (Huynen et al., 2001) [Doepel Strijkers, 2012]



### Climate and comfort - Opportunities for design

An increase of a few degrees in temperature will have a huge impact on the existing building stock. The cooling demand will rise exponentially, and so too the cost of keeping the indoor climate comfortable. Most buildings are mechanically cooled, relying on electricity that is a lot more expensive than the use of residual heat. However, if the temperature increases moderately, the use of passive cooling in the Netherlands will become much more feasible. The form of a building, the design of the envelope, the use of materials and the internal configuration all influence the solar accumulation and potential for natural ventilation. And the use of vegetation and hard dry surfaces can raise or reduce the humidity of the air before it passively enters the building. Climatic parameters can inform the architectural language of a

building, inextricably linking it to the microclimate of its immediate surroundings. The changing climate therefore creates opportunities for rediscovering bioclimatic design in a European setting.

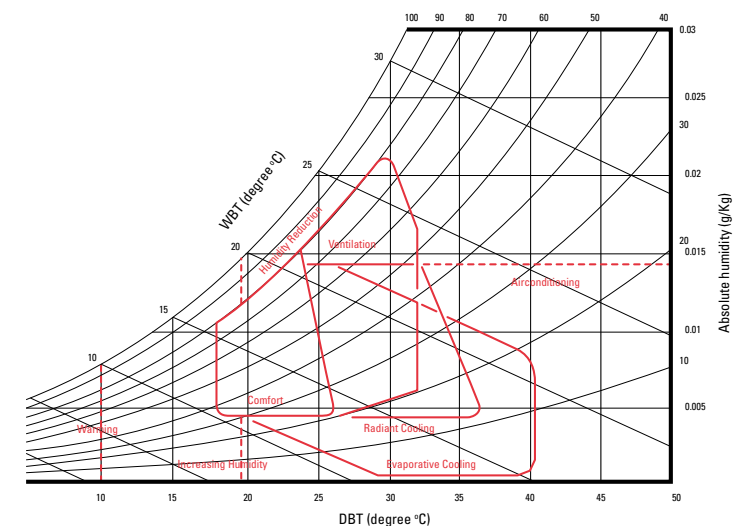
*‘Designers need to think in terms of a spectrum of comfort in designing the reduced-impact buildings of the future.’* - Terri Meyer Boake (2008)

Most buildings are designed to ensure fully mechanised comfort, even in climates where passive solar heating can easily be utilised. According to Meyer Boake (2008), today’s architects and mechanical engineers do not work within a zone, but to a ‘finite point of expected comfort for 100% mechanical heating and cooling’.

Figure 3, taken from the Olgyay brothers’ book, *Designing with Climate*, illustrates the range of temperature and humidity in which people feel comfortable (Olgyay and Olgyay, 1963). As opposed to designing for a fixed temperature, the Olgyays took the natural temperature swings of the environment as well as the human capacity to adjust to small fluctuations in temperature and humidity into account. They defined passive strategies, aimed at expanding the zone of human comfort while reducing the need for mechanical heating and cooling.

Figure 3.

Bioclimatic chart; expanding the comfort zone through bioclimatic design (Olgyay and Olgyay, 1963) [Doepel Strijkers, 2012]



The Olgays' work demonstrates that one must design differently for different climatic regions. This may seem obvious, but office buildings or houses look pretty much the same in temperate and tropical climates around the world. It is logical that if you need heat for much of the year, you will deal with the sun differently than if you predominantly need cooling.

Designing for the zone implies a dynamic definition of comfort and acceptance of seasonal and diurnal fluctuations. The work of Phillippe Rahm takes this as a point of departure for design. In what he terms 'meteorological architecture', convection, pressure, radiation, evaporation and conduction are tools for architectural composition. The architectural form explores the atmospheric and poetic potential of new construction techniques for ventilation, heating, dual-flow air renewal and insulation (Rahm, 2009; Rahm, 2010). This approach to design embraces climate change as an opportunity to create buildings that are in harmony with the environment and take optimal advantage of their specific microclimate (see Image 5 and Figure 4).

**Image 5.**

Convective apartments, Hamburg. (Philippe Rahm Architects, 2010) [Philippe Rahm Architects, 2010]



The design of this condominium building is based on the natural law that makes warm air rise and cold air fall. Very often, a real difference in temperature can be measured between the floor of an apartment and the ceiling, sometimes up to 10°C. Depending on our physical activities and the thickness of our clothing, the temperature does not have to be the same in every room of the apartment. If we are protected by a blanket in bed, the temperature of the bedroom could be reduced to 16°C. In the kitchen, if we are dressed and physically

active, we could have a temperature of 18°C. The living room is often 20°C because we are dressed without moving, motionless on the sofa. The bathroom is the warmest space in the apartment because here we are naked. Keeping these precise temperatures in these specific areas could save a lot of energy by reducing the temperature to our exact needs. Related to these physical and behavioural thermal figures, Rahm proposes shaping the apartment into different depths and heights: the space where we sleep will be lower while the bathroom will be higher. The apartment would become a thermal landscape with different temperatures, in which the inhabitant could wander around as if in a natural landscape, looking for specific thermal qualities related to the season or the moment of the day. By deforming the horizontal slabs of the floors, rooms or spaces are created with different heights and different temperatures. The deformation of the slabs also gives the building its outward appearance (Rahm, 2009; Rahm, 2010).

**Figure 4.**

Functions related to thermal zones. [Philippe Rahm Architects, 2010]



### Peak oil

The biggest social problem is not climate change, but the depletion of our energy reserves, a social economic problem rather than a technical one (Tillie et al., 2009). The Netherlands is addicted to fossil fuels: 96% of the energy we use is derived from non-renewable sources making us one of the least sustainable nations in the European Union (Daniëls and Kruitwagen, 2010). This can of course be attributed to the abundance of natural gas and the investments made in fossil fuel infrastructure over the last half-century. But nothing lasts forever. According to research by ECN and NPL (Daniëls and Kruitwagen, 2010), our natural gas reserves will be depleted within the next twenty-five to thirty years. Peak oil, the point at which we have consumed more than 50% of the world's reserves, was reached in September 2008 (see Figure 5). At one point, the price of oil rose to the unprecedented level of almost 140 dollars per barrel and experts expected it to double. Although prices dropped relatively quickly, it is clear that as oil becomes increasingly scarce, prices will continue to rise. Peak oil also means peak synthetic plastics, as oil is the main raw ingredient for these materials (Faud-Luke, 2009). Exact predictions vary, but experts agree that within seventy-five years, within the lifetime of our children, oil and uranium will be depleted (WNA, 2012; Owen et al., 2010; Appenzeller, 2004).

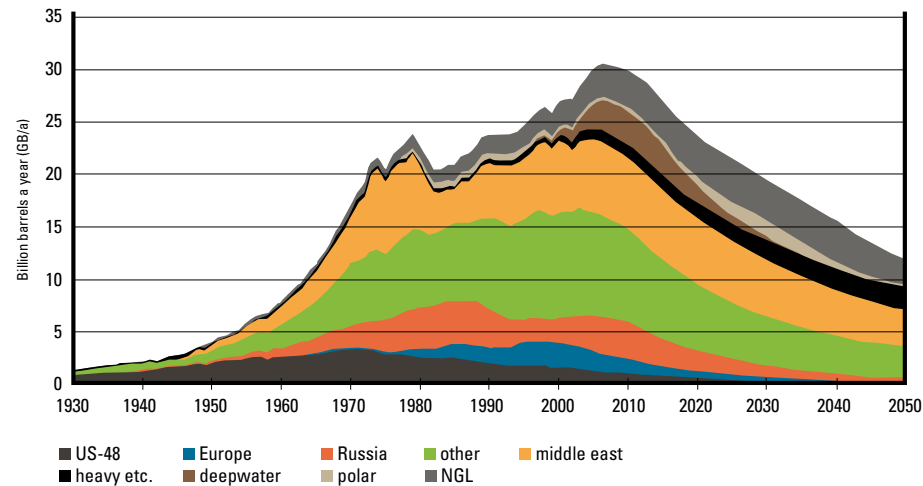
There is a growing awareness that importing energy from other regions should be considered in the light of political dependence, ecological impacts, ethical aspects and, of course, the economic implications (van den Dobbeltstein et al., 2011). Peak oil and peak plastic present two inherent challenges to mankind: making optimal use of our



local energy production potentials and finding alternative biobased solutions for synthetic plastics.

Figure 5.

Global Oil and Natural Gas Liquids Production (The Association for the Study of Peak Oil and Gas, C.J. Campbell, 2004) [Doepel Strijkers, 2012]



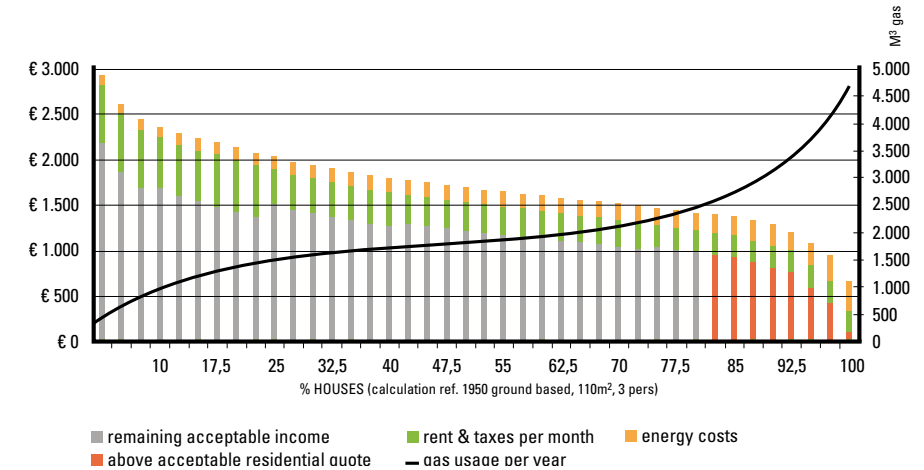
### Energy poverty - Opportunities for design

A rise in energy costs affects everyone, but especially the poor and people living far from amenities. In the early 1990s, Boardman (1991) used the term 'fuel poverty' in her publication *From Cold Homes to Affordable Warmth*. More recently, the term 'energy poverty' has arisen to describe the point at which households spend more of their disposable income on energy than on rent. This phenomenon is already evident in the Netherlands. In 2011 it was estimated that approximately 300,000 households in the social rented sector spend more than the acceptable norm of 38% of their disposable income on energy. Currently, 850,000 households are above the 'energy poverty' borderline. Translated into percentages, 17% of social sector renters are above the acceptable norm and 5% spend more money on energy than on their monthly rent (Croon, 2012) (see Figure 6).

