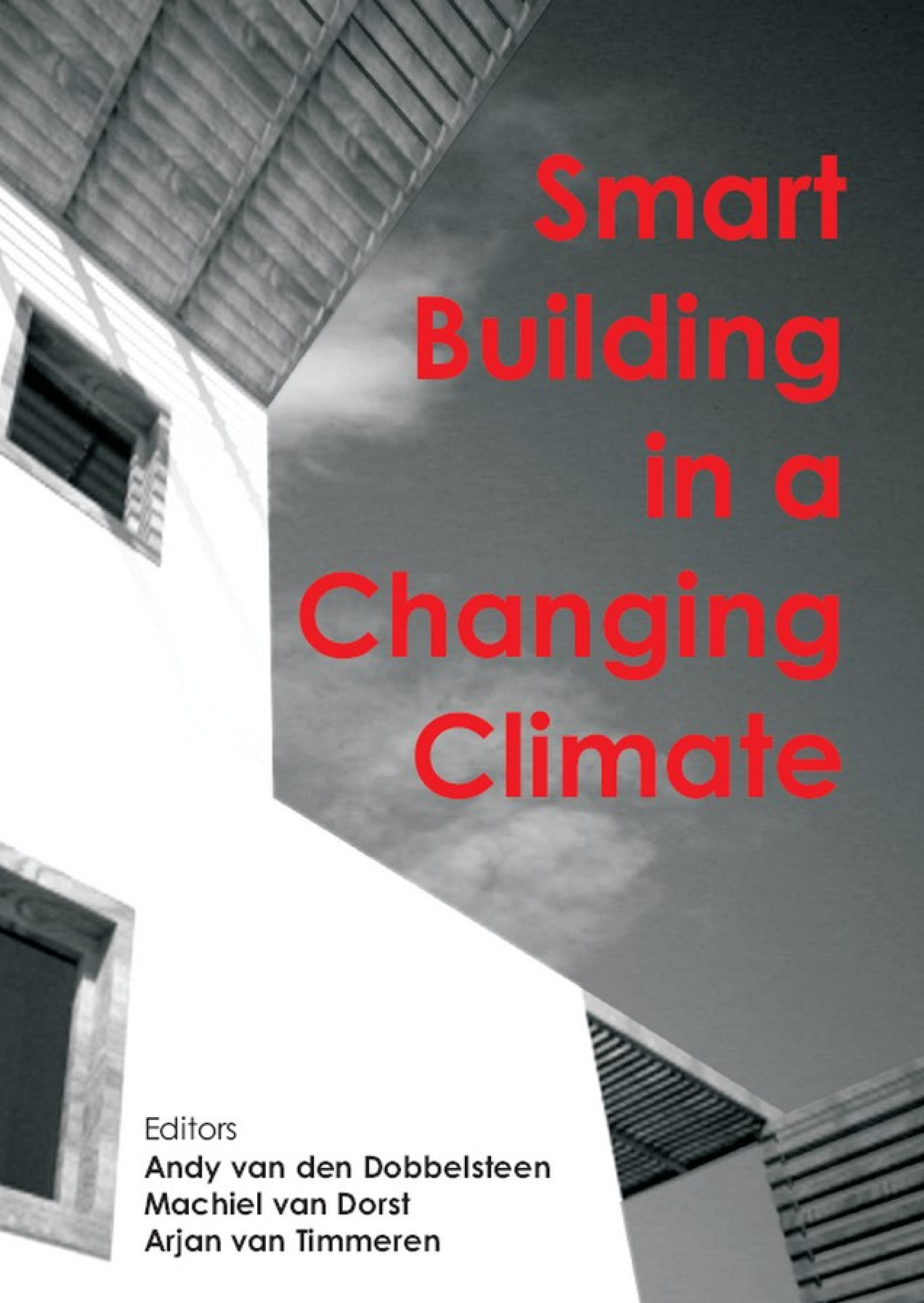

Smart Building in a Changing Climate

Editors
Andy van den Dobbelsteen
Machiel van Dorst
Arjan van Timmeren

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Keywords: sustainability, sustainable design, bioclimatic design, climate change, climate adaptation, climate mitigation, climate pro-activation, wicked problems, swarm planning, energy planning, transformation, architecture, urban design, real estate management, built environment, policy, project development, spatial planning, buildings, technology, smart buildings, multidisciplinary, transdisciplinary, transition

Cover illustration: Prototype of a residential dwelling built to evaluate the ability of the envelope to interact with climatic factors
Image by: Agnese Ghini

2009, Amsterdam, 250 pages
ISBN: 978-90-8594-024-1 (p-version)
ISBN: 978-90-8594-034-0 (e-version)

Published and distributed by Techne Press, Amsterdam, The Netherlands
www.technepress.nl

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Preface

Civilisations and cultures were often born in the border zone land-water. Therefore, it is not a surprise that in the beginning of the 21st century 80% of the largest population concentrations can be found in coastal and deltaic areas. In all these cases, without any exception, there is only limited space available for living, working, tourism/recreation and for infrastructure, while there is the need to preserve or expand valuable environment, nature and landscape.

At the same time we are confronted with the effects of climate change, manifesting itself in rising temperatures, sea level rise, a higher frequency and intensity of storm surges, as well as a higher frequency and intensity of rainfall with intermittently periods of drought. In addition, we have to take into account land subsidence, a higher percentage of built-up area, deforestation, a quicker run-off towards the rivers, and salt water intrusion. We have water as a valuable friend but periodically also as a serious foe. And last but not least we are confronted with a serious increase of the world population, with all its inherent consequences, such as depletion of fossil resources, high energy consumption and high waste production. It is crystal clear that there is an increasing need for sustainable solutions.

This book “Smart Building in a Changing Climate” is an up-to-date compilation of the latest insights with regard to sustainable solutions for the built environment. Professor Andy van den Dobbelsteen, as editor, with his co-editors Dr Machiel van Dorst and Dr Arjan van Timmeren, succeeded in bringing together scientists and well-known visionaries to present their views. Their articles aim at achieving, in due time, necessary sustainable development for the benefit of mankind.

Delft, 12th of May 2009,
Ronald E. Waterman[1]

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[1] Senior adviser to the Ministry of Transport, Public Works and Water Management, to the Ministry of Economic Affairs, to the Ministry of Housing, Spatial Planning and the Environment, and to the Municipality of Rotterdam and Port of Rotterdam Ltd; adviser to the Municipality of The Hague, to the Coast and Delta Institute Deltares, to the Netherlands Organization for Applied Scientific Research TNO, and to the Netherlands Water Partnership; visiting lecturer at 7 Dutch universities, at the International Institute for Infrastructural, Hydraulic and Environmental Engineering (IHE – UNESCO), at the Institute for Housing and Urban Development Studies (IHS); member of the Parliament of the Province of South-Holland and of several Provincial Committees related with Environment, Urban & Rural Planning & Traffic Planning, and Economic Affairs & Energy Supply

Introduction

Prof. Andy van den Dobbelsteen, PhD MSc[2], Dr. Machiel van Dorst, MSc[3],
Dr. Arjan van Timmeren, MSc[4]

Our world is changing, bringing new challenges to the way we live. While some resources may be limited, the imagination isn't. To adapt to the stated change we will need the best of our imagination and creativity, our technology and science and our humanity and vision. This book will help to explore how we can find the spirit, imagination and knowledge to adapt to the challenges facing us.

1. From problem to promise

Having taught sustainable design at the Delft University of Technology from the early 1990s we remember a period when talking about a climate change – let alone the human influence on it – was little or no subject for scientific acclaim. The International Panel on Climate Change [IPCC 2007], the former US presidential couple of Al Gore [Gore 2006] and Bill Clinton and advisors such as Sir David King [Walker & King 2008] have supported the wide acceptance of the problem and helped to put it on the political agendas again.

Much research ever since has been aimed at the determination of the exact impact of climate change on society and the built environment. At the same time the core focus has been predominantly on effects instead of solutions that cope with these effects. Being engineers however, the latter has been our professional challenge and that of many colleagues around the world.

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Human-induced climate change and its impact on the built environment is an immediate challenge which requires a coordinated approach at international levels. Understanding the impacts of climate change on human well-being requires improved knowledge of the interactions between socio-economic factors, ecosystem conditions and built environment / buildings.

Taking climate change as a fact, the 3rd CIB international conference on Smart and Sustainable Built Environments (SASBE2009), in Delft, the Netherlands, supported contributions that put the emphasis on solutions rather than problems. Hence, climate adaptation (the adaptation in the built environment to threats by heat, storm surges, drought and water), climate mitigation (reduction of effects that aggravate the changes) yet preferably even what we call climate pro-activation, i.e. the utilisation of climate change and energy depletion as a means to improve enduring sustainability and liveability of the built environment, and in doing so helping to support the shift from problem to promise for a better world.

For this book we selected and edited peer reviewed papers from SASBE2009 following the themes that are introduced by a divers set of specials from the field of smart and sustainable building.

2. Solutions at our disposal

Is the problem to promise statement about climate and energy just an imaginary desire or can it be real? Some examples could clarify the advantage of climate change.

2.1 Climate and low-ex spatial planning

The first example relates to a low-exergetic principle of site selection. Our ideal thermal human habitat is around a temperature of 21^{o}C. The majority of the world population lives in regions that have a lower average temperature (e.g. in Western Europe around 12 degrees Celsius). Some rise in temperature therefore hypothetically might bring our environs closer to comfort, if (with emphasis) we avoid additional warming by equipment, transport means and ourselves.

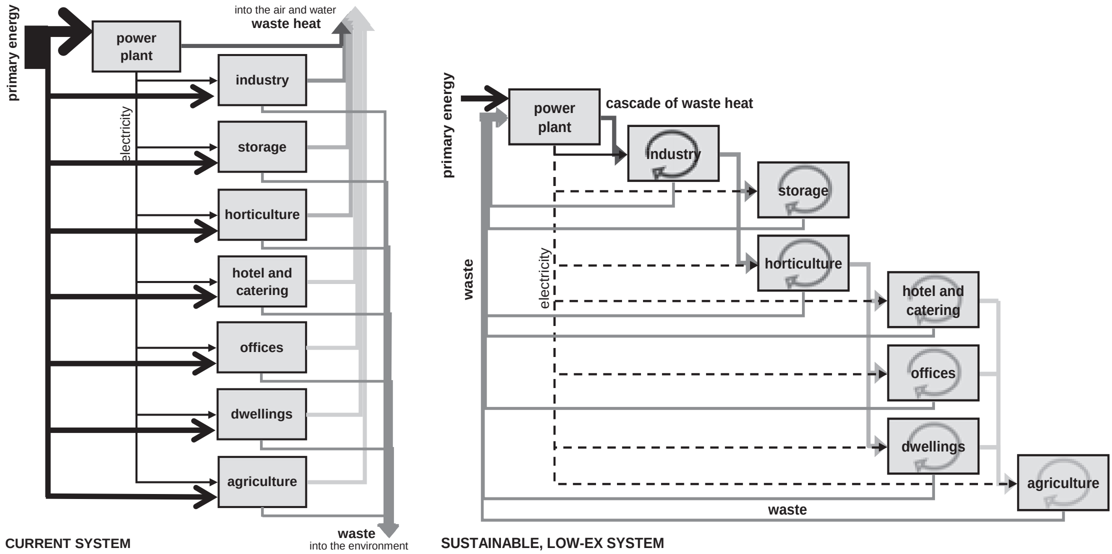

Figure 1 The traditional energy system versus a more sustainable one that uses waste heat optimally

As found in urban heat island studies [e.g. London Mayor, 2006], the accumulation and production of heat in urbanised areas is a problem that locally aggravates global warming. On the other hand, the Northern hemisphere still uses more energy for heating than cooling, so the available excessive production of waste heat should only be made useful. This is a question of having energy at disposal in the right quality, at the right time, in the right place. The built environment of the future therefore should contain means to convert, store and transport (waste) energy. Another approach might be to tune our spatial planning to the presence or demand of energy: locate heat demanding premises close to waste heat producing industries, or introduce a cold requiring (thus waste heat producing) facility in-between heat demanding functions. This can be considered low-ex planning. It’s not the most efficient, but very effective.

2.2 Smart skins and solar energy

The second example of a reality-based promise concerns the immensely unintelligent way we interact with the environment, the climate, the weather. The built environment, buildings in particular, is predominantly static, be it winter or summer, sunny or cloudy, wet or dry. If we accept to learn principles of nature, we will see numerous opportunities to design building envelopes that smartly interact between the indoor and outdoor climate, whilst generating and exchanging energy in an advanced way. Critical to the implementation of a changed approach to building façades in close coherence with integrated resource management in the urban living environment, are reciprocity between façade and surrounding influences respectively indoor comfort and behaviour related influences and climate change influences. Besides, inclusion of low-exergy solutions together with strong feedback systems between the different physical scales, and introduction of regenerative systems will be directive.

At the same time it is important to realise that there is enough solar energy in the world to fully provide our global economy with heat and electricity (and thus cold): we just need to make use of it, by deploying solar-irradiated surfaces more effectively (for energy, purification, nutrition etc.). Trying to prolong the fossil age is fatal: with the current demands for fossil resources, the limits may still be decades away, but when one of these limits is reached, the other resources would need to fulfil the demand for the depleted energy source. The impact would be a swift depletion of another resource, and so on. Nuclear energy is no enduring solution either, since Uranium resources are limited too, approximately 40 years with the current demand. Mallon [2009] calculated several scenarios of fossil age prolongation: each one of them had its limit within 75 years. This is why the depletion of fossil fuel should boost the development of new sustainable technology based on the only primary energy source we have: the sun, as well as its derivatives (wind, tides, biomass). It is abundant, ubiquitous and will be there for another 4.5 billion years. Recent developments in the market, whether ignited by large energy companies or by small-scale initiatives, are promising.