The agenda for the architectural service industry is clear. A major energy renovation of the existing stock is needed, all new developments should be 'energy neutral' or 'energy plus', and local potentials for renewable energy production and reuse of waste streams should be maximised.

Figure 6.

Relationship between acceptable living costs in the social rented sector; 5% of households spend more on energy bills than on rent (Croon, 2012) [Doepel Strijkers, 2012]



According to Croon (2012), a short-term opportunity in the social rented sector is to retrofit 120,000 individual units each year. By linking the rent and energy costs, the total cost to renters remains the same, while the savings from energy reductions over a fifteen-year period are invested upfront in energy reduction measures. The challenge is to retrofit a house in three days to A++ energy label standard, with an average investment of approximately €45,000. As the acceptable pre-investment varies per typology and is affected by aspects such as the age of the buildings and predicted extension of their lifespan, a tailor-made strategy must be developed for each user group and housing typology, and the logistical aspect of when to intervene must be defined. The development of innovative and affordable retrofit solutions is essential if we are to counter this social economic challenge.

### Resource depletion

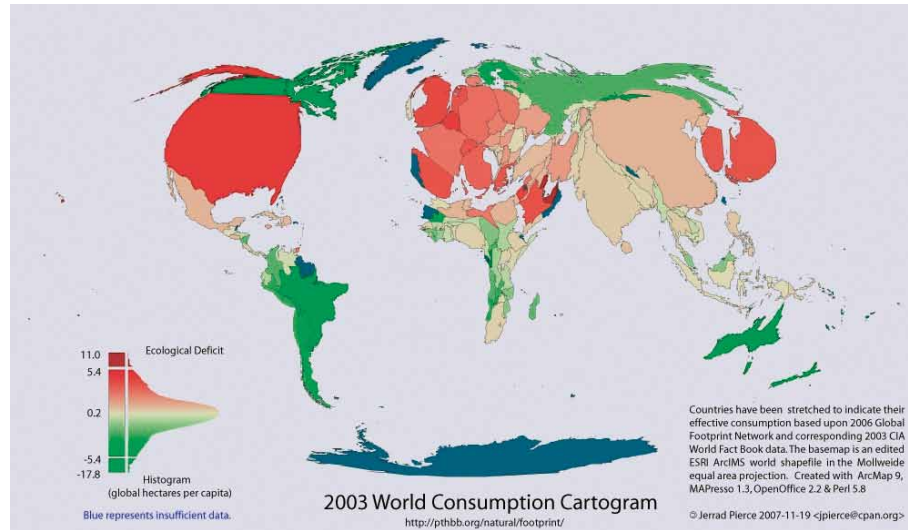
According to the World Wide Fund for Nature (Loh et al., 2006), sometime in the 1980s the rate of consumption of global resources exceeded the capacity of the earth to regenerate itself by 25%. Over the past decades the global rate of consumption has increased dramatically as the world population has grown exponentially, especially in China, India and Asia. Translated into space, mankind is using 1.5 times the natural renewable resources of the planet; if we proceed in this manner, by 2050 we will need the equivalent of three planets to meet our needs.

Besides the unsustainable patterns of consumption, there is a huge discrepancy in the distribution and consumption of resources. Based on 2006 data from the Global Footprint Network and the corresponding 2003 CIA World Fact Book, Jerrad Pierce (2007) depicted the current global resource consumption per country and per capita in a single map (see Figure 7). In a world where resources are equally shared, each

inhabitant would have an eco-footprint of 1.8 global hectares (Wackernagel and Rees, 1996). The map illustrates the imbalance between rich and poor countries, the poorest countries being well below the average and Northern countries like the Netherlands well above 4 and up to 12 global hectares per inhabitant (the top two are the United Arab Emirates and the USA).

**Figure 7.**

Global resource consumption per country, per capita [Jerrad Pierce, 2007]



## Resource efficiency - Opportunities for design

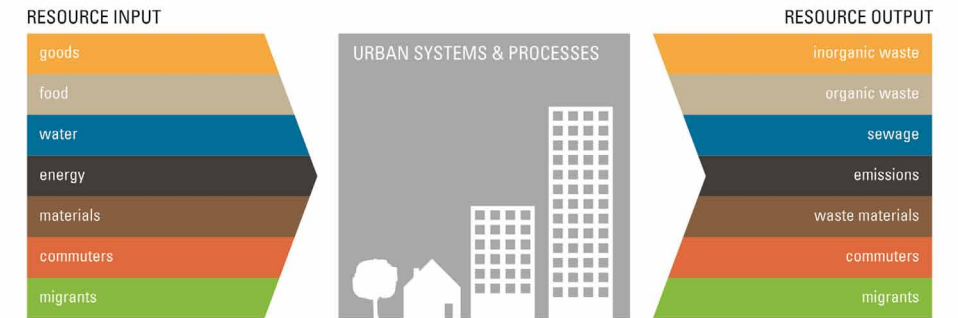
### Reuse and recycling of materials

Designers and architects can play an important role in averting resource depletion by specifying the right materials for a building or product. Every choice a designer makes when specifying materials has an effect on resource depletion and the habitat of other living species, so knowing where materials come from is an essential design skill (Faud-Luke, 2009). Resource efficiency represents an enormous opportunity for the entire service sector. Besides existing strategies such as Cradle to Cradle (McDonough and Braungart, 2002), innovative concepts such as Cirkelstad aspire to connect resource efficiency and a circular economy at the regional scale (see <http://www.rotterdamcirkelstad.nl>). Harvesting and reusing materials from demolition and waste streams from production processes keeps materials in the region, thereby reducing dependency and environmental pressure elsewhere (see Figure 8A and 8B). By explicitly including people in a reintegration process in all phases of the strategy, from demolition to the production of new building materials and construction itself, this concept has positive environmental and economic effects, as well as social returns.

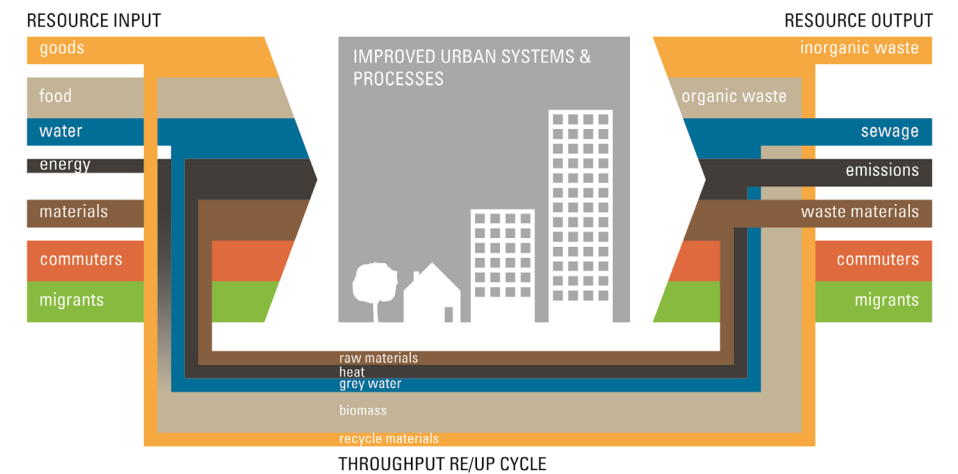
**Figure 8A and 8B.**

Closing city cycles - Circular City Metabolism [Doepel Strijkers, 2009]

### 8A. Linear City Metabolism



### 8B. Circular City Metabolism



In 2009 this principle was tested in an interesting pilot project. The HAKA Recycle Office in the Merwe-Vierhavens area of Rotterdam is a concept that illustrates how the strategy of closing material cycles at the city scale can be translated to the interior of a building (see Image 6A, 6B, 6C and Figure 9). The ambition was to go further than just reducing the CO<sub>2</sub> footprint through the reuse of materials by integrating the social component into the project. A team of ex-convicts in a reintegration programme were engaged to build the objects, making the project more than just an example of how we can make an interior from waste. It creates added value through empowerment and education.

**Image 6A, 6B and 6C.**

Recycle Office, HAKA, Merwe-Vierhavens, Rotterdam (Doepel Strijkers, 2010) [Ralph Kämena, 2010]. This project was performed by Doepel Strijkers in collaboration with Van Gansewinkel and Rotterdam City Council.

**Image 6A.**

Reception counter



**Image 6B.**

Acoustic wall



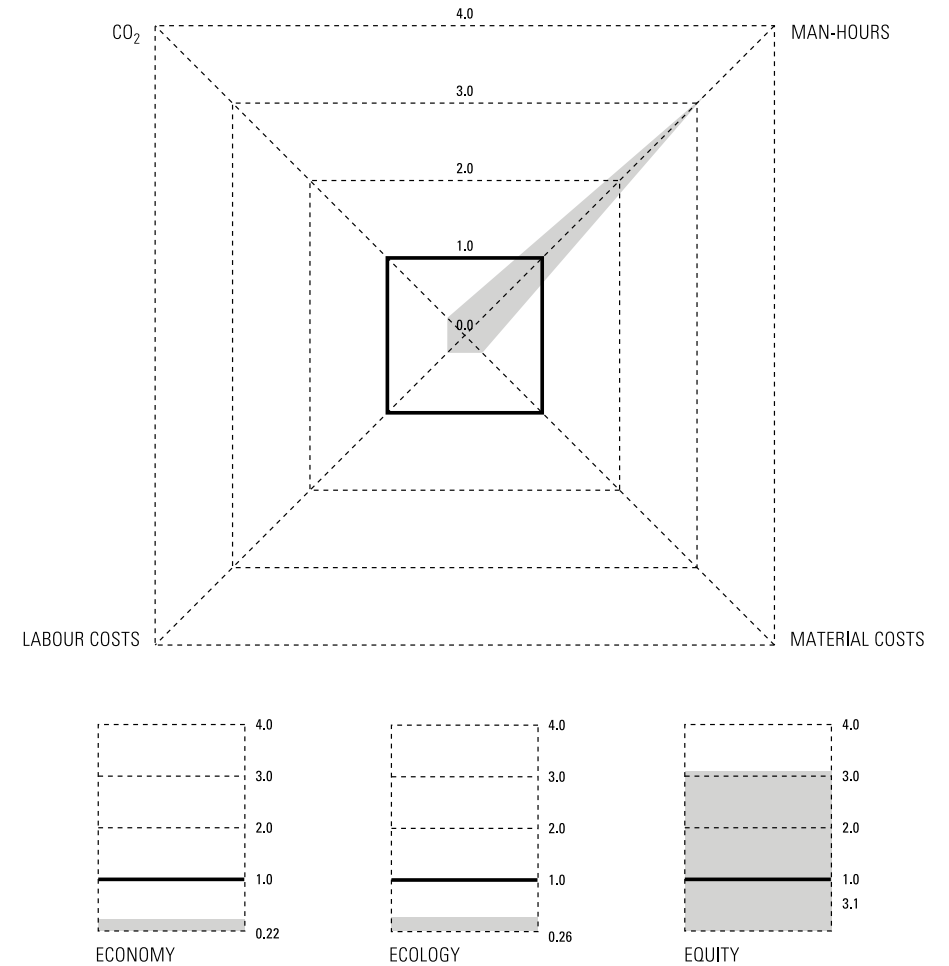
**Image 6C.**

Platform



**Figure 9.**

HAKA Average: comparison with a traditional interior with the same functionality built using new materials and a professional building team. The dark line (1.0) represents the footprint of a traditional interior. [Doepel Strijkers, 2010]



A reduction of approx. 70% was measured for the CO<sub>2</sub> footprint, material and labour costs. However, construction using unskilled labour took three times as long as a traditional interior with a professional building team. Within the framework of this test case, this aspect was deemed acceptable as more time spent on the project meant more training for the ex-detainees. For commercial upscaling of this concept, this aspect could be optimised by using offsite prefab production and linking this with technical secondary education.

**Image 7. (page 26)**

Auditorium (Doepel Strijkers, 2010) [Ralph Kämena, 2010]





### Biobased materials

Reducing the need for resources through reuse and upcycling is the first step in resource efficiency. But recycling will never meet the total demand for materials on a large scale. A second strategy that represents a huge opportunity for the building sector is the use of renewable or biobased materials. If produced on a large enough scale, this renewable source of materials has more favourable environmental impacts than most mineral based options. For many architects, however, the use of natural materials is seen as a limitation that leads to cliché Green buildings (Maas et al., 2010). It is therefore imperative that diverse contemporary architectural applications of biobased materials are developed to stimulate the use of these environmentally friendly products. Their uptake can be accelerated by producing architectural works of international allure that make use of biobased materials. If tackled at the national scale, the production of biobased materials could radically impact the agricultural, energy and building sectors, contributing to the growth of a Green economy.

It is clear that issues relating to climate change, energy poverty and resource depletion represent huge opportunities for the building sector. To be able to respond to this challenge designers need to expand their knowledge of techniques and materials. At the moment, examples of climate responsive architecture in which appropriate technologies and material use are brought into balance with sociocultural influences are thin on the ground. If Green is to escape the commercialisation of the mainstream and develop into a truly integral sustainable approach, the biggest obstacle of all is undoubtedly economic. It can be argued that economic engineering and new temporal models of financing are currently more essential for the transition to a new Green era than technical innovation.

## 03. Incentives for Change

### European directives

If the current trends continue, the global population is expected to grow by 30% to around nine billion people by 2050. Given the exponential growth of countries like China and India, and their increasing levels of welfare and consumption, there is sincere cause for concern. Increasing resource efficiency will become key in securing growth and jobs in Europe. The European Union aims to develop a strategy to create a 'circular economy' based on a recycling society, with the aim of reducing waste generation and using waste as a resource (see Figure 10A and 10B). By reducing reliance on increasingly scarce fuels and materials, boosting resource efficiency can improve security of raw materials supply, making the economy more resilient to future increases in global energy and commodity prices (European Commission, 2011).

In order to achieve this, new products and services need to be developed at the regional and local scales. New ways to reduce inputs, minimise waste, change consumption patterns and optimise production processes will need to be found. This cannot be achieved without the development of innovative management and business models, and improved logistics. It is expected that this will stimulate technological innovation, improve productivity, reduce costs, boost employment in the Green technology sector, open up new export markets and deliver more sustainable products that benefit customers.

In terms of energy resources, there are two dominant issues at European and national levels: the EU is becoming increasingly dependent on external energy sources, and greenhouse gas emissions are on the rise. Energy consumption for building-related services accounts for approximately one third of the total EU energy consumption. Here, the greatest gain can be made by influencing energy demand and one way to reduce energy consumption is by improving energy efficiency. To this end, in 2010 the EU adopted a directive stipulating that all new buildings must be energy neutral by 2020 (2050 for the existing stock). The directive forms part of the community initiatives on climate change (commitments under the Kyoto Protocol) and stipulates that the building sector must adapt to fully integrate energy concepts and resource efficiency in the design of buildings, the urban fabric and landscape (Directive 2010/31/EU).

The result of this European directive is that provincial and local authorities across the country have started offering major incentives to encourage Green building. An example of how fiscal incentives can contribute to energy efficiency in the built environment are the Green Deals between government and industry. Public-private partnerships are seen as the best way to generate a more sustainable economy, removing barriers and opening the doors to innovation. The introduction of the energy label in 2008 is another form of incentive. Homeowners must produce an energy label when selling or renting their home. The expectation is that this will stimulate the private sector to retrofit the existing stock, with the 2050 energy ambitions in mind.



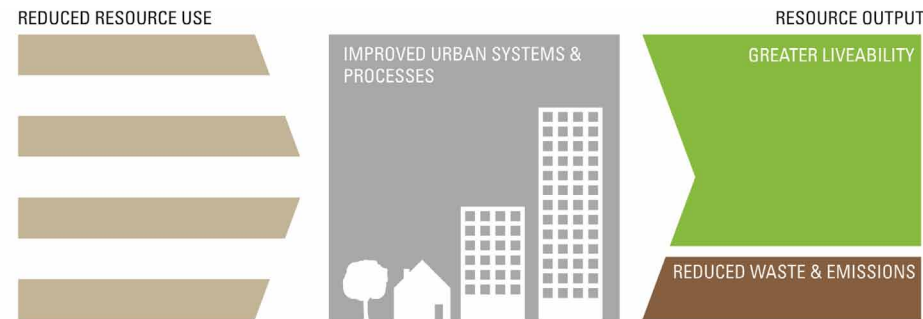
**Figure 10A and 10B.**

Closing city cycles to create a circular economy [Doepel Strijkers, 2009]

**10A. Linear City Metabolism**



**10B. Circular City Metabolism**



**It pays to be Green**

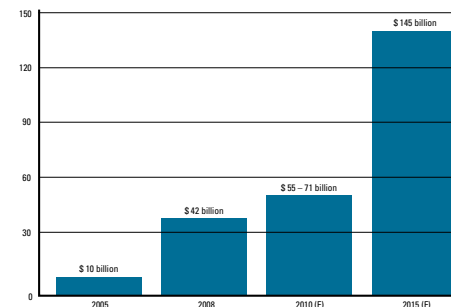
Similar initiatives in the United States, including tax credits, grants, fee waivers and expedited review processes, are starting to have effect. With these incentives in place, developers and homeowners are increasingly finding it more affordable to go Green. The McGraw-Hill Construction Company reports that Green building has grown 50% in the past two years, whereas the total number of new construction starts has shrunk by 26% over the same period (see Figure 11A and B). In their Green Outlook 2011 report, they forecast that the dollar value of the Green building sector will grow to an estimated €55 to €71 billion in 2012. This number is expected to nearly triple by 2015, representing as much as €145 billion in new construction activity. Research by the University of San Diego, McGraw-Hill Construction and property management firm C.B. Richard Ellis indicates that while more building owners are seeking Green credentials for their projects, companies are looking at Green building more as a profit centre, not just as an environmental good deed. Owners of Green buildings report a 5% increase in property value, a 4% return on investment and a 1% rise in rental revenue, as well as an 8% reduction in operating costs compared with conventional designs (Van Hampton, 2010).

**Figure 11A and 11B.**

A doubling in size in the number of green buildings in the last two years in the USA (McGraw-Hill Construction, 2011) [Doepel Strijkers, 2012]

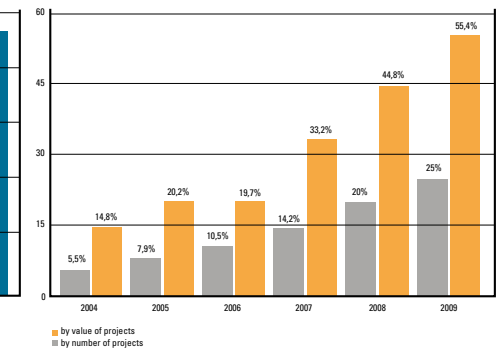
**Figure 11A.**

Green Building Market Size



**Figure 11B.**

Appearance Rate of Leed in Project Specifications



At the moment it is difficult to gauge the effect of government incentives in the Netherlands. What is clear is that the combination of the economic crisis and the sustainability agenda is creating a ripple of change in the building industry. Stakeholders are finding each other in new coalitions and the mentality of short-term returns on investments is slowly giving way to temporal models of development. 'Social ecological urbanism', for example, focuses on socioecological interactions, suggesting a number of substantial reinterpretations of the relationships between social, technical, economic and ecological forces in urban areas. This implies a reconceptualisation of the relationship between the urban environment, nature and natural resources (Voorburg, 2010). Translating potential long-term ecological and social benefits into capital for short-term investment is a key concept for generating equity to make 'positive' development feasible.

It is clear that the incentives for change are having some effect. But given the current economic crisis, the financial, organisational and technical innovations necessary for acceleration cannot be expected to come solely from the market. It is essential to continue to bring research and practice together in concrete demonstration projects to test and develop tools and methodologies for integral sustainability. Through an iterative process these can then be improved and scaled up for commercial application.

## 04 Tools and Methodologies for Integral Sustainability

The architectural service sector is not yet adequately geared to tackling the issues relating to climate change and resource and energy efficiency. Although a lot of research has been done into all these topics, the gap between science and practice is immense. The mainstream building sector is governed by old-fashioned principles and techniques, making it difficult to implement innovative solutions on a large scale. Moreover, designers may themselves prove to be the biggest obstacle in achieving real change. Critics argue that the Green agenda limits the potential for design and leads to ugly buildings. Compact volumes and limitations on the size and positioning of openings are viewed as unwelcome design constraints, limiting creativity and potentials for architectural expression (Maas et al., 2010). Indeed, there are few examples of aesthetically well designed Green buildings, compared with the array of bad examples where the tell-tale Green attachments such as solar panels and windmills dominate the overall image. To overcome this shallow commodification of Green, it is imperative that the potentials for a rich, integrally sustainable language are explored and translated into design instruments for widespread adoption by the design community.