2.3 The existing stock and vigour

The previous two examples of the hope we may find in climate change and energy depletion refer to planning and design, whereas the predominant part of our built environment of the near future already exists. This should be considered as a great advantage: we don't need to build everything from scratch any more in the future. However we will have to reconsider more strongly the existing building stock and urban settings. Management of the built and unbuilt environment therefore is essential. E-novation (energy renovation innovation) will become a keyword and the main challenge to respond to the changing boundary conditions of climate and energy. Instead of tackling buildings separately, the enormous assignment we take upon us will require an approach on a larger scale, with joint projects of neighbourhoods, districts and entire cities. Climate initiatives such as in Melbourne, London, Vancouver, Shanghai and Rotterdam illustrate this.

Cynical about the actual execution of the technical and spatial solutions? We think that change can be enforced or stimulated by inspiration and creativity. The people we mentioned at the start are the paragon of this. Profound understanding and a simple incentive can alter the way we approach our living environment. Vigorous legislation can transform the attitude towards sustainable solutions. One of the best examples perhaps is the German *Einspeichergesetz*, a law that ensures individuals and companies good prices for sustainably generated power, while taxing polluting, fossil fuel based energy provision. This policy has transformed the roofs of Germany and still does.

3. Outline

The three elaborate examples above are just three examples of many initiatives and ideas that relate to our preferred positive attitude towards climate change and energy depletion. There are many more, coming from scientists, inventors, designers, governments and the market. This book contains cutting edge work from scientists and influential planners and designers, which may give way to further progress into a sustainable direction.

Smart Building in a Changing Climate consists of three main parts – Regional and Urban Planning; Building, Skin and Technology, and Management and Transformation – each of which containing four scientific papers, swivelled by a special contribution from prominent experts in the area.

This main part is preceded by an appealing pamphlet from Dr. Ken Yeang.

We hope that through all ideas and findings presented in the book you as a reader will be inspired, challenged and incited to come up with personal ideas and projects.

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What Is Green Design and Planning?
Five Propositions

Dr. Ken Yeang[5]

We might contend that there is no one single best approach to achieving effective green design. Instead there are a number of ways to arrive at the same goal of achieving a state of stasis in the global environment.

There are a number of propositions as to what green design and planning is.

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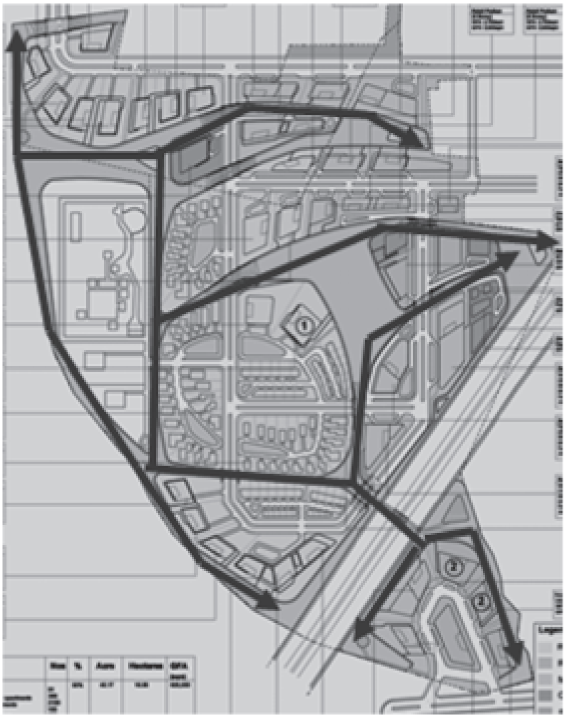
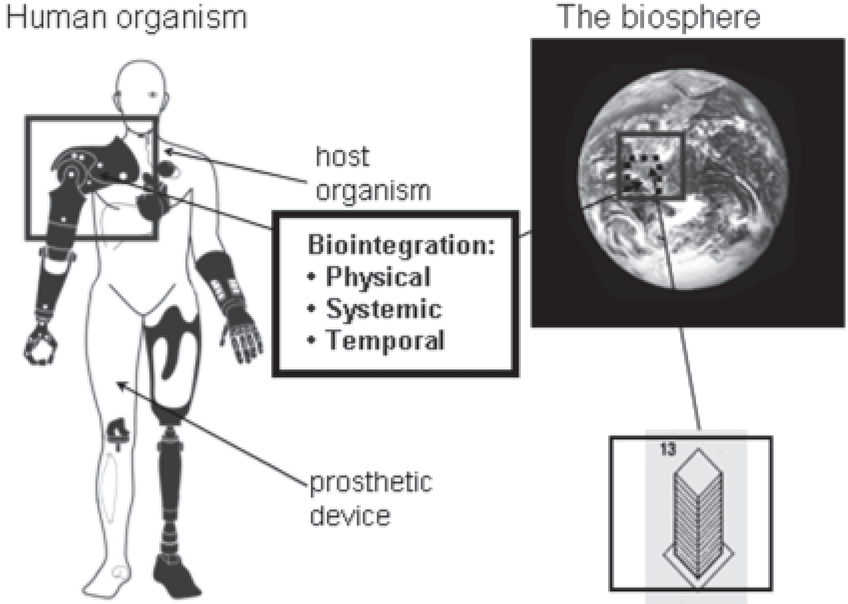
[5] DMPN, PhD (Cantab.), A.A. Dipl., D.Lit. (Hon.), FRSA, APAM, FSIA, RIBA, ARAIA, Hon. FAIA, Hon. FRIAS, Director of Llewelyn Davies Yeang, London and of TR Hamzah & Yeang, Kuala Lumpur Distinguished Plym Professor at the University of Illinois, Adjunct Professor at the University of Malaya, University of Hawaii at Manoa, and University of Tongji (Shanghai)

1. First proposition



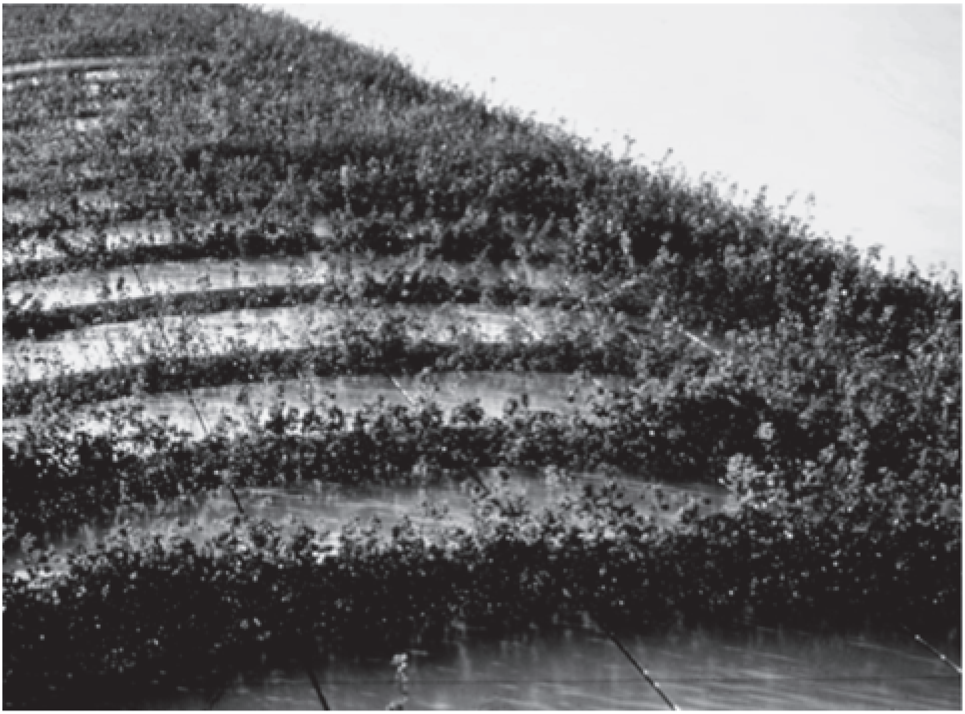
The first proposition is to view green design as the seamless and benign biointegration of four sets of infrastructures: the ‘grey’ (ecoengineering systems and utilities), ‘blue’ (water management and closing of the cycle by design, and sustainable drainage), ‘green’ (green ecoinfrastructure) and ‘red’ (human systems, spaces, society and regulations), as a method for resolving green design issues by the blending of all these four sets of ecological and artificial armatures into masterplan form or built form.

2. Second proposition



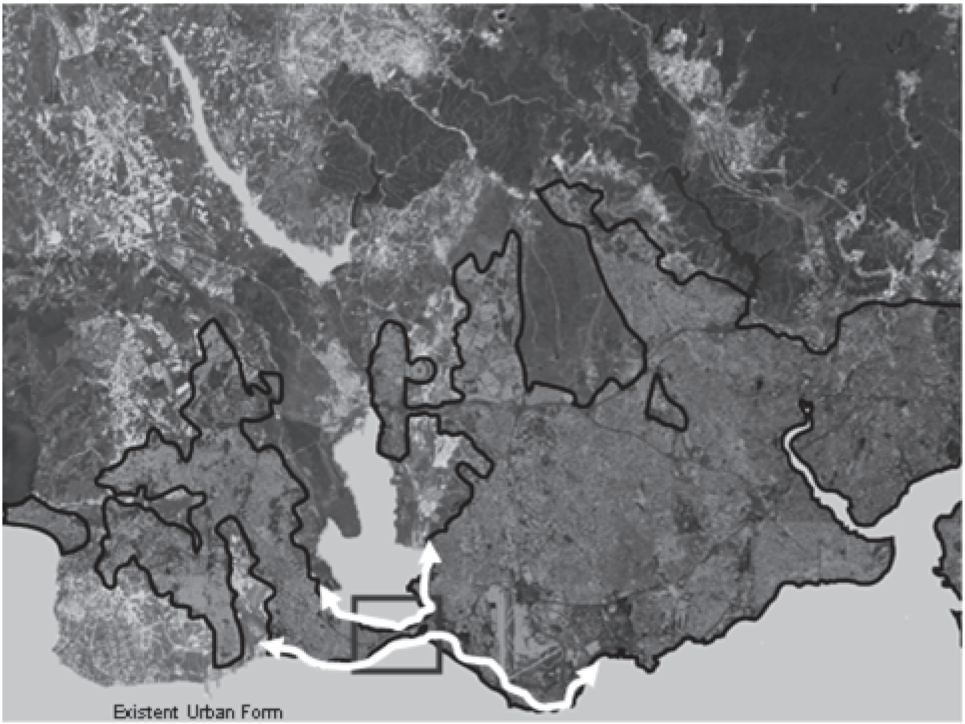
The second proposition is to regard green design as the seamless and benign biointegration of the artificial (human made) with the natural at three levels: physically, systemically and temporally. Biointegration is regarded here as similar to medical and surgical integration in prothesis design.

3. Third proposition



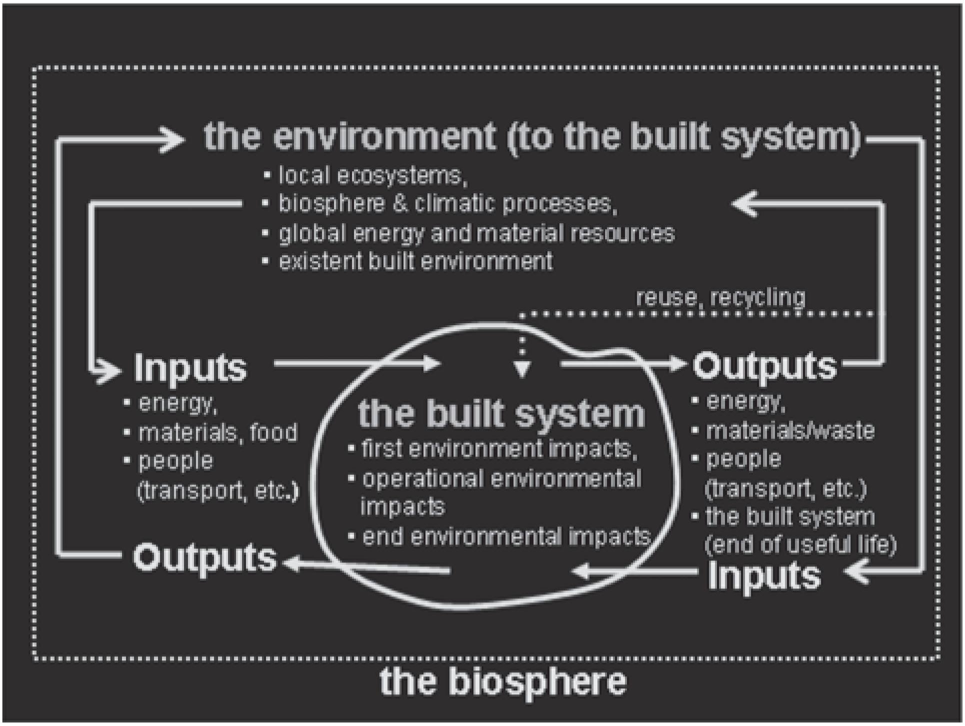
The third proposition is to regard green design as ‘ecomimesis’ as imitating ecosystems based on the processes, structure, features and functions e.g. recycling, using energy from the sun through photosynthesis, systems that heads towards increasing energy efficiency, holistic balance of biotic and abiotic constituents in the ecosystem, etc.