For many architects and builders the perceived complexity that Green brings to the building arena is also an obstacle. New technologies, knowledge of materials and life cycle analysis, and the multitude of certification and validation systems, such as LEED, Cradle to Cradle, and BREEAM, introduce more constraints to the design process. The development of BREEAM NL by the Dutch Green Building Council and the introduction of the Material Performance Coefficient (MPC) in 2013 will undoubtedly help to simplify the rules of engagement. Although these tools are absolutely necessary to evaluate aspects of the sustainability of a project, they are also limited in the sense that they cannot address the complexity of sustainability at a systems level and a city scale. These tools take on greater meaning when applied within the context of broader issues, made possible, for example, by tools such as SiD (Symbiosis in Development). SiD is a methodology for solving complex, multifaceted problems using systems thinking, network theory and life cycle understanding. SiD combines theory, method, practice and tools in one holistic system that allows different disciplines to work together, evaluate sustainability spectrum-wide, and find symbiotic solutions quickly (Bosschaert and Gladek, 2010).

SiD and a broad range of similar tools and methodologies now under development can facilitate a more integral design process by helping designers to deal with more design constraints and performance criteria. Besides tools for achieving eco-efficiency, some tools, such as BIM (Building Information Modelling), focus on the process of integrated design.

## Building Information Modelling (BIM)

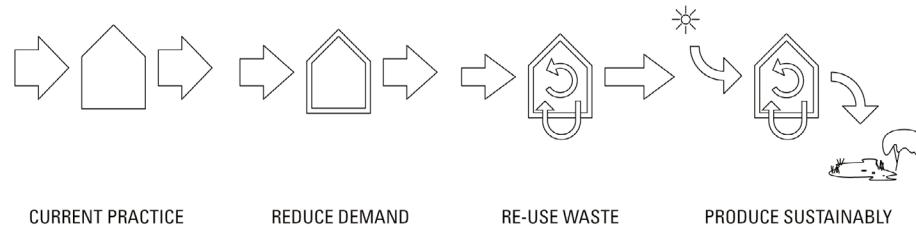
The Government Buildings Agency stipulates that from 1 November 2012, BIM (Building Information Modelling) must be used by design teams for all DBFMO (Design, Build, Finance, Maintain & Operate) tenders. Architects, builders and engineers will work together on one central virtual building model, the BIM model. By exchanging their information in a structured manner using open source standards, all the partners in the building chain will create a complete centralised digital description of the building. The overall timeframe for the process remains the same, although more time is spent on communication and exchange of information than in a traditional design process. Increased communication and interaction in an early phase can lead to better solutions, and the use of BIM limits the margin of error experienced in traditional building processes in which each partner has their own model and drawing set. The use of BIM will increase exponentially in the decades to come. It is a useful tool as it facilitates communication and exchange of information and thus promotes transdisciplinary collaboration.

## REAP+

REAP+ is a methodology or approach for use by architects and urban designers to increase integral sustainability through design. It is based on the Rotterdam Energy Approach and Planning (REAP; Tillie et al., 2009) and is currently under development. REAP+ expands the three-step strategy for energy (van den Dobbelsteen et al., 2008) to include water, materials and waste. The strategy involves reducing resource inputs, waste and emissions by improving urban processes (see Figure 12). It addresses the complexity of these urban systems, and takes into account the interrelations of resource flows. The fundamental concept is the continuous upgrading of anthropogenic systems to attain closure of material, waste, water and energy cycles at the building, cluster, district and city scales. When combined with innovative co-creative processes, this approach leads to more integrated forms of sustainability in which energy, water, materials and waste systems are designed efficiently and brought into balance with natural systems at the appropriate physical scale and within the appropriate time frame.

**Figure 12.**

REAP+, the three-step strategy for integral sustainability, based on REAP (Tillie et al., 2009) and the New Stepped Strategy (van den Dobbelsteen, 2008). [Doepel Strijkers, 2009]



The strategy involves three steps and is organised by scale (from the building, cluster, district to city scale):

Step 01. Reduce demand (energy, water, materials and waste)

Step 02. Reuse waste streams (waste = resource)

Step 03. Produce sustainably (on the appropriate scale)

Energy, water, materials and waste are seen as layers in spatial planning, each with their own logic and economy of scales. REAP+ offers designers a step-by-step approach, facilitating the mapping of each system and its boundaries. By overlapping the different layers, designers get a grip on where the systems interact, which helps them to determine the spatial parameters for the design of the physical interface. Anthropogenic and natural systems also connect at different scales, offering potentials for increasing biodiversity and embedding a building within its wider context. REAP+ is an approach that gives designers an understanding of the complexity of the different physical urban systems and how they could interact to inform design decisions.

## Climate as an instrument for design

### Bioclimatic design

Bioclimatic design aims to improve human thermal comfort by natural conditioning, conserving resources, and maximising comfort through design adaptations to site-specific and regional climatic conditions (Hyde, 2008). It is characterised by strategies to reduce or eliminate the need for non-renewable energy resources (for artificial conditioning) by optimising the orientation, building form, envelope, interior configuration and shading of a building.

Research suggests that bioclimatic buildings use five to six times less energy than conventional buildings over their lifetime (Jones, 1998). Energy consumption in bioclimatic buildings is reduced primarily by designing the building form and envelope to make use of the local microclimate (see Image 8). In warm climates, where cooling is needed most of the year, 34% of energy consumption in buildings is used for air conditioning, resulting in high energy use and greenhouse gas emissions. In most cases this is due to the poor design of the building envelope (Parlour, 2000). But by using parameters such as air temperature, solar radiation, wind and humidity as inputs to architectural and urban design, the climate itself can become a 'design instrument'.

In the current Dutch context, bioclimatic design principles find expression in concepts such as the passive and active house. As heating is the primary need for housing in the Netherlands, these strategies focus on reducing the heating demand by implementing passive solar principles. Sun, wind and light are the main elements utilised in passive design. An example of how passive solar strategies can impact on the form and use of the dwelling is the use of winter gardens and patios as interstitial (buffer) zones. These interstitial spaces lengthen the summer season by capturing spring and autumn sunlight and using it to lower the heating demand of the dwelling.

Warm air collected in these spaces in the summer can be used to induce natural ventilation (Vollaard, 2012). A good example, soon to be realised is CHIBB (Concept House IBB), an initiative by the research chair for Sustainable Building, started by the minor sustainable building technology of the Rotterdam University under the leadership of associate professor Arjan Karssenbergh. The CHIBB-concept strives for an optimal form and orientation for maximum benefit of the sun, light and air. It makes use of a greenhouse to create an interstitial buffer zone with integrated green for climate regulation and optimal ventilation. The form and functions are optimally positioned to reduce transmission losses. The passive heating and cooling principles demonstrated in CHIBB are exemplary and will need to be adopted on a larger scale as temperatures rise in the coming decades.

But in a temperate climate like the Netherlands, passive design strategies alone will not suffice. Hybrid active and passive systems will be necessary to maintain comfortable indoor climates throughout the year. Active systems vary in complexity from traditional installations and shading devices to more innovative solutions such as CABS (Climate Adaptive Building Shells). These envelopes or facade elements save energy by adapting to prevailing weather conditions, and support comfort levels by immediately responding to the occupants' wishes. CABS have to resolve conflicts and trade-offs between energy consumption and thermal and visual comfort requirements (Loonen, 2010). The challenge for designers lies in the integration of technical installations in the overall design, allowing for the replacement of elements as these become more efficient in time through technological innovations. For example, the design integration of photovoltaic panels, solar collectors and wind turbines for onsite energy production will become more pertinent in the future as the energy and resource directives take effect.

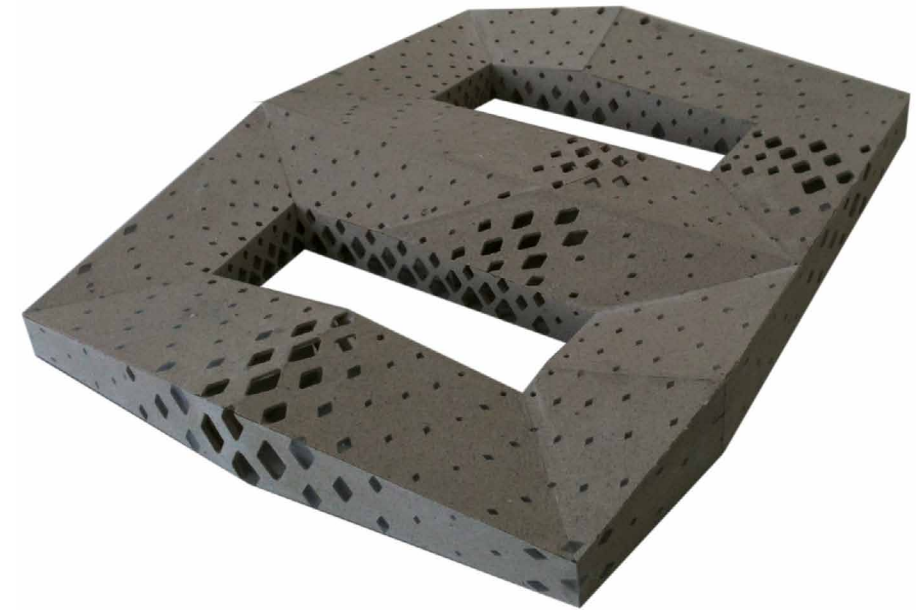
It will become increasingly necessary for the broader industry to adopt bioclimatic design principles if we are to meet the 'energy neutral' or more ambitious 'energy plus' challenge on a large scale. Although a lot of research into bioclimatic design has been done in warm countries, the temperate North-Western European countries lag behind. Of course, exceptions exist, such as the inspirational work being done at the AA in London and, closer to home, in research departments at universities such as the Climatic Design research headed by van den Dobbelsteen at TU Delft. More insights are needed into the potentials for an architectural language if the mainstream architectural service industry is to adopt this approach. More concrete demonstration projects are needed to turn the considerable theoretical research into more practical applications.

#### Image 8.

Macuil Tochtli: bioclimatic design of a tequila factory in the Jalisco region of Mexico [Doepel Strijkers, 2010]

Based on the traditional hacienda typology, the Macuil Tochtli project combines the use of local materials and vernacular building methods. The building is sculpted from the inside out, based on the movement of the sun. Daylight, passive cooling and the visual and physical connections to the surrounding landscape are the

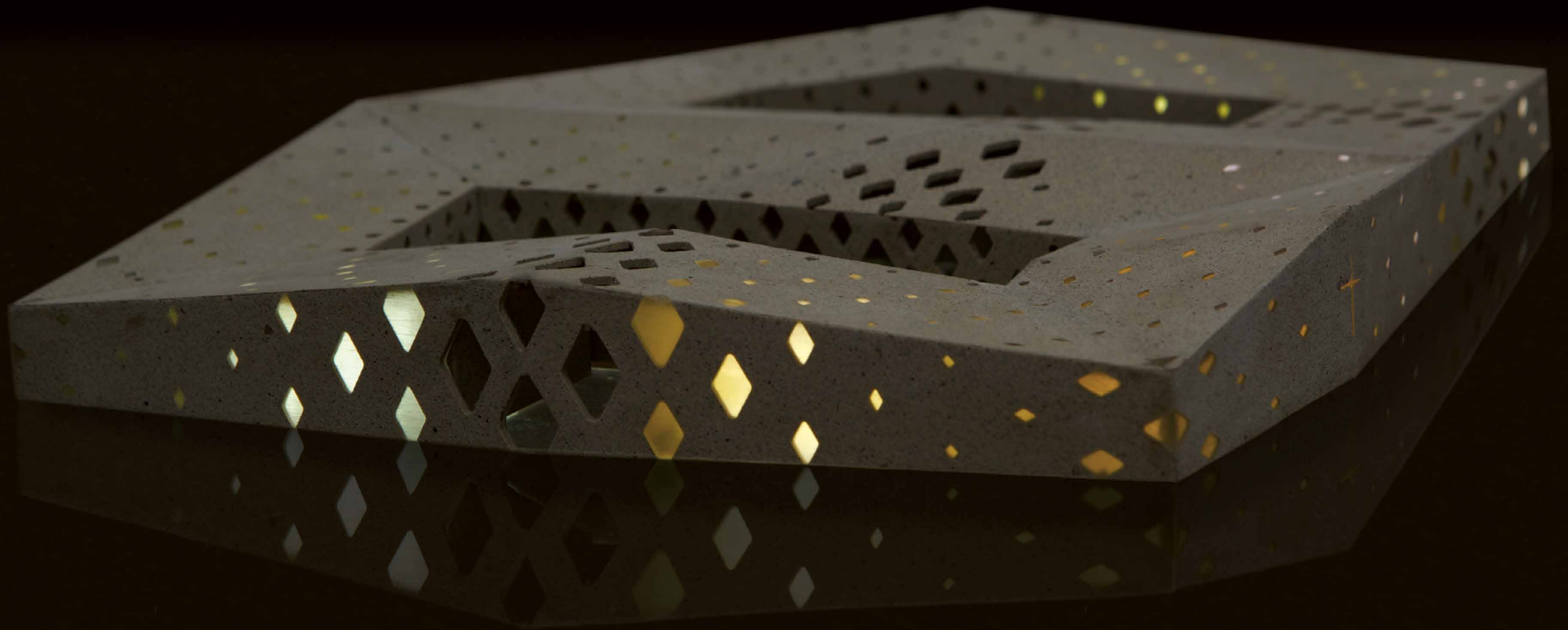
main parameters that inform the architectural form. The complex is conceived as a 'wasteless' building. Waste streams from the tequila making process are utilised in secondary production chains resulting in textiles made from fibres, agave honey, perfume, inulin for high-energy snacks, and biogas. Besides reducing consumption through bioclimatic design and reusing waste streams, the building makes optimal use of the local water and solar resources. By integrating photovoltaic panels and solar collectors in the envelope, the building can operate independently of the grid. Apart from the ecological and economic benefits for the region, the complex offers habitation for nine nuns, who teach the children of the factory workers during the week. Besides the classroom, a library and chapel introduce a social aspect to the complex, embedding it in the local culture and society that will benefit from it.



#### Parametric design

The developments in CAD (Computer Aided Design) over the last decades have been driven primarily by the engineering industry. CAD packages can be combined with BPS (Building Performance Simulation) software, making it possible to measure just about anything from material use and structural strength to comfort and energy performance aspects such as daylight penetration, thermal temperature, humidity and air circulation. But the architectural service industry is slow to adapt. Instead of using CAD to help deal with the increase in design constraints introduced by the new Green agenda, most architects use it in the traditional sense, as an electronic drawing board.

Parametric design offers a valuable tool for designers to help them deal with the additional constraints imposed by sustainability issues such as resource efficiency and dynamic comfort. By constraining the design potentials through computational parametric frameworks, a parametric methodology enables the designer to explore a wider range of solutions more systematically. These allow the designer to compare different options and form a virtual spatial framework for the final design (Gane, 2004).





## The Origins of Bioclimatic Design

Bioclimatic design theory evolved in the 1950s in the work of the Hungarian brothers Victor and Aladar Olgyay who published the book *Design with Climate: An Approach to Bioclimatic Regionalism* in 1963. The US based duo used their architectural practice to research concepts and techniques for alternative forms of climate control and energy reduction. By looking at vernacular architectures in extreme climates around the globe, they collected ideas that could be integrated into a modern idiom in a Western context. In *Design with Nature*, their most influential publication, the Olgyays argued for a proactive approach to designing with climate. The regional building typologies, building traditions and use of materials they studied demonstrated that with a thorough knowledge of local climate and regional specificity, smarter buildings could be designed that make use of passive natural systems integrated into the architectural form of buildings. Their motives were ethical and ideological, perhaps the reason why their work was never really picked up by the mainstream architectural service industry (Vollaard, 2012).

**Image 10.**

Lehman Hall, Barnard College, Morningside Heights, NYC (O'Connor and Kilham, 1959). This building houses Barnard College's Wollman Library and was designed by O'Connor and Kilham, with assistance on the facade screen from Victor and Aladar Olgyay.



The work of the Olgyays remained marginal and was not integrated into educational institutions until Otto Koenigsberger, who had been active in climatic building in Africa, Asia and the Pacific in the 1950s, established the Department of Tropical Architecture in the AA in London a decade later. It was not until the 1980s that the Malaysian born Ken Yeang, who studied at the AA, picked up the thread of bioclimatic design. In his early work, predominantly in Asia, Yeang explored bioclimatic office ty-

pologies that demonstrate a regionalist approach in which the architectural aesthetic and significance is derived from the specific context in a specific time (Vollaard, 2012). Still practising today, Yeang has started to capture the minds of a small group of architects attracted to the idea that regional, microclimatic and cultural parameters can inform an architecture that makes sense in the light of current sustainability concerns.

**Image 11.**

Spire Edge Eco Office Complex, Manesar, India (Hamzah & Yeang Sdn. Bhd, 2008) [Hamzah & Yeang Sdn. Bhd, 2008]

Designed and developed by the renowned firms of Ken Yeang, Sanjay Prakash & Associates, Abaxial Architects and S K Das Associated Architects, Spire Edge is an active intelligent building system that strives to imitate the processes of nature to achieving maximum efficiency and minimum wastage. Based on a philosophy and a process called 'Mainstream Green', it aspires to combine commercial market imperatives and practices with environmental sustainability. It successfully addresses current needs and future aspirations within the framework

of available and scarce resources. It goes beyond the simplistic act of conservation into the realm of generating a responsive and responsible architecture. Spire Edge is envisioned to be a radical, unconventional and, most importantly, sustainable prototype that will serve as a point of reference for future infrastructure developments in India.



**Image 9. (page 38)**

Macuil Tochtli: bioclimatic design of a tequila factory in the Jalisco region of Mexico [Doepel Strijkers, 2010]

*‘A parametric representation of a design is one where selected values within the design model are variable, usually in terms of a dimensional variation. But any attribute like colour, scale, and orientation could be varied, through a parameter. To design parametrically means to design a parametric system that sets up a design space which can be explored through variations of the parameters.’* – Axel Kilian (2004)

Any design process relies on multiple constraints. Before proceeding to design, an architect translates the specifications and design brief into sets of rules. These can either operate independently or semi-independently, be driven by the aesthetic urge, follow some performance criteria, or in the case of a poor rule-maker, ignore all together the constraints that would refine the design results (Gane, 2004).

### Parameters

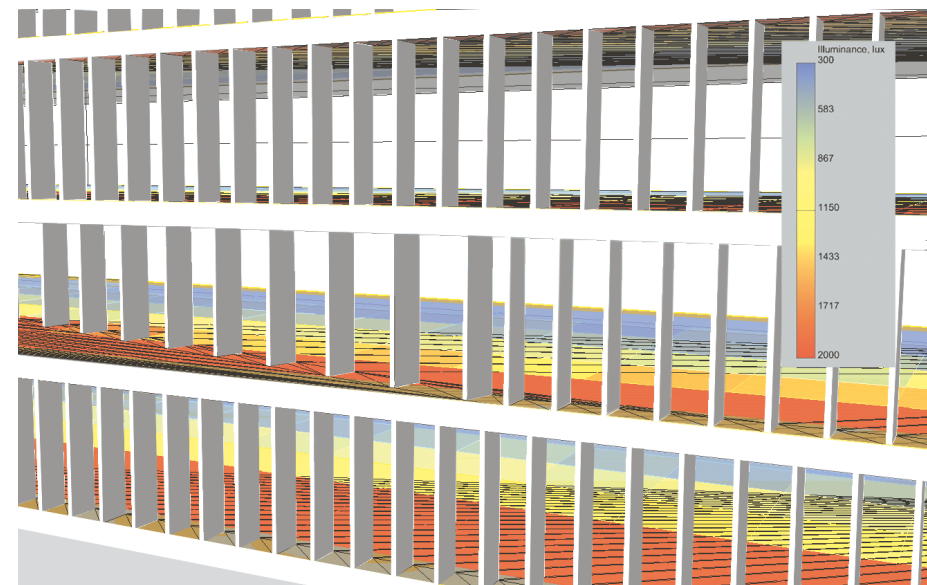
Parameters are the main building blocks of any design and can define a system and determine or limit its performance. They are critical for the operation of rules and make variations possible. Two main types of parameters can be distinguished: explicit and implicit parameters. Implicit parameters are abstract or open to interpretation and mostly affect aspects relating to form. Designing with implicit parameters is less constrained and leads to more differentiation in the emerging results. Explicit parameters, on the other hand, result in designs of a completely different nature, because of the way the parameters affect the implementation of rules. The clarity and predictability of the variations in the resulting spatial framework make them more appropriate for use in the design of buildings and urban configurations. Geometric parameters have an impact on the form of the building and how it relates to its physical surroundings. These may be a set of dimensional parameters, such as the length, width and height defining the building volume. It is also possible to define the relationship between the building and its context, for example the distance to the pavement or to other buildings, sight lines, shadows or circulation paths (Gane, 2004).