4. Fourth proposition



Fourthly, ecodesign is regarded not only as creating new artificial 'living' urban ecosystems or rehabilitating existing built environments and cities, but one of restoring existent impaired and devastated ecosystems in the regional landscape.

5. Fifth proposition



The fifth proposition regards ecodesign as one of global monitoring of environmental stasis and devastation by humans, natural disasters and impacts of our built environment, activities and industries as sets of environmental interactions. A theoretical model for green design is presented here together with the attendant technical and design issues.

PART A

REGIONAL AND URBAN PLANNING

Sustainable Real Estate for a Changing Climate

Prof. John Worthington[6]

1. Introduction

The crisis we now face is, more than the 7-10 year property cycle of 'boom and bust', the precursor of seismic change in the way the economy operates. The recession of the mid 1970s and the political unrest heralded the shift from an industrial to a service economy. Twenty five years later, the negative equity and recession of the early 1990s combined with the take up of Information and Communications technology triggered a restructuring of the office service economy (Worthington, 2006). Today I would argue we are confronted by a rethinking of values which is resulting in a restructuring of the financial investment sector, of which real estate is an intrinsic component.

Four themes are influencing the way we organise and accommodate living and working, as we enter the twenty first century. Information and Communications Technology (ICT) has miniaturised, converged and become ubiquitous (DEGW and Teknibank, 1992). Organisations and functions are geographically spread, exchanging knowledge through both virtual networks and at distinctive physical places (Harrison, Wheeler and Whitehead, 2001); functions, ownership and political boundaries are becoming blurred (Moor and Rowland, 2006); and decisions are framed less as choices of *either* this *or* that, but more as accommodating the paradoxes of *both* … *and…* (Leaman & Bordass, 1996). The crisis we face today is one of both economic and environmental under the banner headlines of *the credit crunch* and *climate change.* Both concerns, though following

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[6] John Worthington is co–founder of DEGW, an international consultancy specialising in workplace design and briefing. He currently holds the Graham Willis professorship in architecture at the University of Sheffield, is a Professorial Fellow at the University of Melbourne and Visiting Scholar at Pembroke College, Cambridge. He is the past chair of CABE/RIBA Building Futures and from 2004-2009 was a Board member of London Thames Gateway Development Corporation. He has advised on high building strategies for Rotterdam and Dublin where he continues to chair an advisory board on managing the process of innovation and change. John is currently on the advisory board of Climate Change Capital Property Fund and leads the Academy of Urbanism Learning from Place initiative.

different agendas, are linked by the common themes of values, behaviour, regulation and the allocation of resources.

2. A changing real estate perspective

Office buildings today are no longer just commodities but recognised as instruments that can: support, or hinder, an organisation's business objectives; generate wealth; and open up possibilities for future growth and change. Similarly, the emerging distributed organisation is recognising that the building envelope no longer defines the boundaries of work. The company office, as a place to work, is just one of a network of options. The UK central government in their agenda for workplace change have reframed the agenda and recognised "work is what you do, not a place to go" (Office of Government Commerce/DEGW, 2008). The city has become the office and at the same time the office has taken on the characteristics of the city. Work has become distributed across networked metropolitan regions. The model of the compact city is being questioned [7] and in its place a model is emerging of high-density, distinctive nodes, connected well by a choice of modes of public and private transport, in a low-density urban conurbation. To meet the requirements of economic, social and environmental sustainability such a model increases choice, allows for greater flexibility in the use of space and time, and potentially provides the adaptability for future change. A company's portfolio of buildings and network of settings, become the 'billboard' to communicate organisational ideas, values, culture and brand. The new knowledge-based workforce demand flexibility about how, when and where they work resulting in the workplace becoming a hybrid network of places and settings.

Corporate distributed workplace programmes are being shaped by a variety of different drivers, including:

- **Technology;** where wireless internet access is ubiquitous.
- **Eco-responsibility;** with a growing sensitivity of staff to environmental impacts and workplace sustainability.

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[7] Alex Gordon in his presidential RIBA address in 1972 was an early proponent of such an approach. John Weeks Planning for Growth and Change; Architects' Journal 7 July 1960; DEGW Design for Change; The Architecture of DEGW, Watermark/Birkhauser; Basel 1997

- **Business continuity;** by providing insulation from unexpected disruption.
- **Global economic volatility;** resulting in uncertainty of forecasting and fluctuating space demand.
- **Competitive advantage;** where leading organisations are always looking for an edge.
- **Talent and skills;** with the ‘squeeze’ to compete for the best in a global market.
- **Real estate;** with a focus on efficiency and utilization.

The corporate social responsibility agenda of the 1990s is widening through governmental and workforce commitments to that of the **sustainable business** where sustainable thinking and behaviour is integrated into business functions, goals and strategies.

The triple bottom line benefits of distributed working are recognised as at the level of the:

- **Individual**: the opportunity to blend living, working and movement, so optimising the use of time, enhancing the experience and increasing choice.
- **Organisation**; the freeing up of assets, so liberating capital to be invested into new ways of interacting and supporting innovation.
- **City**; increased choice, triple bottom line sustainability and a re-invention of the city.

Companies are recognising the business benefits and sustainability gains of using space more intensely over longer periods of time by overlapping uses, sharing facilities and allowing for flexible working. Major savings can be achieved as well as greater functional, financial and physical flexibility by reconfiguring the real estate portfolio to reflect a combination of tenure and accommodation types, for:

- **Core space;** owned or on very long leases often specialised or iconic space that reflects the values of the organisation or accommodates long term specialist functions. Typically this might only be 20-30% of the total portfolio.
- **Flexi space;** generic space on short term lease (3-5 years) suitable to absorb the projects which grow, change or disappear, say 40% of the portfolio.

- **On demand space;** facilities shared with others in the neighbourhood, contracted out functions, e.g. printing, testing, records storage etc., or short-term hire e.g. serviced offices or conference facilities.

Investors and developers are recognising property not only as a commodity to trade, but a means, through service and management to diversify revenue streams and distribute risk.

The new property offer, exemplified by companies such as Workspace in the UK or TCN in the Netherlands, who provide a total accommodation service combining, flexibility of tenure, space on demand, support services and wider amenities for staff, customers and the company network.

3. Meeting the sustainability agenda

For those in the built environment and property sectors the words sustainability and climate change are frequently used as an interchangeable descriptor. Whilst interdependent, their outcomes can differ in one significant way. A dominant focus on climate change tends to focus on the goal of optimising the reduction of energy and maximising the use of physical resources. Sustainability with a long-term perspective on economic, social and environmental wellbeing within a holistic framework is concerned not to optimise but to leave sufficient 'slack' to adapt to future demands. What has been described as the principle of 'long life loose fit' or by others the 'under-functionalised design of space', as distinct to designing for a precise functional fit (Jenks, 2008). Wishing to achieve the highest levels of excellence, through optimisation of each separate element, can result in a solution which is excellent in reducing energy and using the natural elements, but constrains future planning flexibility, so limiting future options. An office building which cannot be partitioned to provide a high proportion of enclosed individual spaces may rate highly on energy efficiency, but is not very sustainable if it does not meet the expectations of the potential users.

The 'sustainable' building rating tools such as BREEAM have had a hugely beneficial impact on raising awareness, and improving standards. However, used as an auditing rather than appraisal tool, they can lead to a 'tick box' approach rather than a tool for questioning, and innovative design. The pressure will increase as the market recognises that certified buildings can attract a rental premium compared with buildings of similar size and age in the locality (Eichholtz, Kok, Quigley, 2008). Research at the University of Maastricht identified that “rents for green offices are about 2% higher than comparable rents”, whilst effective rents, those adjusted for occupancy, “are 6 – 9% higher in green buildings than for rents in comparable office buildings nearby”. Similar research from the Henley Business School, Reading, suggested that “certified buildings offer a bundle of benefits to occupiers relating to business productivity, image and occupancy costs”. The outcome being that “certified buildings are likely (to) lead to higher rents and lower holding costs for investors… and require a lower risk premium.”

Green Star in Australia, closely followed by Green Mark in Singapore, have recognised the need to assess different stages of the design and use the process to gain holistic improvements, by assessments of: what you intend to build; what you actually build; what you put inside the building; and how you manage the building, with also an assessment of the neighbourhood within which the building is located. Separate points are given for innovative thinking with the possibility of discussion with the assessors of how a solution that scores low in the current rating could have even more major energy reduction returns if applied at another scale . For instance the question about recycling and local energy generation within the building may have even greater impact at a district scale.

Workplace sustainability gains can be made by lean thinking, intensification of use of resources, being prepared to rethink the ways of working and changing behaviour. Maximising the use of resources both reduces waste and improves business returns. Organisational sustainability strategies primarily focus on:

- Intensifying the use of space over time, by broadening the number of locations available, with greater mixing of functions and sharing of use over a greater part of the time available. Dramatic increases in capacity can be achieved by extending use into ‘dead time’ and changing work patterns. At Heathrow airport, by 1992 the airport had reached capacity. Without a long and risky programme of building additional capacity the only alternative was to increase ‘yield’. Extra capacity of passenger through-put was achieved by selling discount tickets to transfer passengers, who came in off peak and left off peak, and stayed airside in the intervening period so not putting extra pressure on passenger processing and the access road to the central area terminals. Between 1992 and 2004 passenger numbers increased from 45 to 67 million, with transfer increasing from 4 to 23 million (86% increase) with no major additional infrastructure required.

- Use communications technology to reduce the need for travel and drive a distributed global workplace strategy.
- Locating corporate core offices at well-connected areas that are attractive for staff and have good supporting amenities.

The traditional approach to energy reduction was to target savings in infrastructure, capital costs, and operating, revenue costs, separately. By thinking holistically, and addressing infrastructure and operations as one, the opportunity for even further reductions has been realised. Savings through intensification can be achieved through:

- Urban planning controls that support higher densities and more intensive ground cover at locations with good public transport.
- Re-use and mixed use, of redundant or underused buildings, through flexible land use zoning and allowing activities to change within the original use class.
- Re-invention of patterns of operation to use the space more effectively.
- Overlapping uses to share between compatible functions. In 1998 DEGW Twynstra were asked by Shell International to provide a learning centre for the training of senior managers from Shell Worldwide (Andrew Laing DEGW, 2008). The brief was to provide a residential venue for three-day courses, to be available during the week and not for 8 weeks in the summer when most of the managers would be on vacation. The solution was a deal with Holiday Inn, whose peak times of use were the weekends and summer holidays. It was a perfect fit and maximised the usage of the facilities. When Shell were in residence the space was personalised by the use of projected logos, hinge down room names with Shell branding and a new build small auditorium which was used at weekends as a cabaret theatre. Both parties gained, space use was intensified and 5 years later Shell moved out as planned to a long-term facility with the minimum of wastage.

By embracing new ways of working to achieve more with less, unrecognised and under-exploited sustainability benefits are there to be gained. Space is always heated, cooled and lighted, but seldom fully utilised. DEGW observation of company utilisation of conventional offices shows that within the working day dedicated workspaces are typically vacant for 60% of the time and meeting and conference rooms vacant for 40% of the time. This pattern is reinforced by the assignment of one person to one desk, a limited choice of settings, rigid boundaries between functions and groups and restricted mobility.

With the greater mobility and freedom to choose when, where and how we work and a strategy that provides the technology to enable mobility, soft boundaries between functions, a wide diversity of settings and shared space, space utilisation can be considerably improved. The flexible use of space can intensify use and drive down per capita energy-related emissions.

As an example a traditional workplace solution with 640 staff each with their own workstation compared with a flexible approach with 400 assigned desks and 220 touch-down spaces would house 210 additional people, saving 2,000 Metric tons of CO_2 per annum, the equivalent emissions of driving a car 5.5 million miles. Greater flexibility will also drive down commuting-related emissions. Say the average employee commutes for an hour and twenty minutes (46 miles) per day, that is 3.9 Metric tons of CO_2 per person per year. If there are 450 'flex' workers in the future who are better equipped to work anywhere, each might reasonably work remotely once a week, thereby saving 360 Metric tons of CO_2 per annum. The combined savings from applying the 'flex' space model and reduced commuting is 2,360 Metric tons, compared with a planned photovoltaic array at the site which might reduce the annual CO_2 by 348 Metric tons. Studies have shown that, comparing conventional open plan, remote work and the flexible workplace, flex work scores highest in cost savings, increased productivity, increased satisfaction and greenhouse gas reductions (Andrew Laing DEGW, 2008).

4. Conclusion

Buildings are changing from the single function of the past and the multiple uses of today to simpler, more generic building typologies that can accommodate a variety of different functions over the long term and a variety of settings for different functions over short periods. Building structures may become simpler, the management and operation more sophisticated and the city more complex in its governance, infrastructure and integrating systems.