A wide range of programs, such as Grasshopper, Maya, CATIA, Solid Works, Inventor and Revit, are currently available for parametric design. These programs can be used in combination with BPS (Building Performance Simulation) software such as TRISCO, ANSYS, BINK and Ecotect, making it possible to visualise and simulate a building’s performance within the context of its environment. Energy use, carbon emissions, heating and cooling loads, daylight infiltration, solar radiation, the thermal effects

of occupancy and internal airflow are some of the aspects that can be simulated. In so doing, designers can gauge the effect of spatial decisions on performance and comfort, thereby integrating sustainability constraints into the iterative design PROCESS (see Figure 13 and Image 12A, 12B, 12C).

**Figure 13.**

Testing the performance of a louvre design for natural daylight penetration on 21 September at 14:00 for the bioclimatic office building by Doepel Strijkers (see also Image 12A, 12B and 12C) [Wouter Beck, Ascendilex, 2012]



This parametric approach to design will prove to be a valuable tool for tackling the contemporary sustainability issues relating to resource efficiency and climate adaptation. Defining the appropriate parameters with climate and comfort as the dominant criteria can generate a diverse architectural language for regionally appropriate designs. Meaningful steps towards comfortable climatic cities can be made by combining the possibilities of parametric design and BPS (Building Performance Simulation).

More constraints (climate, resource efficiency, energy efficiency and comfort) lead to more sustainable buildings, but increase the complexity that designers need to handle. To help them deal with this, designers can turn to methodologies and approaches like REAP+ and tools such as BIM, parametric design and BPS. The concept of regional bioclimatic design introduces constraints that can inform the architectural language of buildings, embedding them in the local context and microclimate. The next step is to bring these together in the form of Parametric Bioclimatic Design.



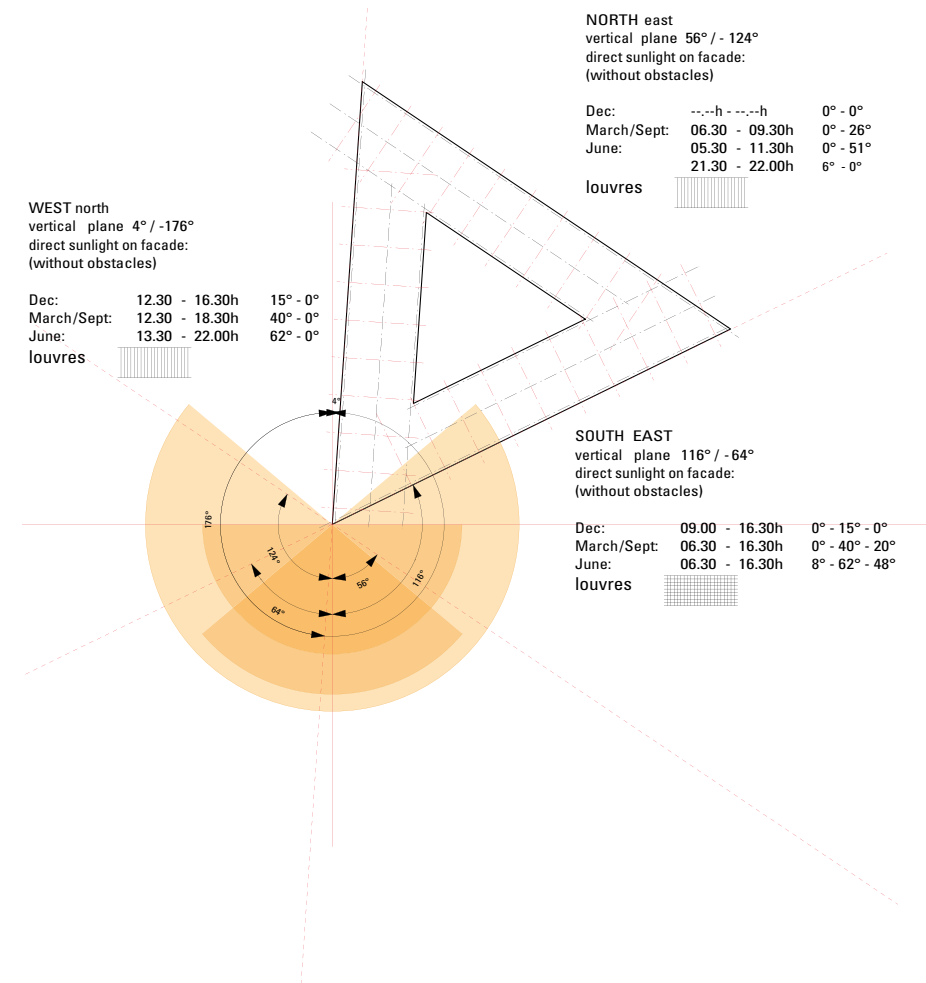
**Image 12A, 12B and 12C.**

Bioclimatic design of an office building in the Netherlands using daylight, thermal accumulation and passive cooling as the main parameters (Doepel Strijkers, 2010)

The compact triangular volume with a central atrium creates three facade conditions. The design of the sun screening per facade is optimised to allow daylight to penetrate the space, reduce thermal accumulation and optimise visual comfort. The distance and depth of louvres is influenced by setbacks resulting in an irregular facade. The design aesthetic is inextricably linked to the influence of climatic parameters, user comfort and the quality of the interior space.

**Figure 14.**

Building orientation in relation to the sun path [Doepel Strijkers, 2010]





## 05 Research Agenda

### Parametric Bioclimatic Design on the building scale

Parametric Bioclimatic Design is a concept and approach to design that utilises existing CAD and BPS technologies to facilitate an integral bioclimatic design process. The goal is to develop regionally specific, climate responsive designs that are culturally embedded in the local context through the appropriate use of materials, state of the art technologies and building traditions. The principles of Parametric Bioclimatic Design can be applied at the building, district or even city scale, for both the future and the existing urban fabric.

#### Existing fabric

The built environment is responsible for 41% of the total energy consumption in the Netherlands (Hellinga, 2010). Besides the energy used for running a building, huge amounts are lost through leaky building envelopes, leading to high energy bills and uncomfortable indoor climates. If one considers that in 2050, 85% of the existing building stock will still be in use, it is clear that from a sustainability point of view, the challenge and opportunities for the building industry lie here.

*‘Europe’s buildings are leaking big time.*

*Money, energy and emissions are literally flowing out of the windows and cracks as we speak.’*

- Connie Hedegaard, European Commissioner for Climate Action (2011)

When viewed in the light of the already existing issue of ‘energy poverty’ and the expected rise in temperature due to climate change, it is imperative that smart retrofit solutions are developed to reduce energy and resource consumption and improve user comfort in the existing building stock. The research will focus on achieving this by using passive heating and cooling strategies to adapt the building envelope and interior configuration, based on the notion of dynamic comfort.

#### Future fabric

Although the existing fabric presents the biggest challenge, all new buildings must be energy neutral or even energy plus by 2020. Within the next eight years, techniques for sustainable design and financial and organisational models must be further developed and adopted by the building industry.

*'Building shells are at the interface between the building interior and ambient climate, and therefore fulfil a number of vital functions that dictate most of the buildings energy consumption.'* - Loonen (2010)

Parametric Bioclimatic Design can play an invaluable role in meeting these ambitions for housing, but also for larger scale buildings such as offices and mixed-use developments. The use of BPS for proof of concept, particularly for larger scale buildings, will become increasingly important. An integrated design and development process is the only way this can be achieved.

The main research topics pertaining to Parametric Bioclimatic Design relate to energy and resource efficiency, climate adaptation and user comfort, and can be applied to both existing and future fabric:

- a) Energy efficiency: investigate the potentials for reducing energy consumption, primarily through the form and building envelope by making use of the local microclimate; optima forma - the relationship between building form, energy reduction and comfort; the use of interstitial (climatic) zones and their impact on the form and interior quality of buildings; architectural efficiency versus installation efficiency; interior configuration in relation to dynamic comfort and energy performance;
- b) Passive design: using a range of biophysical elements such as thermal, humidity and water sinks; adaptive thermal defences; use of flora as heat sinks; phase change materials, heat storage and radiant defences;
- c) Integrated power: integration of energy generation in the building envelope (Vollaard, 2012); exploring the combination of hybrid passive and active facade solutions;
- d) Resource efficiency: the potentials for the reuse of waste and demolition materials in the building industry on a regional scale; the potentials of biobased materials; design for disassembly and reuse;
- e) Climate adaptation: adapting the existing stock to the effects of climate change, such as increased cooling demand and water retention;
- f) Parametric design and Building Performance Simulation (BPS): testing multiple design options by combining explicit physical constraints with performance and comfort constraints (energy performance, daylight penetration, thermal temperature, humidity and air circulation);
- g) Development of design tools for Parametric Bioclimatic Design.

The main research themes are summarised in the following table:

Research fields	Output
Parametric Bioclimatic Design Principles	A parameter-driven design instrument that brings climatic and spatial parameters into alignment using a design rule set, with comfort (health) as the primary evaluation criterion.
Bioclimatic Design Principles	Design instruments that employ climatic conditions to reduce consumption and generate user comfort at either the building or urban scale.
Climate Scenarios	Defining the consequences of different climate scenarios on the functioning of certain bioclimatic systems.
Parametric Design Principles and software tools	Rule-driven instruments that generate morphology based on explicit constraints relating to form and performance.
Typology, function, scale and PBD	Typologies of bioclimatic design that are optimised for certain parameter sets.
Material use and energy performance	Inventory of materials sorted by effect on energy performance and comfort, resulting in material performance constraints for Parametric Bioclimatic Design.
Energy performance and comfort	Monitoring and prediction tools to analyse dynamic comfort based on comfort zone as opposed to the energy performance coefficient.

Experts agree that in terms of sustainable change, more can be gained at a cluster and district scale than at the scale of the individual building. Due to the economy of scale, the potentials for energy exchange increase at the cluster and district scales. Besides the increased technical efficiency, clusters also present other challenges and opportunities for applying Parametric Bioclimatic Design principles.