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Urban Sustainability Science as a New Paradigm for Planning

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1. Introduction

Ever since Rittel and Webber published their seminal paper on the notion of planning problems as “inherently wicked” and defying principles of rational (scientific] decision-making (1973:160), the quest has been on to find a planning paradigm that can accommodate the complex problems of cities and their sustainability. Planning theorists have proposed numerous alternatives to the rational planning paradigm that recognise the complexity and unpredictability introduced by social factors, e.g. transactive planning (Friedmann, 1973), deliberative planning (Forester, 1989 and 1999), community-based planning (Leavitt, 1994), communicative rationality (Innes, 1995), and collaborative planning (Healey, 1997). The introduction of sustainability to the goals of planning added another layer of complexity brought about by the inclusion of environmental considerations to the general social and economic concerns. This, in turn, led to calls for an ecological or sustainability planning paradigm (e.g. Blowers, 1993; Lyle, 1994; Van der Ryn and Cowan, 1996; Beatley and Manning, 1997; Berke and Conroy, 2000). However, as Cooper (2002:117) discusses, drawing on Palmer *et al.* (1997), there is “no consensus on what sustainable urban development is …nor on what a sustainable human settlement looks like or how it functions”. To achieve such a consensus, Jepson (2003:391) argues for a definition of [urban] sustainable development that is based on scientific principles derived from the theoretical frameworks presented by, for example, ecology and thermodynamics of living systems.

Discerning that sustainability is a problem described by the complex dynamics of human-nature interactions, and that it requires a decisive change in the way that science is undertaken, the National Academy of Science in the USA

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formally recognised sustainability science as a branch of science (US National Research Council, 1999). As such, sustainability science is a product of the convergence between an emerging ecological/ whole systems worldview and its associated scientific and social paradigms, and what is probably the most critical challenge of current times: the transition of society towards a more sustainable developmental pathway (Du Plessis, 2008:61), and it offers a definition of (urban] sustainability that is based on both a scientific and philosophical understanding of the world.

This paper presents an argument in favour of sustainability science as a theoretical basis for a planning paradigm (i.e. a shared set of concepts and practices, as defined by Kuhn, 1996) that can effectively engage with the wicked problems presented by cities (as systems of humans and nature) and their sustainability. It is grounded in the work of the Southern African Sustainability Science Network (published in Burns and Weaver, 2008), as well as the author's ongoing PhD work, which constructed a meta-theory of urban sustainability within an ecological worldview from an extensive analysis and synthesis of literature drawing on domains ranging from science (e.g. ecology, new physics and complexity), philosophy, and comparative religion, to theories of sustainability, planning and development. The paper first provides brief backgrounds on the notion of wicked problems, the field of sustainability science, and the concept of the city as social-ecological system (SES), before exploring the concept of urban sustainability science as planning paradigm by asking how the notion of the city as a complex, adaptive, self-organizing SES would change the way planners engage with the problems and the praxis of urban planning. Unfortunately limitations of length necessitate an extremely superficial discussion. Furthermore, the objective of the paper is not to present a tested hypothesis as illustrated through case studies, but instead to provide a philosophical starting point for discussion, reflection and further research.

2. The wicked problems of planning

In her book 'The Death and Life of Great American Cities', Jane Jacobs observed that the problems presented by cities are neither simple two or three variable problems, nor the problems of disorganised complexity which form the domain of statistical analysis and probability theory, but are instead problems of organised complexity, i.e. "problems which involve dealing simultaneously with a sizeable number of factors which are interrelated into an organic whole" (Jacobs, 1992:432). The premise of her larger argument is that traditional city planning approaches either reduce the problems of a city to problems of simplicity, dealing with closely-linked cause-effect relationships (e.g. the relationship between population and housing needs), or use statistics to determine the provision and location of facilities such as schools, hospitals or shops. These approaches treat the city as a problem of physics and mathematics, and therefore as a dead object, resulting in cities that are slowly dying. It is only by seeing the city as a problem of organised complexity, and therefore a problem of the sciences of life, that cities can be kept alive.

There is a growing body of work that seeks to model cities as dynamic and complex, adaptive systems (e.g. Casti, 1997; Alberti and Waddell, 2000; Batty, 2005). This work focuses mainly on cellular automata and agent-based modelling that proceeds from the premise that most growth in cities is based on bottom-up individual decisions and not according to a centrally-devised grand plan (Batty, 2005:107). However, in hoping to identify general generative rules that guide bottom-up behaviour with the aim of eventually being able to predict the behaviour of agents and the consequences of their actions, the approach is still based on the assumption of rational decision making by agents. As such it does not allow for the 'irrationality' of influences such as human emotions, norms and value systems that fluctuate depending on the context of the agent, and singular conditions produced by the interaction of environmental, economic and social factors in a specific time and place. These are the essence of wicked problems.

Rittel and Webber (1973:160) point out that "the kinds of problems that planners deal with are inherently different from the problems that scientists and engineers deal with". They propose that whereas the problems of science are mostly "tame", i.e. they are clearly defined problems with a clear mission and clear indicators for when the problem has been solved, this is not true of most planning problems, which they classify as "wicked" problems (*ibid*.) These wicked problems have the following ten characteristics: there is no definitive problem formulation, instead "the formulation of a wicked problem *is* the problem" (*ibid.:*161); there are no criteria to indicate when a solution has been found and the eventual 'solution' is arrived at through reasons external to the problem such as funding or time constraints; solutions to wicked problems are value-based, that is "they are not true-or-false, but good-or-bad" (*ibid*. 162); there is no way of testing and fully appreciating the consequences of a solution as the full scope of its repercussions cannot be traced; there is no opportunity for trial and error, every solution has an immediate and irreversible impact on the system; there is no fixed number or set of permissible solutions to a wicked problem; "every wicked problem is essentially unique" (*ibid*.:164) and therefore there are few replicable solutions; wicked problems are nested across levels in the sense that "every problem can be considered a symptom of a problem at a different level" (*ibid*.:165); in wicked problems the usual rules of science to formulate and test a hypothesis cannot be applied, and the explanation for a discrepancy, and hence the proposed resolution of the problem, is mainly determined by the 'world view' of the analyst; and lastly, unlike the scientist whose hypotheses can be refuted without major consequence, the planner cannot afford to be wrong as the solutions to planning problems have direct and irreversible impacts. One of the key reasons why planning problems can be considered as wicked is the fact that planning "inevitably involves value-choice issues" (Lane, 2001:659) that are further complicated by the multiple perspectives on the problem brought by different socio-economic and biophysical systems and actors in the city (Courtney, 2001:31). To develop decision support tools for planning that engage with these multiple perspectives and the underlying norms, beliefs and values that guide behaviour, Peter (2008:471) suggests instead an approach based on contemporary ideas about social-ecological systems as described by sustainability science.

3. Sustainability science

Sustainability science concerns itself with studying the "fundamental character of interactions between nature and society" (Kates *et al*., 2001:641). Rapport (2007:77) describes it as "a transdisciplinary effort to come to grips with one of the most perplexing issues of our time: how to achieve a symbiotic relationship between biological and social-cultural systems so that future options are not foreclosed". Kates *et al*. (2001: 641) propose that further development of sustainability science will require substantial advances in understanding the behaviour of complex self-organizing systems, in order to address the responses of social-ecological systems to "multiple and interacting stresses". They further suggest that "combining different ways of knowing and learning will permit different social actors to act in concert under conditions of uncertainty and limited information". The key characteristics of sustainability science can be summarised by three main ideas: it deals with problems that encompass multiple and interacting scales, levels, dynamics, actors and system thresholds in social-ecological systems; it emphasises learning, adaptation and thus reflection; and it acknowledges and makes use of multiple participants (e.g. scientists, stakeholders, practitioners) and epistemologies to co-produce knowledge (Kates *et al*., 2001; Burns *et al.*, 2006; and Martens, 2006).

As such, sustainability science is an interface (or transdisciplinary) science in that it draws on many scientific disciplines across the natural and social sciences, as well as other knowledge systems (e.g. indigenous knowledge, tacit practitioners' knowledge) in order to study the dynamic interactions within social-ecological systems. It is also science that is "use-inspired" (Burns *et al*., 2006:380), and "problem-driven, with the goal of creating and applying knowledge in support of decision-making for sustainable development" (Clark and Dickson, 2003:8059). However, as Burns *et al*. (2006:381) point out, the debate on how sustainability science should be practiced is still in its infancy. Swart *et al*. (2002:1994) propose that sustainability science would require "the evolution of methods that can adequately and rigorously capture uncertainty, the capacity for system discontinuity, and the normative content of sustainability problems". Martens (2006:38) suggests that the novel models and techniques required for sustainability science can be characterised as demand-driven, participatory, subjective, exploratory and uncertain, and as "heuristic instruments, as aids in the acquisition of better insight into complex problems of sustainability". Swart *et al*. (2002:1994) further identify the following challenges for sustainability science: "linking themes and issues (e.g. poverty, ecosystem functions, and climate); understanding and reflecting deep uncertainty; accounting for human choice and behaviour; incorporating surprise, critical thresholds, and abrupt change; effectively combining qualitative and quantitative analysis; and linking with policy development and action through stakeholder participation".

From the above descriptions it can be seen that there are strong similarities between the problems of sustainability science and the wicked problems of planning identified by Rittel and Webber (1973). A further connection between sustainability science and planning is that the main problem space of sustainability science is that of social-ecological systems (SESs), of which the city is a particularly significant example.

4. Understanding the city as a social-ecological system

The idea of the city as system has been around for at least as long as systems thinking. Apart from its obvious infrastructural and management systems, the city has been described as an ecosystem (e.g. Odum, 1969; Lyle, 1994; Girardet, 1996; Alberti, 1996; Newman and Jennings, 2008) with both biological and technological metabolisms (Rees and Wackernagel, 1996); as a complex adaptive system (e.g. Waldrop, 1992; Holland, 1993; Johnson, 2002; Batty, 2005); and as a social-economic system (e.g. Jacobs, 1970; Castells, 1983; Hallsmith, 2003). However, as Kohler (2002: 131) suggests, it is necessary to develop a common model of urban reality that would include not just the biophysical and technological systems, but also economic, social and cultural systems – that is of the full social-ecological system.

The exact nature of social-ecological systems (SESs), or what it is that differentiate SESs from other types of ecological systems, is still open to debate. The Resilience Alliance (2006) describes SESs as “complex, integrated systems in which humans are part of nature.” However, while there are numerous methodologies and conceptual frameworks for studying aspects of social-ecological systems, the understanding of how the social and ecological components are to be integrated into one system is still evolving. Grimm *et al.* (2000) suggest a modelling framework that would include variables in social patterns and processes and human perceptions as drivers of change together with ecological drivers. Alberti *et al.* (2003) propose a similar conceptual model that links human and biophysical drivers, patterns, processes and effects. However, both these models are limited to a view of humans as another species of mammal within an ecological system, with no attempt to address those aspects that differentiate social-ecological systems from other types of ecological systems. Haberl *et al.* (2004) move some way towards addressing this gap by suggesting that social-ecological systems should be seen as a ‘biophysical’ sphere of causation governed by natural laws, and a ‘cultural’ or ‘symbolic’ sphere of causation reproduced by symbolic communication. An analysis of papers published over the past ten years in the main journal of social-ecological system research, *Ecology and Society*, suggests four propositions as the cornerstones of a conceptual framework for understanding social-ecological systems, including cities (Du Plessis, 2008).

The ***first*** of these propositions suggests that social-ecological systems can be seen as consisting of interpenetrating biophysical and mental phenomena: an 'exterior' biosphere created by biogeochemical processes (including those originating from human activities), and an 'interior' noosphere created by and experienced through the human psyche and processes of thought and social interaction. This view brings together the two aspects of a city identified by St. Isidore of Seville (AD 560-636) in his Etymologies (described in Arida, 2002:xix): the *urbs* (the physical aspects) and the *civitas* (the emotions, rituals and rules), in an understanding of the city as a phenomenon originating from and created by both mental-social and technological-natural processes. As the noosphere is a property that emerges from the biosphere, it relies on the functional integrity of the biosphere for its continued existence. At the exterior level, humans and their artifacts (i.e. technology, infrastructure, and buildings) are an indivisible part of the biosphere and they, like any other organism, participate in and co-create the metabolic and change processes that shape the biosphere. Humans are bound by the same natural laws that apply to other organisms, but their interior processes allow them to apply these laws to create and adopt technologies that introduce novel components to the system at scales both above and below that of the individual human.

The ***second*** proposition suggests that a social-ecological system consists of relationships between elements at a number of scales, across biophysical and mental levels, and in nested systems. Two key concepts that describe the specific hierarchical nature of SESs are holarchy and panarchy. Koestler (1975:103) coined the term holarchy to describe a systems hierarchy where each element is simultaneously a whole (as an individual entity) and, as an element in the system at that level, a part of a larger whole. The whole can thus be seen as an emergent property of the structural relationships and interactions of the parts. Furthermore, each holarchic level operates according to its own set of rules or patterns that determine behaviour at that level. However, lower levels can influence higher levels through upward causation and higher levels can control or influence what happens at lower levels through downward causation (Roger Sperry cited in Wilber, 2000:28). This notion of interaction and influence across different hierarchical levels is the central tenet of the second concept, namely panarchy.

Holling *et al.,* (2002) coined the term 'panarchy' to provide an organising framework for theory dealing with cross-scale dynamics in natural and social systems. The term is a complex wordplay on the idea of hierarchy (of level and scale) combined with the prefix ‘Pan’ to indicate change across the whole. Within the panarchy, change (as expressed through an adaptive renewal cycle of breakdown and release, re-organisation, growth and exploitation, and conservation) is a constant phenomenon at each level or scale of the system. Within each of these stages of the cycle different survival strategies are privileged, thus driving different types of agent behaviour. However, the adaptive cycle phases at different levels also interact or connect with one another, thus driving system change across levels. The panarchy is constructed gradually as potential accumulates at one level, until a threshold is passed that allows the establishment of a slower and larger level. Conversely, the panarchy collapses or enters state breakdown when there are simultaneous crises at different levels (e.g. all levels of the system enters the breakdown phase of their individual adaptive cycles at more or less the same time) or a crisis cascades across all levels. From this point of view, the objective of [urban] sustainability initiatives is not to resist or reverse change, but to accept that change is inevitable and manage the phase changes within systems in such a way that the system does not lose its functional integrity and tip into another stability regime, or that such collapses do not cascade upwards into the larger system. This means managing the capacity of the system to experience shocks while retaining essentially the same function and structure, and therefore identity, a concept known as resilience (Holling *et al.*, 2002; Walker and Salt, 2006).

In order to understand how resilience can be managed, it is necessary to introduce the ***third*** proposition: SESs are systems that are complex and adaptive, with properties of self-organisation and emergence. SESs are complex, in that they are diverse and made up of multiple interconnected elements, and adaptive, in that they have the capacity to change and learn from experience. Within complex, adaptive systems (CASs), micro-level agents interact to create the global properties of the system. These global properties then feed back into the micro-level interactions. Lucas (2004) explains that the essence of CASs is that they self-organise to optimise the function of the system, creating new niches as necessary, and changing their composition (i.e. the elements and relationships of which they are composed) to fit the changing patterns they encounter. Understanding SESs as CASs means that the important properties to consider are those related to change and the system’s ability to deal with change – for example, resilience, adaptability, transformability, connectivity and diversity. A key aspect of CASs is that their constituent agents are constantly making predictions based on their various internal models of the world (i.e. implicit or explicit assumptions about the way things are out there), and adapting to each other and to the external environment. These adaptive responses and interactions allow the system as a whole to undergo spontaneous self-organisation into collective structures with properties that cannot be predicted from the properties of the parts, and which the agents may not have possessed individually (Waldrop, 1992) - a concept referred to as emergence. This happens in both physical and social systems. What differentiates physical systems from social systems is that the agents in social systems often alter their behaviour in response to *anticipated* outcomes.

This brings us to the ***fourth*** proposition: what differentiates SESs from other systems is the introduction of abstract thought and symbolic construction. As Westley *et al.,* (2002:108) explain, the ability of humans to make sense of their world through abstract thought and symbolic construction allows “the formation of social systems and a ‘virtual reality’ through which options and scenarios can be explored and new possibilities can be imagined”. They suggest four elements of symbolic construction: the creation of a hierarchy of abstraction (which allows the agent to separate him/herself mentally from the realm of time and space); the capacity for reflexivity; the ability to remember the past and learn from it (hindsight) and imagine the future and plan for it (foresight); and the ability to externalize symbolic constructions in technology. The ability to use symbols and with symbols, language, allows humans to develop sophisticated means of communication that allow abstract ideas to be communicated not just across vast distances, but also across time. The capacity for symbolic construction further introduces new types of entities that only exist in the symbolic realm of the noosphere, e.g. nations, corporations, and legal, political and economic systems, as well as values, norms and beliefs (i.e. rules of engagement) that influence agent behaviour. It is this sophisticated interior aspect and the opportunity it creates for novelty, foresight, reflection and learning, as well as the rules of engagement that are formed at this intangible (mental) level, that differentiate SESs from other ecological systems.

Within this conceptual framework, sustainability science focuses specifically on understanding the dynamic interactions of SESs at and between all levels (e.g. biosphere and noosphere) and scales (e.g. household, neighbourhood, suburban or metropolitan) of the urban system with the aim to understand the factors that determine the resilience, vulnerability and adaptability (seen as the conditions for sustainability) of the city. It therefore addresses the ever-changing, unpredictable and cross-scale nature of the wicked problems of planning, as well as the aspects of these problems that lie in the domain of the human mind at both individual and social levels such as values and multiple perspectives. Sustainability science further offers a particular interpretation of the sustainability of cities and how the planning profession should engage with urban sustainability.

5. Sustainability science and the problem of urban sustainability

From the above understanding of cities as social-ecological systems (SESs), it can be argued that the objective of urban sustainability is to uphold relationships and dynamics (within and across levels and scales) that maintain the ability of the city to provide not just life-supporting but also life-enhancing conditions for the local and global community of life by maintaining the critical structures, functional integrity, overall health and well-being, and capacity for regeneration and evolution of the city, its sub-systems and the global SES of which it is a part. This would require learning how to respond and adapt to, and evolve with change and surprise, while avoiding changes that would move SESs at levels from global to local into stability regimes that would threaten the life-supporting and life-enhancing capacity of these systems. What is important in this interplay of allowing and adapting to change, and ensuring the persistence of conditions that would keep the system within a preferred stability regime, is the need for reflection in order to learn from both failures and successes, and to achieve sufficient understanding of how global and local social-ecological systems function to be able to learn from, work with and anticipate the dynamics within and between these systems. Achieving such an understanding is the objective of sustainability science.

In their seminal paper Kates *et al.* (2001:641) propose a set of core questions for sustainability science that have become the main point of departure for studies in this field. These are concerned with how the dynamic interactions between nature and society can be incorporated in models that integrate both earth systems and human systems (i.e. social-ecological systems); how long-term trends in environment and development are reshaping nature-society interactions; what determines the vulnerability or resilience of the different nature-society systems; whether scientifically meaningful limits or boundaries can be defined that would provide effective warning of serious degradation risks; how existing monitoring and reporting systems can be extended to provide more meaningful guidance for efforts aimed at a sustainability transition; and how to integrate activities of research, planning, monitoring, assessment and decision support in systems for adaptive management and societal learning.

Building on these early questions and the understanding of the city as social-ecological system (SES) within a global SES, urban sustainability science would ask the following: what determines the functional integrity and resilience of the urban SES; how do we most effectively participate in the functioning, regeneration, evolution and overall well-being of the urban SES; and do we understand the dynamics of urban processes within the SES, that is, do we understand the system structure (the networks of relationships) as it spans across the different scales and mental and physical aspects of the city, do we know the critical variables and their parameters which describe the stability regimes within which we need to keep the urban and global SES, and can we determine and monitor the system's position relative to these parameters? Engaging with urban sustainability from a planning perspective is therefore not necessarily about how to make 'correct' choices of technology or social and economic ideologies, or to find solutions to a range of pre-determined problems (e.g. poverty, pollution, crime, or waste), but to understand the dynamics that gave rise to desirable and undesirable phenomena so as to participate most effectively in the natural evolution of the city while keeping the urban and global SESs from crossing critical thresholds.

6. Discussion: a planning paradigm based on sustainability science

The theoretical basis provided by sustainability science as discussed in section 5 offers a number of new concepts and practices to planning. Let us look at the first characteristic of sustainability science as dealing with problems that encompass multiple and interacting scales, levels, dynamics, actors and system thresholds in social-ecological systems. What is particularly new about the perspective offered by sustainability science is the emphasis on understanding networks, relationships, flows and thresholds, instead of quantitative and qualitative analysis of the parts of the urban system. This requires that planning and regulatory processes are guided by an understanding of systemic interactions; take into account issues of behaviour, relationship, resource flows and resilience across the social-ecological system; and acknowledge that uncertainty and unpredictability is a characteristic of cities that requires adaptive management and flexibility in implementation.

It further introduces a view that integrates the physical aspects of the city as biosphere (i.e. spatial patterns, infrastructure networks, flows of energy and matter, ecological relationships and biogeochemical processes) with the aspects of the city that sit in the noosphere (e.g. values, norms, beliefs, legal, economic and political systems and noospheric entities such as corporations, governance structures, and civil society organisations) into a model of the interactions and relationships between bio and noospheres. This would require that the conceptual and other models used to inform systemic planning processes account for the flows between interior aspects (e.g. value systems or structures of legitimisation such as regulations) and both interior changes (e.g. a shift towards a specific value system such as environmentalism) and exterior change (e.g. changing value systems driving the development of new technologies). It must further be able to close the loop by accounting for changes in the exterior related to manifestation of interior events (e.g. the use of a new technology increasing pollution levels).

Sustainability science further shifts the objective of planning away from providing solutions to problems that appear to be "easily definable, consensual and judged undesirable by the predominant opinion" (Rittel and Webber, 1973:156), and then solving the problems created by these solutions. Instead, the objectives of the planning professional become to a) study, understand and monitor the thresholds and boundaries that define the preferred stability regime of the urban SES and the variables that influence them; b) study and understand the dynamics that gave rise to undesirable phenomena in order to find the most effective leverage points at which to intervene to keep the urban SES within a desirable stability regime; and c) develop management structures and performance measures that accept and embrace change and novelty while building the capacity for resilience in the interaction between noosphere and biosphere.

This brings us to the second characteristic of sustainability science – its emphasis on learning, adaptation and thus reflection. In an environment that has to deal with constant change and uncertainty, planning changes from a prescriptive activity to a process of reflection and adaptation that needs to happen at several levels. The first level of reflection is about our understanding of the possible consequences of an intended action, not just at the scale or level of the system where the action is intended, but also the consequences of such actions at lower and higher scales or levels and the appropriateness of the proposed action to its context. However, it is important that such precautionary reflection is an ongoing process, leading to the second level of reflection, which is to remain aware as we act of what is happening, and to respond and adapt to changing circumstances, new knowledge and surprise. This, in turn, feeds into the third level of reflection which requires reflecting about what was learnt during the entire cycle of decision, implementation and outcomes, and how this learning can be fed back into future actions.

However, in order to get a broad enough perspective on the dynamics of the system that would allow meaningful reflection on possible consequences and broad access to the lessons from previous actions, the planner has to not only consider the knowledge obtained from multiple sources (e.g. scientists, stakeholders, practitioners, indigenous knowledge) and epistemologies, but accept that adequate understanding of the complexity of the urban dynamics can only be achieved through co-production of knowledge with multiple participants. This is the third characteristic of sustainability science and it takes earlier notions of participatory planning one step further in that it not only considers the needs and wishes of communities and groups within communities, but also includes the perspectives brought to the table by the knowledge and understanding of these communities about the dynamics of the SES.

7. Conclusions

The objective of this paper was to explore whether sustainability science could offer a theoretical basis for a planning paradigm that can effectively engage with the wicked problems presented by cities and their sustainability. Sustainability science is a relatively new and unproven scientific domain, but it holds much promise as an approach to dealing with wicked problems. The paper presented an argument in favour of sustainability science as basis for a new planning paradigm that a) links the type of problems explored by sustainability science to the wicked problems that are the domain of planning, b) illustrates how the understanding of cities as social-ecological systems provides a conceptual framework for addressing some of the challenges presented by the characteristics of wicked problems, and c) suggests some of the concepts and practices sustainability science would bring to planning. As yet this argument is untested and in the early stages of development and it is hoped that this paper will stimulate further discussion and development of the ideas by a larger community.

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Regional Planning for a Changing Climate in the Province of Groningen

Rob Roggema, MSc[9]

1. Groningen: key characteristics and problems

1.1 Map 800

The province of Groningen is located in the northernmost part of the Netherlands. The province has a long and intense history in having to deal with water. The entire province is surrounded by water. Fringed between the Wadden Sea and the high sandy plateau in Drenthe, Groningen historically had to deal with dynamic marine circumstances as well as runoff water, which was transported from the plateau, through brooks, towards the sea.

The map of 800 AD shows the northern part of the Netherlands at a time when there was a very subtle and sustainable balance in the natural system (fig. 1.1). Man had had almost no influence on the forming of the landscape. The dynamics of the sea changed the landscape permanently and a natural process of land forming secured the balance. Along the coastline in a broad zone marine clay was deposited on peat and in front of the coast a tidal salt marsh emerged. Little brooks discharged the rainwater from the plateau, where the water was sponge-like stored in the vegetation, into the sea. Several larger rivers, like Lauwers, Fivel, Eems and Middelsee, were penetrating the coastline (Ven, 2004). In between brooks and rivers, where grounds were high enough, people started to live on so-called *wierden*, artificial mounds amidst the periodically flooded landscape. People living in this area were only protected from drowning by natural processes, which caused a continuous rise of the ground level of the land.