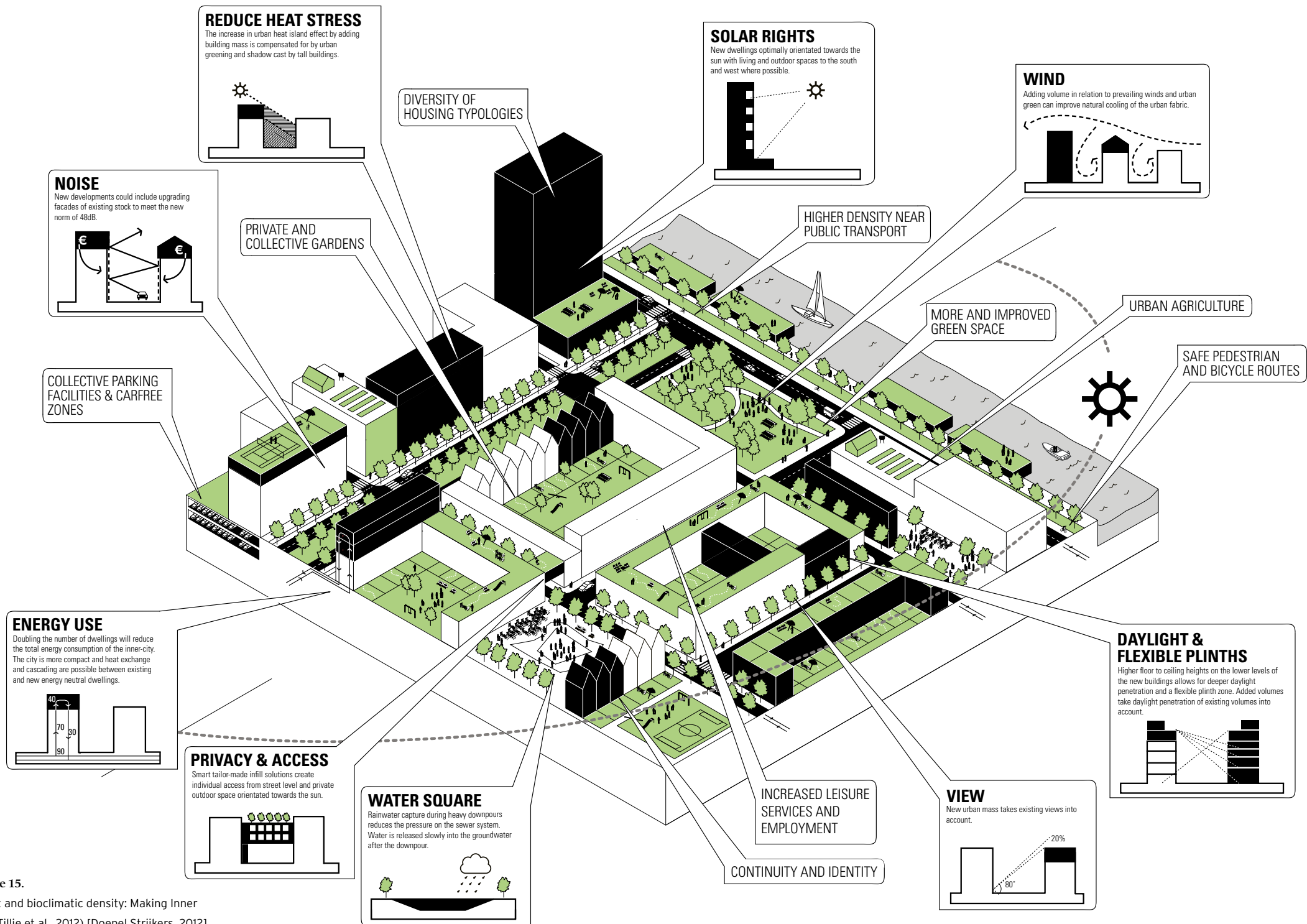


Figure 15.  
Smart and bioclimatic density: Making Inner  
City (Tillie et al., 2012) [Doepel Strijkers, 2012]

### Parametric Bioclimatic Design at the urban scale - Inner city densification

Inner city densification will be the main strategy for housing the expected 700,000 new inhabitants of the Netherlands by 2037 (source: CBS). Smart and bioclimatic housing typologies need to be developed, not only to make energy neutral densification possible, but also to improve the existing spatial, social and economic quality of inner cities (see Image 13). Densification in an existing urban fabric is a matter of precision. Besides creating the right mix of dwellings and amenities to strengthen the identity and quality of an existing biotope, the overall comfort in both buildings and the public realm can be improved by smart and bioclimatic design.

To begin with, daylight, solar rights and views from existing dwellings must be preserved. Small, precise interventions can capitalise on existing residual space without reducing the quality for existing inhabitants. Adding volume in the right place can even have a positive effect on the microclimate of a block or street. Normally, more mass means more thermal gains, which can increase urban heat stress. However, light and reflective facades can counter this effect and the smart placement of volume can create welcome shade, lowering cooling demands. An additional advantage of adding homes and related functions to the city, from an energy perspective, is that each function has its own energy consumption pattern. By adding functions in the right place, heat and cold can be exchanged between buildings, delivering immense reductions in energy use for the existing stock. This smart form of energy exchange requires new coalitions and organisational innovations, but can potentially help the city to radically reduce its eco-footprint. In addition, the smart positioning of volume in relation to prevailing winds, urban green and water bodies can be a valuable instrument in cooling the inner city, making it more comfortable in our increasingly hot and dry summers.

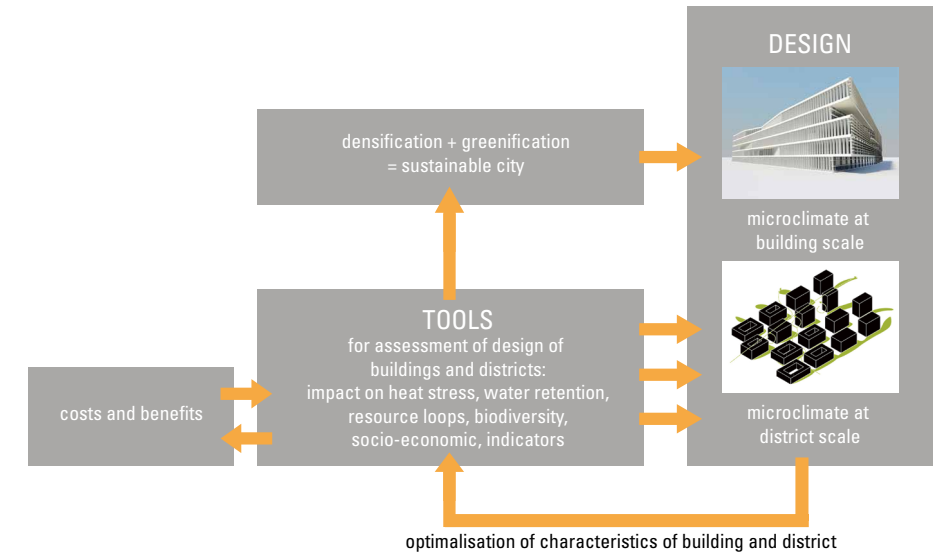
The city can therefore be viewed as a 'climate installation' (Hagendijk, 2012). Trees and green urban 'blankets' can be used to provide shade, street and park strips act as air canals, vegetation and surface water can act as humidifiers and coolers for purifying the air, cold urban surfaces act as dehumidifiers, and roofs, facades and streets work as urban radiators for heating, or - in the form of reflective surfaces - for cooling. In this way, increasing urban density could potentially be a valuable instrument for improving the microclimate of the city, and thus the quality of life for its users (see Figure 15).

The main research topics pertaining to Parametric Bioclimatic Densification relate to the ecological, social and economic effects of densification and can be identified as:

- Design: optima forma, the relationship between densification, form and urban comfort; morphology (form and orientation to the sun and prevailing wind), texture and materials, urban blue and green networks.
- Development of instruments for assessing designs at the district scale to measure the impacts on heat stress, water retention, resource loops, biodiversity, socioeconomic indicators, etc.; this parametric feedback process re-informs the design, allowing for optimisation.
- Cost-benefit assessments (see Figure 16).

**Figure 16.**

Parametric Bioclimatic Densification [Borsboom-van Beurden and Klok, 2012]  
Development of instruments for the assessments of parametric bioclimatic design: morphology, orientation, texture, form, materials, urban blue & green and wind.



The research into Parametric Bioclimatic Densification will be done in collaboration with TNO, the TU Delft, Wageningen University, Arcadis, Doepel Strijkers and the research chair for Sustainable Architecture and Urban (Re)Design.

**Image 13. (page 54)**

Improving Urban Green, Making Inner City (Tillie et al., 2012) [Sander Lap, 2012]







## 06 Living Lab Approach

Based on the idea that concrete demonstration projects that include all complex aspects of sustainable design can effectively accelerate change, the RDM Campus designated Heijplaat as a Living Lab in 2004. The RDM Living Lab is a user-centred, open-innovation ecosystem. The Golden Triangle of research, education and the market are brought together in innovation teams that integrate innovation processes within public-private-people partnerships. The concept is based on a user co-creation approach, allowing stakeholder involvement in the assessment of both the global performance of a product or service and its potential adoption by users. The Living Lab concept is supported by the local authorities, which have embraced the idea of a real-life space for designing, exploring, experiencing and refining sustainable solutions. The Living Lab not only functions as a pressure cooker for accelerating change, but the social, ecological and economic strategies that emerge can also influence local decision making and ultimately policies for the sustainable transition of Rotterdam as a resilient delta city.

### Concept House Village

Numerous technical solutions have been developed in the last twenty years. The effectiveness of these concepts depends on how they are implemented in the building process and how future residents use them. Unlike most other products, such as smart phones and computers, the most expensive product we ever use - our home - is rarely tested before it is launched on the market.

The purpose of Concept House Village is to test sustainable living concepts in various kinds of prototype housing. Concept House Village will develop and test many innovative models for the Dutch housing market and dismantle them after a few years to simulate the entire life cycle of the building. This will be an international showcase of building research and innovation and a prime example of sustainable district development.

The construction of prototype housing is a collaborative effort by companies, research institutes, public institutions and (collective) private contractors. All these parties are involved in innovation in the built environment in both new housing and existing urban developments.

Concept House Village is expected to develop into a building and knowledge community within a period of four to eight years. The intended result is ten to twenty prototypes of sustainable living in the New Village on Heijplaat (see Image 14). Situated on sites made suitable for experimental housing, and given the status of a 'free zone', these prototypes can, if desired, be connected to the municipal infrastructure and utilities. Working together, construction companies and students will have the chance to design, build and test their prototypes as well as use them for technical and behavioural research. Once the design and build phases are complete, visitors will be allowed in to see the prototypes in action.

The houses will be showcases for the latest technological applications in sustainable energy, water, sanitation and intelligent homes (home automation) on both building and district levels. In addition, Concept House Village will facilitate the development and testing of innovations in public spaces and the surrounding infrastructure. Practical tests will take place while students and Heijplaat villagers are living in the houses.

### Practical research

Concept House Village offers research opportunities for:

- 1) Innovations in the built environment: innovative prototype housing, construction elements, techniques and sustainable materials, new applications for public space, process innovation and forms of collaboration;
- 2) Sustainable behaviour in the built environment;
- 3) The effect of the building process on current and future users (residents), clients and other stakeholders.