After this period, man started to make use of the natural processes by capturing sand and mud actively in front of the coast and when the land was high

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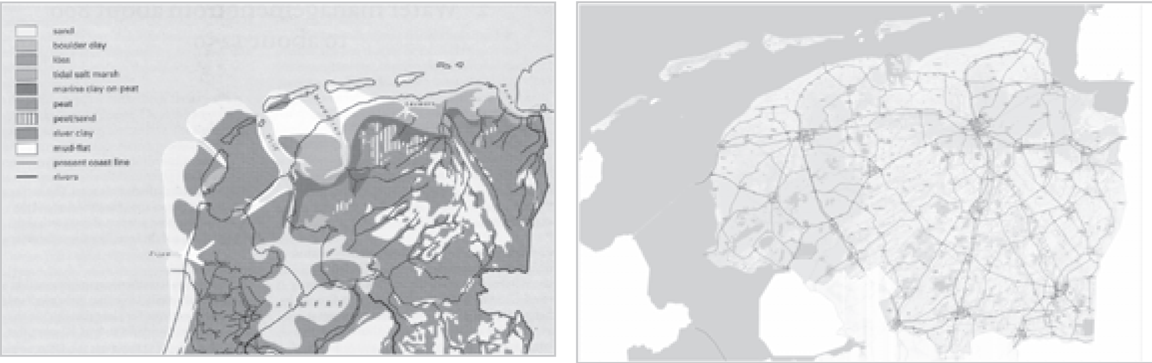


Figure 1.1 Historic map (800 AD) of Northern Netherlands (left), compared with current situation (right) [Sources: Ven, 2004 & DLG, 2005]

enough they built the first dikes around it. This process of land reclamation went on for centuries until the current coastline was shaped (fig. 1.1). The final result of the occupation is that the land is well protected against storms and high tides, but the fierce dike stops the natural rising of the land. Another effect of the subsequent reclamations is that grounds near the coast are highest and the inside landscape lies lowest. The difference between the ‘highlands’ and the deep polders is 1.5 meter on average.

The landscape as it is now can be characterised as a controlled landscape with a strong diversion between land and sea. The rainwater is discharged through a system of canals, pumps and dams and is transported into the sea as quickly as possible. The waterways are standardised in order to be capable of discharging just the right amount of water. The requirements according to which the dike is built take into account a representative storm, which is likely to occur once every 4000 years. Since every inch of the land is standardised, the landscape is very inflexible in comparison to the landscape in 800 AD.

1.2 Climate change

The climate in the province of Groningen is affected by changing temperatures and precipitation as well as a rising sea level. The annual precipitation increases or decreases slightly, depending on the chosen scenario.

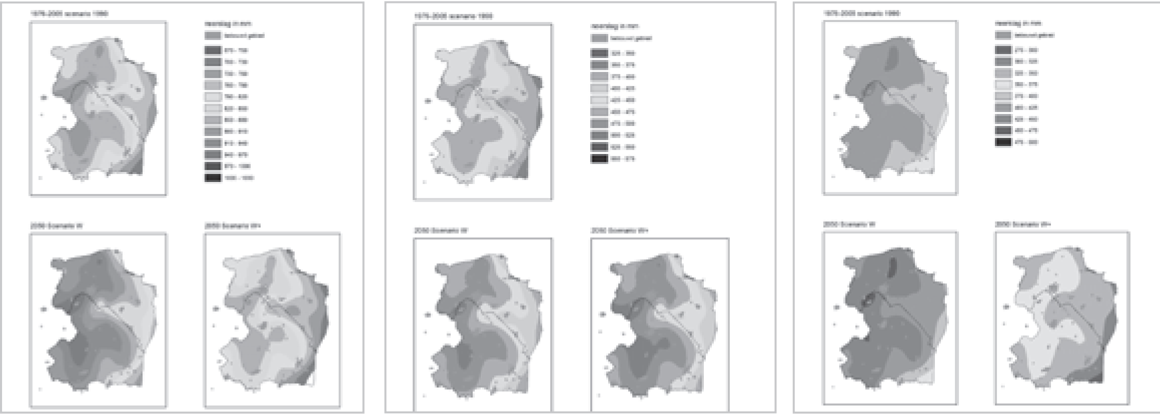


Figure 1.2 Climate Maps for Groningen and Drenthe: from left to right: average precipitation, precipitation in Winter and average precipitation in Summer [Source: Alterra et al., 2008]

During the six months of winter precipitation is increasing in both scenarios, while the six summer months show a severe decrease in one scenario and stabilisation of precipitation in the other (fig. 1.2) [Alterra et al. 2008]. These shifts in timing of rainfall cause extra water to be discharged in winter and dry circumstances in summer.

In addition to precipitation changes there are more variables that change. Numbers of days with intense rain showers and tropical days increase, whereas frost days become rarer. The increasing number of days with intense showers may cause trouble in urban areas and agricultural ground, as a sudden large amount of water cannot easily be discharged. The increasing number of tropical days may influence the comfort in urban areas and may even cause heat stress there. Fewer frost days may cause an uprise of plagues in agriculture.

Projections for the relative sea level rise (measured with regard to ground level) in the Netherlands show a maximum of 40 centimetres in 2050, 130 centimetres in 2100 and four metres in 2200 [Deltacommissie, 2008]. An average soil subsidence of five centimetres was discounted in these figures. Due to gas extraction in the province of Groningen by 2050 soil subsidence is expected to be 42 centimetres in places threatened most [NAM, 2004]. No further soil subsidence is expected after 2050. Therefore, the maximum relative sea level rise in the Groningen area will be 77 centimetres (40-5+42) by 2050 and 167 centimetres by the end of the 21st century. This will cause serious problems to the coastal defence, which has proven to be weak at some parts even today.

1.3 Problem

The general problem, which has become apparent for the last decennia, is the lost balance between the pace of depletion of natural resources and the carrying capacity of the earth [WWF, 2008]. One of the main reasons behind the disturbed balance is that mankind strongly believes that people can create the environment according to their own will and that technological solutions 'overrule' the laws of nature.

Besides, the environment increasingly has to deal with turbulent circumstances. A turbulent environment is defined as follows [Emery and Trist, 1965]: *"the dynamic properties arise not simply from the interaction of the component organisations, but also from the ground itself. The 'ground' is in motion."* Translated to a spatial context a turbulent environment may be defined as follows: the development of the region not simply arises from the interaction of the component functions, but also from the natural system itself. Natural resources are in motion. Mankind depletes and pollutes resources in such a way that the natural system is thrown out of balance. For example, the relations between the atmosphere, the water cycle and ecological systems become unpredictable and the dynamics of the earth system change, probably in an uncontrollable way. If the concentration of CO_2 in the atmosphere is not be brought back to a level of 350 ppm within the next 5-12 years the system will be out of control [Hansen, 2008] and uncertain rapid changing circumstances will occur. The urgency for mitigation measures is evident, to commence with phasing out the use of coal, according to Hansen. But even if the CO_2 concentration is brought back to a reasonable level the inertia of the earth's system implies that the effects of global warming will be felt for decades [Hansen, 2008]. This means that as of today up to at least the end of the century society will have to deal with a turbulent environment. Climate changes are there, with as a consequence that mankind needs to adapt to uncertain changes in climate. Spatial planning is a potential powerful tool to do so.

In Groningen, the main climate-induced changes are the altering precipitation figures. The wetter winter, in combination with the rising sea level and the subsidence of the soil, causes problems with the discharge of water into the sea. In addition, even higher dikes are at risk due to a rising sea level, and in summer fresh water needs to be taken in from elsewhere to prevent agricultural grounds and ecological reserves from drying out.

The final question that may be raised is to which extent the planning practice is ready to deal with unforeseen, unpredictable and turbulent circumstances, used as it is to predictable and measurable programmatic input.

2. Development of a planning method

2.1 Existing shortcomings

When current planning practice is analysed a couple of characteristics are relevant:

- The first one is the time horizon of spatial planning. The regional plan for the province of Groningen has a horizon of ten years [Provincie Groningen, 2008]. This causes difficulties because, as stated before, the time-frame of climate change is decades or more (fig. 2.1, page 52).
- The second characteristic of current planning is that a '*from A to Z'* planning process is used in which the problem is seen as a tame problem. In these planning processes the first phase describes the calculated needs, such as the housing program, the need for office space and the required areal of open water, nature etcetera (fig. 2.2, page 52). The second phase consists of putting together a zoning plan in which the programmatic needs are arranged. Climate change cannot be calculated exactly. Space required for adaptation to climate change is changing under influence of new insights and can only be given within certain margins. This makes it difficult to integrate climate change in regular spatial planning [Roggema, 2008a].
- The third characteristic of current spatial planning is that it is thinking in standards (fig. 2.2). If every sector meets its own standards, the planning is OK. Climate change requires an integrated coherent approach, because if one sector is affected by changes it immediately will have impact on the entire natural system and thus on several other sectors as well [Roggema, 2009].

It may be concluded that current planning practice at least has these three shortcomings in dealing with climate change.

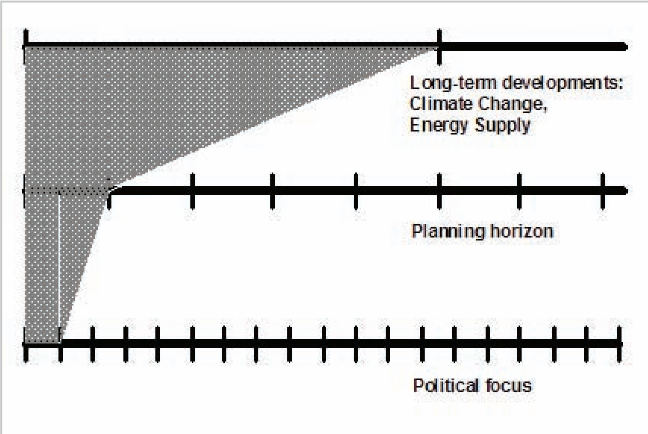
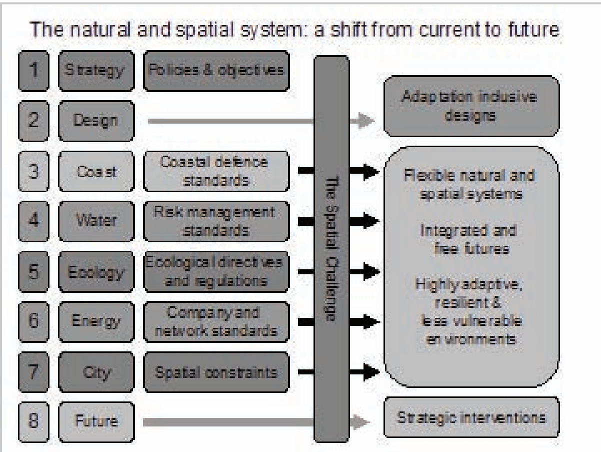


Figure 2.1 Difficulties between time frames of climate change, planning and politics [Roggema, 2008b]



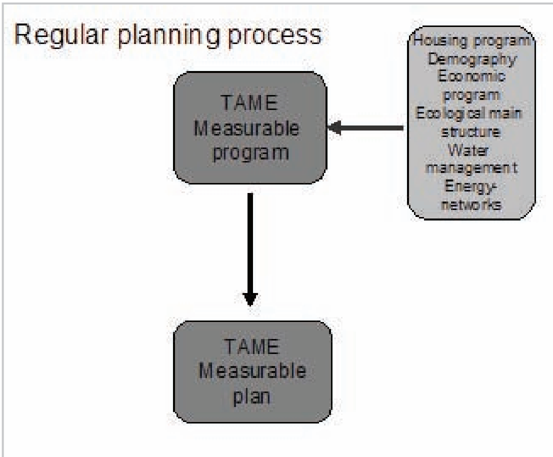


Figure 2.2 Existing shortcomings in spatial planning [Roggema, 2008a and Roggema, 2009]

2.2 Climate proof adjustments

The planning practice requires adjustments in order to provide climate proof spatial developments. The problems associated with the regular, tame, planning processes can be characterised as [Conklin, 2001]:

- Relatively well-defined and stable problem statement;
- Definite stopping point, i.e. we know when the solution is reached;

- Solution can be objectively evaluated as being right or wrong;
- A problem belongs to a class of problems which can be solved in a similar way;
- Solutions, which can be tried and abandoned.

When climate change is considered in a time perspective many uncertainties are experienced. Different aspects of climate change are interrelated, and mutual influences are difficult to define. In several occasions the problem becomes clear when a solution is found. These characteristics correspond with wicked problems, which are characterised as [Rittel and Webber, 1973]:

1. There is no definite formulation of a wicked problem;
2. Wicked problems have no stopping rules;
3. Solutions to wicked problems are not true or false, but better or worse;
4. There is no immediate and ultimate test of a solution to a wicked problem;
5. Every solution to a wicked problem is a “one-shot operation”; because there is no opportunity to learn by trial-and-error, every attempt counts significantly;
6. Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated in the plan;
7. Every wicked problem is essentially unique;
8. Every wicked problem can be considered to be a symptom of another (wicked) problem;
9. The causes of a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem’s resolution;
10. (With wicked problems) the planner has no right to be wrong.

Wicked problems need to be approached in a more integrated and holistic way. For a wicked problem it is impossible to define standards that function in every similar situation. For wicked problems a specific and unique environment is to be created every time, which meets the requirements of the problem at that time. It is essential that the specifications of the location are clear in order to understand the local functioning and potential solutions.

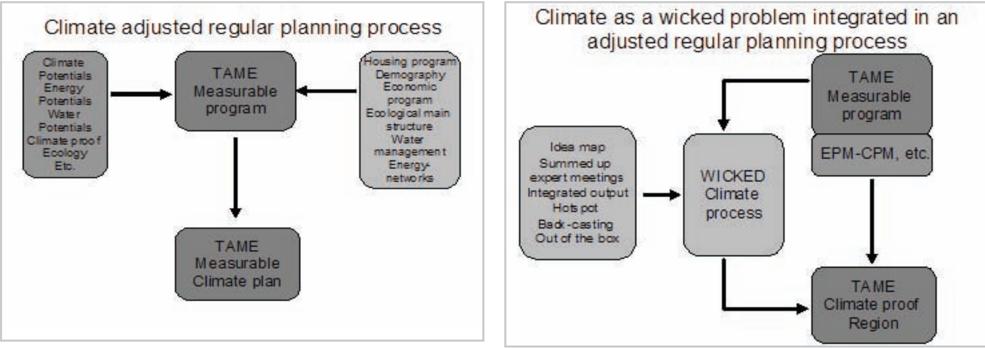


Figure 2.3 Two pathways to integrate wicked problems in regular planning processes [source: Roggema, 2008a]

When climate change is taken into account two pathways can be defined (fig. 2.3) [Roggema. 2008a]:

1. Creation of understanding the local potentials (i.e. climate and energy potentials) and integration of these potentials in the regular planning process;
2. Creation of a ‘wicked bypass’ that functions parallel with the regular planning process, where problems are discussed, new insights enter permanently and where possible solutions are proposed.