**Image 14.**

Concept House Village, Rotterdam Heijplaat [Rutger Wirtz, 2009]



## Two prototype houses

### Biobased Retrofit

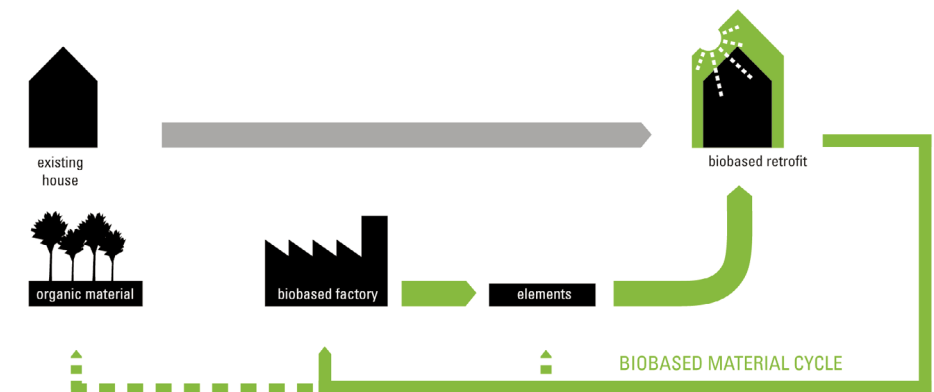
The Biobased Retrofit pilot explores the potentials of bioclimatic passive principles in combination with smart innovations for affordable energy neutral renovation of the existing housing stock (see Figure 17). In collaboration with Woonbron, Hunter Douglas, Pantanova, Studio Bouwhaven, ICDUBO, DGMR and Doepel Strijkers, the Rotterdam Academy of Architecture and the research chair for Sustainable Architecture and Urban (Re)Design will explore the possibilities for retrofitting six social rented houses in Concept House Village.

Most retrofit projects in the Netherlands focus on reducing energy demand through insulation and making the installations more efficient. Heating, and in some cases cooling, is always achieved mechanically. Biobased Retrofit explores the potentials for reducing the energy demand by adapting the form and interior configuration of the building in relation to the microclimate, thereby optimising the use of passive systems and minimising the dependency on heavy installations. Energy performance, resource efficiency, comfort, interior quality, logistics, upscalability, costs and user co-creation will be the drivers of the research and design. The effects of climate change will be taken into account, resulting in a retrofit strategy that will be able to deal with increased cooling demands in the future.

The design and research will focus on adapting the envelope and interior of the building. The use of interstitial (climate) zones and the reconfiguration and dynamic temporal use of the interior as strategies will be explored in relation to environmental performance, comfort and user experience. The smart positioning and design of openings and (active) shading devices in relation to the movement of the sun, prevailing winds, vegetation, water and views will be parametrically brought into alignment with performance and comfort aspects such as energy and material performance, thermal, hygrothermal, visual and acoustic comfort.

**Figure 17.**

Biobased Retrofit [Doepel Strijkers, 2012]



The potentials of biobased materials will be explored along with their environmental impacts and effect on interior comfort. The use of biobased materials in retrofitting has not yet taken off in the Netherlands. Many people have negative 'eco' associations with biobased materials due to their natural 'ecological' appearance. As this may be an obstacle to the large-scale application of renewable materials, it is imperative that innovative examples that demonstrate the diverse possibilities of these materials are developed. Besides the energy reductions that can be achieved through smart (re) design of the envelope, integrated energy production on location will also form part

of the research. As photovoltaic (pv) panels become cheaper, and efficiency continues to rise, their widespread use in the existing urban fabric will increasingly become an aesthetic issue. In most cases, pv panels are simply pasted onto existing roofs and do not add to the visual quality of the existing structure. The integration of pv and solar collectors in the design of the envelope will therefore be an important aspect of the research.

The research will result in a specific design proposal for the structure in question, but also in a catalogue of generic Parametric Bioclimatic Design solutions for multiple orientations for this typology. The design research will continually be tested for economic feasibility and potential for upscaling.

### Active ReUse House

The implementation of bioclimatic design principles is a prerequisite for achieving the low energy buildings of the future. In recent years, the lessons learnt from passive house design have been incorporated into a new concept, the active house. The active house principles adopt some of the passive house experiences and take them even further to account for the indoor climate and health of the inhabitants (see <http://www.activehouse.info>).

The essential components of the vision are energy, indoor climate and environment. An active house integrates the demands of comfort, climate, energy, environment and ecology into an attractive whole, resulting in increased architectural quality and human health and wellbeing. The design of the interior and the manner in which end users can interact with the spaces and systems of the dwelling add to human enjoyment and support environmentally responsive family life.

The Active ReUse House combines the principles of the active house with an innovative strategy for closing material cycles developed by Cirkelstad (see Figure 18). Cirkelstad aspires to close regional material cycles to tackle the challenge of resource scarcity. The goal is to realise a circular economy with positive social returns. The Active ReUse House consortium will take this social aspect as a point of departure for the development of the dwelling, drawing on new models of development that involve people in a reintegration processes, such as ex-detainees, or school leavers without a diploma. Learning modules relating to each stage of the building process - from demolition to the production of new building elements from re(up) cycled materials, to the construction of a building and final disassembly in the future - provide a means to empower a large disadvantaged group and integrate them into the market. The Active ReUse House will be an energy plus dwelling built solely from recycled and recyclable materials that can be scaled up to the district level. This will result in a prototype in concept House Village to test the concept in practice.

Consortium partners such as the Rotterdam Municipality, Van Gansewinkel and Cirkelstad will play an important role in the research into material flows. Additional partners include Woonbron and BAM, Studio Bouwhaven, DWA, SBR, DGMR, Hunter

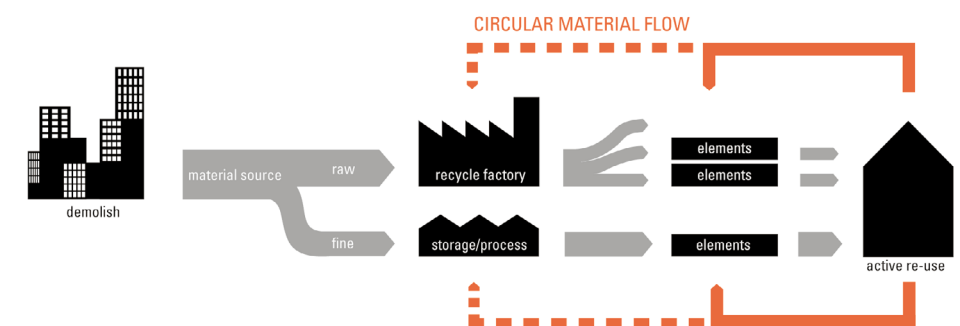
Douglas, Doepel Strijkers, the Rotterdam Academy of Architecture and the research chair for Sustainable Architecture and Urban (Re)Design.

The ambition of the Active ReUse consortium is to construct an energy plus house with onsite energy production integrated into the building envelope. The research will explore the possibilities for the flexible use and user adaptability of the interior. Besides the obvious performance criteria relating to air quality, adequate thermal climate and appropriate visual and acoustic comfort, the research and design will explore how occupants can control the indoor climate and how the design can encourage responsible environmental behaviour.

The identification of primary materials from demolition flows in the coming decades will determine the use of re(up)cycled materials, and will be key in defining the appropriate construction and sustainability concepts for the development of the prototype. The use of re(up)cycled materials, in the form of new building elements designed with disassembly and future reuse in mind, lowers the environmental impact of the building, reducing the need for resources from elsewhere.

One of the characteristics of both active and passive houses in northern countries is the use of large window areas to allow deep daylight penetration. This has a positive effect on the interior quality and visual relationships to the exterior. According to Haase et al. (2010), however, many passive houses have problems with overheating during summer. Even in Norway the very well insulated buildings suffer from overheating during the period from March to October. This is natural if you build with large glass areas and do not provide sufficient sun screening and natural cross ventilation for comfort during summer. The Active ReUse consortium will therefore explore the potentials for both passive heating and cooling through the smart design of the architectural form, interior configuration and building envelope.

Figure 18.  
Active ReUse House [Doepel Strijkers, 2012]





## 07 Conclusion

Green has clearly entered the mainstream of the architectural service industry. To ensure that it does not just become commodified by our consumerist society, it is essential that the principles of integral sustainability are widely adopted. Moreover, turning the challenges of climate change, energy and resource efficiency into meaningful design constraints requires a systems approach. This, however, increases the complexity that designers have to deal with. Further development of tools and methodologies is needed to enable the entire building sector to assimilate these principles of integral sustainability into practice, and to evaluate the effects of their design decisions before construction.

Parametric Bioclimatic Design is a design approach that fuses the concepts of climate responsive design, resource efficiency and comfort at the building and urban scales. It combines a range of existing methodologies and tools for the elaboration of design constraints to incorporate a broad range of sustainability issues into the design process. This will enable design teams to explore more design options within a virtual spatial framework. The insights gained into the relationship between the design of buildings and the configuration of urban clusters, as well as their performance in terms of efficiency and comfort, will enable them to make more informed design decisions.

Moreover, the Parametric Bioclimatic Design approach gives designers an understanding of the possibilities for integrating not only performance but also experiential values into their design aesthetic. When embedded in a local climatic and cultural context, and combined with smart processes and financial constructions, this approach will help designers to contribute to the positive development of social, economic and ecological capital.

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## Creating Comfortable Climatic Cities

Comfort and Climate as Instruments  
for Healthy Interior, Architectural & Urban (Re)Design

**After decades of being deemed the idealistic hobby of a niche group of fanatics, Green has finally entered the mainstream of the architectural service industry. However, most architects and urban planners are not yet adequately equipped to translate the challenges of climate change and resource and energy depletion into integrated sustainable solutions.**

Parametric Bioclimatic Design is an approach that fuses the concepts of climate responsive design, resource efficiency and comfort at the interior, building and urban scales. It combines a range of existing methodologies and tools for elaborating design constraints to incorporate a broad range of sustainability issues into the design process. Climate and comfort are brought into alignment, forming valuable design instruments that link the realms of architecture, engineering and building. The aim is to develop regionally specific, climate responsive designs that are socially and culturally embedded in the local context through the appropriate use of materials, state-of-the-art technologies and building traditions. When combined with smart processes and financial constructions, this approach will help designers to contribute to the positive development of social, economic and ecological capital.

The research chair for Sustainable Architecture and Urban (Re)Design at Rotterdam University of Applied Science is headed by Professor Duzan Doepel. Trained in South Africa and the Netherlands, Doepel draws on third world design and development strategies to inform the local sustainability discourse. His practice, DOEPEL STRIJKERS, strives to bridge the gap between research and design through the realisation of integrated sustainable interior and architectural projects and the development of urban strategies.

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