The wicked bypass is also useful in tackling the described unbalance in the natural system, caused by a more rapid depletion of natural resources than the carrying capacity of the earth can handle. The wicked bypass offers an environment where insights can be gained as to the natural balance at a certain location, using the backtracking method.

2.3 Backtracking method

There are several ways to gain insight into future developments and to prepare society for these changes: forecasting, backcasting and backtracking (fig. 2.4) [Dam et al. 2005]. The forecasting method predicts trends that have developed over some time already, estimates the consequences of current developments and leads to gradual steps based on the current paradigm. The backcasting method describes a desired (sustainable) future state and translates this back to strategies and measures to be applied,from today on. Finally, the backtracking method defines historical circumstances at the time of a sustainable equilibrium, brings

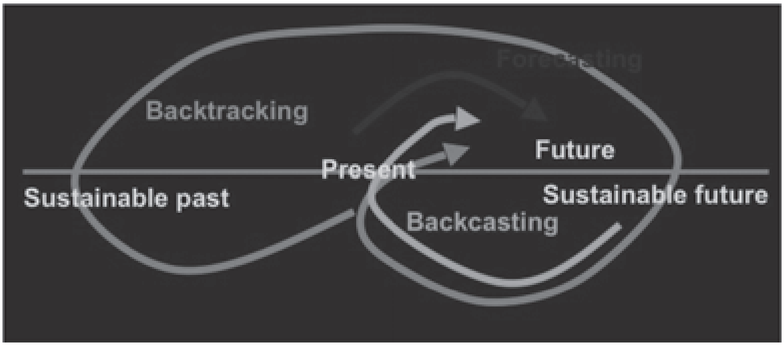


Figure 2.4 Forecasting, Backcasting and Backtracking [Source: Roggema, 2005a]

these valuable historical solutions back to present-day planning, links the present to qualities of the past and defines the strategies and measures to be taken as of today. Originally, the term backtracking is used in computer science. When an optimal solution needs to be found in a large pool of possible solutions backtracking can be a useful method, as not all solutions need to be taken into account. During the process of problem solving choices need to be made. When at some point it turns out that a wrong choice has been made the process needs to return to the point where the choice was made and find another track, which is better capable of solving the problem. It is not necessary to investigate all other tracks (fig. 2.5). In the practice of backtracking it means that every branch is followed to an extent that a solution or a dead end is found [Koljonen & Alander, 2004]. If this backtracking principle is used in a planning process, the right track can be found by looking for a moment back in history of sustainable equilibrium. Starting on that track a sustainable future can be defined, followed by the definition of the steps from present day onwards that are necessary to realise that future (fig. 2.5).

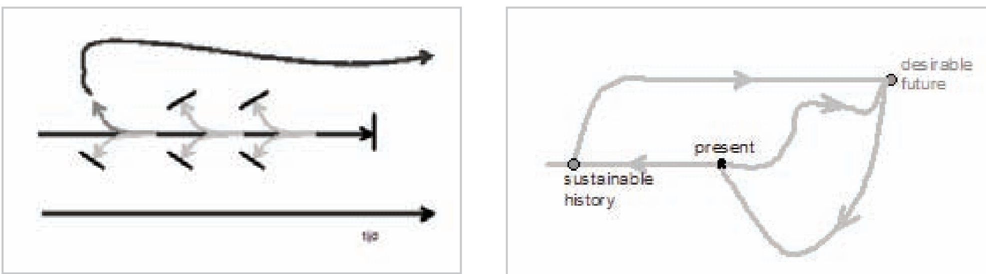


Figure 2.5 Backtracking until the right track is found (left) and the use of backtracking in planning (right)

3 The Groningen case

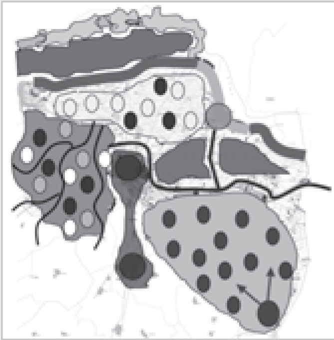
3.1 Backtracking Groningen

When the backtracking method is used in Groningen province the track back to a sustainable equilibrium can be given by figure 1.1. The key elements are: a continuous rise of the land; marine clay on peat and a tidal salt marsh in the coastal zone; little brooks and sponges storing water on the plateau; larger rivers penetrating the coastline; and people living on higher grounds between rivers and brooks.

If these characteristics are combined with accelerated climate change, with a sea level rise of five metres or more by 2300 [Vellinga, 2008], and if these are used in a planning process, the following three spatial models can be developed (fig. 3.1) [Pauw et al. 2008].

Natural heightening behind the dike (fig. 3.1 left) aims to continue the free discharge of surplus water into the sea by creating a lake around the Eemskanaal, of which the water level is raised to make this possible. The consequence is the need of heightening surrounding areas. This heightening is proposed in a natural way, by reintroduction of the sea inlets in well-defined areas. In these areas agriculture has to move temporarily. Therefore, the areas are inundated subsequently. After heightening the first area agriculture can re-occupy this fertile land and inundation is displaced to the next area.

Something above Groningen (fig. 3.1 middle) proposes to meet the fast rising sea level with several offensive defence lines. The existing islands form a connected line of new dunes and behind this defence a sweet water reservoir for storage emerges. The existing dike is broadened and transformed into an unbreakable multifunctional dike zone. Behind this dike zone compartments are created for different functions: storage basins, the energy-colony, or the renewed granary of Groningen. In times of high sea levels every compartment is well protected against heavy storms by defensive walls and surrounding dikes.



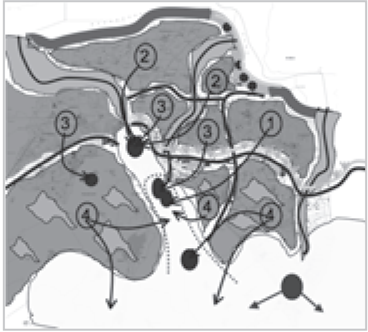


Figure 3.1 Backtracking the future of Groningen. Left: Natural heightening behind the dike; Middle: Something above Groningen and Right: The drowned land of Groningen [Source: Pauw et al., 2008

Drowned land of Groningen (fig. 3.1 right) states that a sea level rise of five metres urges the population of Groningen to withdraw in several stages. In the first, second and third stage the northern compartments are made subject to the dynamics of the sea. This implies the formation of islands by several higher rudiments of dikes and harbours. The strong dike of the current A7 motorway will be a barrier for a long period. When this barrier breaks the ultimate situation is reached. People live on existing higher grounds (above the present-day height of 5 metres above sea level) and on higher grounds in the newly formed sea. In front of the 'new coastline' a Wadden-like wetland environment emerges, with sandbanks and islands.

In these three scenarios several key elements from the historic sustainable equilibrium were used as inspiration and can be found in transformed form in the sketches:

- Dynamics of the sea and land forming, natural heightening (I and III)
- Living at higher places or in protected compartments (I, II and III)
- Creation of a water reservoir in order to keep water available (functions like a resilient sponge) (I and II)
- Sea and larger rivers penetrating the land (I and III)
- Natural vegetation as tidal marsh will develop (III)

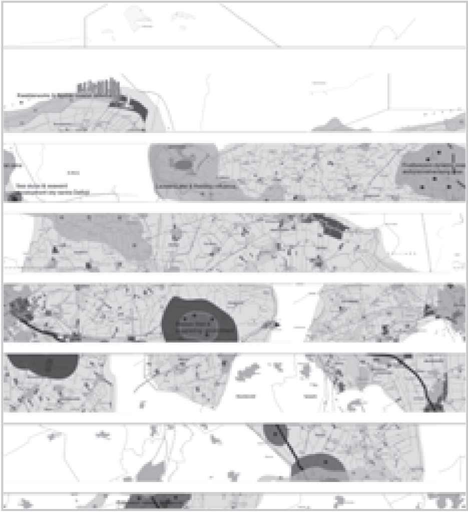


Figure 3.2 Strategic interventions in the regional spatial system Groningen [Source: Roggema, 2008a]

3.2 Strategic Interventions

From a perspective of planning strategy the results from the backtracking method cannot be implemented as a whole right away, since there is a strong demand for measurable solutions and since people tend to perceive these solutions as ‘impossibility’ or ‘imagination’. Nevertheless, it is important to take the first steps, which eventually will lead to futures described by the models. It is unimaginable that from one day to another the entire landscape will be transformed. A different approach is necessary to start realising and adjusting the ideas step-by-step. In order to start up spatial processes in the area, strategic interventions (fig. 3.2) must be implemented [Roggema, 2008a].

These interventions are projected at strategic points in the regional system, i.e. where they may have the largest impact in changing the region in the desired future direction. Regarding the adaptation to climate change these interventions should prepare the population for future changes, increase the resilience and decrease vulnerability of functions and people. An example of such an intervention is the heightening of the Lauwersmeer dike in order to create a large fresh water basin. This spatial intervention will not only accomplish the goals mentioned, but in the mean time change the entire landscape upstream.

Figure 4.1 Eemsdelta region as a dynamic coastal zone [Source: Roggema et al. 2006]

The way by which these strategic interventions intervene and emerge can be compared with a swarm of birds, changing its shape under influence of an impulse but remaining the same group of birds. The same thing happens spatially after an intervention: the landscape alters but remains the same area. Therefore, this way of planning is called 'swarm planning' [Roggema, 2005b].

4 Eemsdelta case

4.1 Strategic intervention

In the Eemsdelta region the strategic intervention consists of allowing sea water to overflow the dike (fig. 4.1). This results (in times of heavy storm surges) in temporary inundation of the hinterland by salt water. In future times, when the sea level will have risen, this inundation will happen more frequently. This strategic intervention has impact in two ways:

1. In a spatial sense it creates an attractive environment behind the dike. High ecological qualities will develop here, living amidst the dynamic water is possible; one can experience the seasons and the weather. This offers an opportunity to create new typologies of housing, which is a welcome option in this area where the population is shrinking.

2. Psychologically, the people behind the dike are getting used to circumstances of the future at a very slow pace. First, they experience water in their surroundings once a year; by 2050 this will happen every month and by the end of the century weekly. During this period people start to adapt to these new circumstances. Farmers shift to new cultivation; inhabitants transform their houses so they become waterproof. It makes society highly resilient and less vulnerable. When water enters the surroundings once again, they will already have adjusted to it. Compared to a heightened dike, which seems strong but proves vulnerable in case of a breech, this solution is more resilient.

4.2 Process

In order to define, design and implement such a strategic intervention, an *A to Z (tame) process* is dysfunctional. A wicked bypass needs to be designed, a process architecture that enables thinking outside existing procedures and including intensified involvement at the same time. Only if wicked thinking is rewarded with joint efforts and commitment to the project, long-term and unforeseeable developments of climate change can be successfully dealt with. Therefore, a joint problem definition by the key decision makers of all parties involved, as well as several Eems Delta summits and a multiple-day ‘charette’ with the participation of all key stakeholders, are part of the proposed process for a climate proof area development of Eems Delta (fig. 4.2) [Boulevard Management & Advies, 2008]. These strategic steps and moments in the planning process shape the required wicked environment.

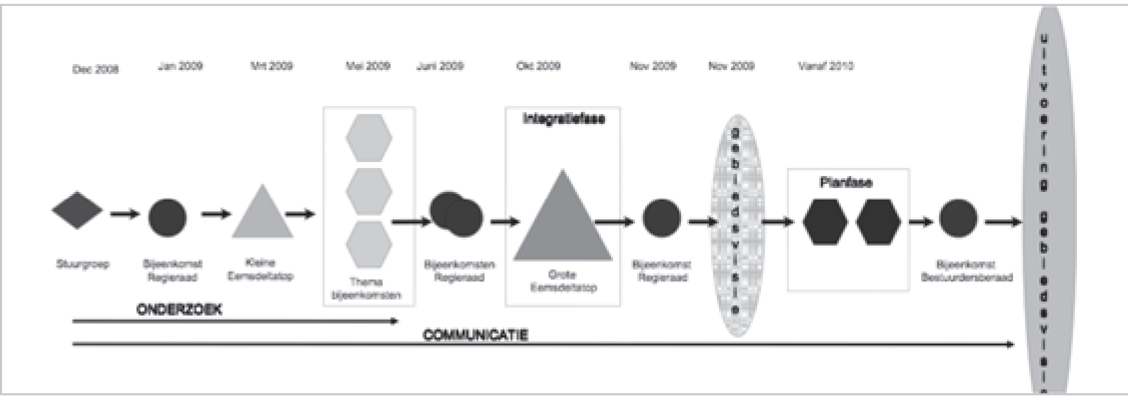


Figure 4.2 Climate proof area development in Eems Delta [Source: Boulevard Management & Advies, 2008]

5. Discussion

Adaptation to climate change is necessary and can be applied at a regional scale. However, several conditions need to be fulfilled.

- The planning process needs adjustments. Space needs to be created for off-track routes of thinking via a wicked bypass. Commitment from principals of organisations involved needs to be arranged through immediate and open participation. The adjustment of the regular planning process is not easy. A wicked bypass approach has no proven results yet and large groups of people are used to the existing way of planning.
- The backtracking method is very useful, but due to the long-term perspective results are often wide in range. This requires a very careful approach in presenting results and explanation of the concrete effects of these results for individuals today: prepare the audience!
- Swarm planning is a powerful tool, but from decision makers it requires the release of their need for control afterwards and confidence in the self-organising capacity of the population. This especially is hard for politicians.
- The implementation of strategic interventions needs to be done very carefully, because the spatial effects may be surprising over time. A secure definition of the boundaries of the area in which the effects of the intervention may be felt as well as the best possible insight in expected effects is necessary.

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Urban Water Tissue:
Analysing the Urban Water Harvest Potential

Claudia Agudelo, MSc[10], Adriaan Mels, PhD[11], Ronald Rovers, MSc[12]

1. Introduction

Over centuries, cities have been seen merely as avid consumers and waste producers, while ignoring their resource potential. Currently, cities are highly dependent, and have a low resilience. This situation can be improved by better resource management. Accelerating urbanisation, increasing scarcity of resources and climate change force us to re-think and redesign urban systems towards closing of cycles, minimisation of impacts and strategic management of resources. Rapid urbanisation can also be an opportunity to foster changes in existing systems and improve resources management. As stated by Leduc et al. (2008), "the new urban regions – the expanded cities with their suburbs - offer ample possibilities for changing the future of cities".

Nowadays, urban planners face the enormous challenge of meeting citizens' needs while protecting and assuring natural resources. Population growth and higher living standards will cause ever increasing demands for good-quality municipal and industrial water, and increasing sewage flows within a limited area (Jiménez et al., 2008). At the same time, more irrigation water will be needed to meet greater demands for food for a growing population. Also, more and more water is required for the protection and restoration of aquatic ecosystems, for recreation and landscaping functions. The problem with regard to the requirement for water by terrestrial ecosystems (including humans) is not only related to its availability, but more in particular to its quality, notably its chemical and bacteriological composition (Worp, 2002 in Bruggen et al., 2005).

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On local levels, and especially in urban areas, water scarcity can be a big concern. At a global level, water availability for 2006 was 8,462 m^3/capita.yr but at a regional level it may be as low as 1,380 m^3/capita.yr in the Middle East and North Africa. Even in regions with good water availability problems may occur. For instance, in Europe, with a water availability of 10,680 m^3/capita.yr, 11 of 38 countries are under water stress conditions. This represents both a risk and an opportunity to improve water resources management (Jiménez et al., 2008).

Using the concept of urban metabolism, and the metaphor of the city as an organism, the Urban Harvest approach has been developed as a strategy to investigate all possible options for harvesting local resources and (re)using emissions and wastes within the urban area. Thus, its focus is on the potential sources within the urban system itself. Urban Harvest is seen as a positive contribution to the needs of cities, complementary to reducing negative impacts of consumption, and limiting inflow (Rovers, 2007). The approach takes the potential of primary and secondary resources into account and values both the quality as well as the quantity of these resources. The main objective of Urban Harvest is to valorise all flows that come in and out of the city system. Within Urban Harvest there are no wastes but only resources in different qualities. Each flow of resources has a remaining quality credit after a certain activity or process. The flow can subsequently be used to fulfil the demand and quality requirements of another activity. As such, Urban Harvest addresses the capture of any renewable primary resource and any secondary resource within an urban system and aims for the (re)use within that same urban environment system (Rovers, 2007).

Urban metabolism studies have shown that, in terms of sheer mass, water is the largest and the most vital component (Kennedy et al., 2007). This chapter addresses the Urban Harvest approach to analyse urban water flows and determine the average urban water tissue. Similarly, an urban average tissue was developed for energy by Leduc et al. (2008).

Comparing water usage versus water consumption at domestic level, only 6% of potable water is consumed (drinking and cooking) and 94% of the volume is used for other purposes, mainly for personal hygiene and cleaning, which do not require that quality. During these processes water is not lost from the household, but its quality is deteriorating. As an output, water of a lower quality is produced and discharged. A general scheme of the existing situation is shown in figure 1, in which different activities within the built environment require different water qualities. A ”quality surplus” is evident, as well as efficiency losses due to the

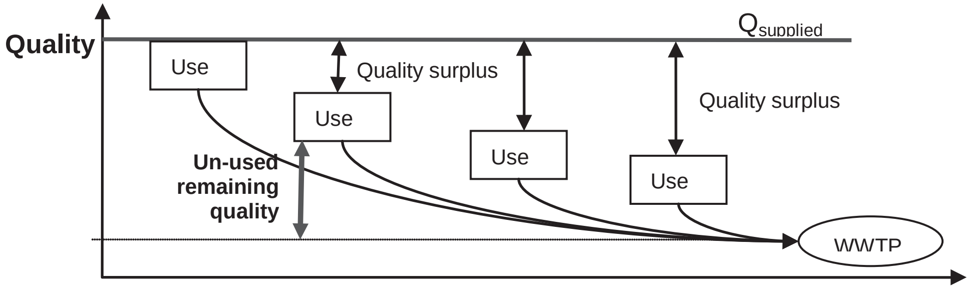

Figure 1 Schematic presentation of various household water uses that require different water qualities.

unused quality of the flow that is discharged into the wastewater treatment plant (WWTP). In this chapter we will address whether there are better ways of meeting the various qualities and consequently reducing our water needs.

The quantitative assessment of water quality and its relationships with management activities is a necessary step in efficient water resources management. The term water quality is commonly used relating to the necessities of ‘sustainable’ and ’optimal’ management of water resources (Parparov et al., 2006). However, “the quantitative assessment of water quality is a challenging scientific problem and its solution forms an important stage in the development of scientific background of water resources management” (Ryding et al.,1989; Chapman, 1992; Hakanson et al., 1995; Parparov, 1996; Boon et al., 1997; Hakanson et al., 2000; WFD, 2000 in Parparov et al., 2006).

Most of the current improvements in the field of integrated water resources management are aimed at end-of-pipe technologies for wastewater treatment to fulfil discharge requirements. Existing integrated water resources management strategies include best available technologies for (waste)water treatment, for limiting demand, etc. They are, however, not feasible in every situation and they tend to overlook new paradigms. There are many unexplored potentials within urban areas to (re)cover water resources demand, and a single criterion - effluent quality – is not enough to evaluate the sustainability of a wastewater treatment system. Future developments must also consider all other resources, including capital, energy and nutrients (Wilsenach et al., 2003). “However, the task of optimal water resource management requires predefined standards of water quality as integral components of the optimisation criteria” (Kalceva et al., 1982; Straskraba et al., 1985 in Parparov et al., 2006). Parparov et al. (2006), state that “water quality should be expressed in measurable form to allow analytical expression of relationships between water quality and various driving factors that can affect water quality (e.g., external nutrient loading, intensity of water supply)”. However, an appropriate definition of the resources quality should be linked to the function fulfilled by the resources . For this reason it is important to couple demand needs with supply characteristics.

2. Water harvesting strategies

As expressed by Han et al. (2008), ‘multi-sourcing’ is the key to guarantee a stable offer for the existing demand. Asano (2002), states that “for more than a quarter of a century, a recurring thesis in environmental and water resources engineering has been that it is feasible to treat wastewater to a high enough quality that it is a resource that could be put to beneficial use rather than wasted”. Water reclamation and water reuse provide opportunities to augment traditional water supplies (Asano, 2002).

Within the urban harvest strategy, when wastes are seen as resources, the urban system has to be modified in a certain way that uses resources optimally. The aim is to achieve a customised fit for purpose supply. According to the general principles of the Urban Harvest strategy the development of the urban water tissue is a focus on mainly four aspects, which are shown in figure 2:

- Multi-sourcing
- Cascading
- Quality upgrading and recycling
- Quality upgrading and closing loops

Multi-sourcing refers to the use of different water sources to obtain water with different qualities that could match the demand directly. And it promotes the use of unused resources within the urban system. Multi-sourcing has already been applied by some cities yet not always successfully. For instance, in some cases the option of using ground water ended up in an over-exploitation of reserves causing additional problems, such as subsidence, lowering of the water table, etc.

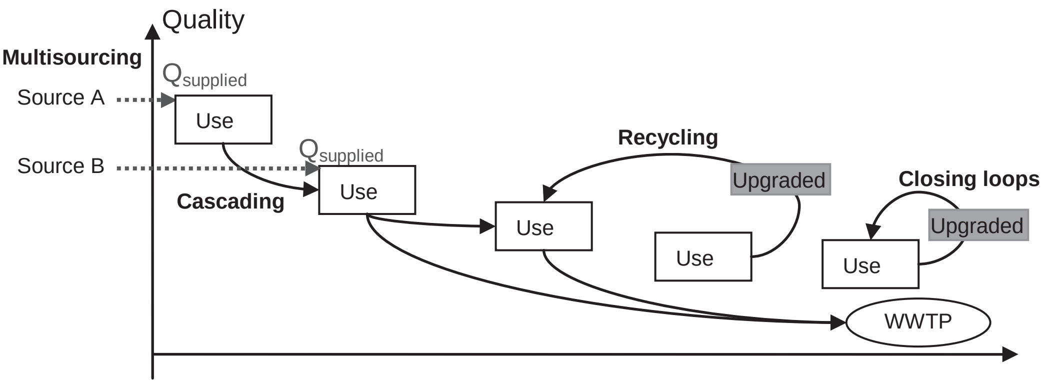

Figure 2 Strategies to harvest water within the urban tissue based on cascading and water quality upgrading.

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When approaching multi-sourcing, it should be in a broader sense, making visible hidden flows and secondary resources coming from cascading or recycling activities. There are several flows within the city, such as grey water or rain water, that are collected and not seen as desirable flows. In reality they are hidden resources that can fulfil an urban water demand. In this way not only body waters or reservoirs are water sources, but one industry can be the water source for another.

Water cascading or re-use implies losses of quality in each step: a percentage of quality is consumed during each activity, although a quality level is remaining and the same flow can be reused for an activity that requires a lower quality, for instance, toilets, or car washing. Cascading is a consecutive use of the remaining quality of the flow. With this principle, the same flow can have many purposes. And the ‘wastewater’ of one activity becomes the inflow for a different activity. With this approach, as described by Sirkin et al. (1994), the highest-quality resources are reserved for the most demanding tasks first, at the beginning of the resource cascade. The less demanding the task, the lower down in the chain it will be placed.

Nowadays, water quality can be upgraded, to certain levels by different technologies; the same flow can be reused by activities that require the same or higher-quality requirements. “In principle, wastewater or any marginal quality waters can be used for any purpose as long as adequate treatment is provided to meet the water quality requirements for the intended use” (Asano, 2002). This process is called recycling and it implies a treatment in order to enter again in the cycle. An example is grey water reclamation.

Water loops refer to closed cycles in which no water inputs or outputs are present. The flow is used, treated and reused on site. This can be established when industries re-circulate their water using on-site technology, and it can be seen as the optimal on-site recycling process.

3. Methodology

3.1 Functional unit and definitions

Urban tissue (UT)

"In general a built environment is regarded as a city with its urban administrative boundaries, but can be adapted to a pre-defined tissue, a neighbourhood, a surface area, or else" (Rovers, 2007). Within the Urban Harvest approach the functional unit is the urban tissue (UT). Leduc et al. (2008) defined the urban tissue as "a conceptual approach towards visualising resource demand and resources supply potential of an urban area, in an easy-to-grasp visualisation". The urban tissue is a standard unit that allows identification of the different flows within the urban region, such as energy, water, food, etc. UT simplifies the complexity of the urban flows, seeing the city as a system. The Urban Average Tissue (UrbAT) is a way to express the typologies of the built environment. It can be used as a general benchmark to compare the urban harvest potentials with other cities with different typologies (Rovers, 2007).

Harvesting potentials

When determining the harvesting potentials in a given urban tissue, according to Rovers (2008) three different concepts are analysed and quantified: Potential Urban Harvest, Maximum Technical Available Harvest and the Urban Maximum Technical Harvest.

Potential Urban Harvest is the maximum amount of a source that is or can be made available, collected or captured, within the boundaries of the urban tissue.

The Maximum Technical Available Harvest, also called "Max Tech Harvest", is the maximum amount of ready-to-use product output from the (re)sources potentials, via the best available technology for capturing and converting.

Urban Maximum Technical Harvest, also called urban Max Tech Harvest, is the Max Tech Harvest made available for actual re-use including the limitations given by urban typology. Even though there is a maximum potential available, two factors can affect the real harvest: technological efficiency and urban typology. Existing technologies cannot always achieve 100% capture, and not all systems can be adapted to existing urban areas. Then, the Urban Maximum Technical Harvest can be calculated as described in (1), where $Ø_{tech}$ and $Ø_{urban}$ are reduction factors related to technical efficiency restrictions and urban typology restrictions, respectively.

$$\text{Urban Max Tech Harvest} = \text{Potential Urban Harvest} \times \phi_{tech} \times \phi_{urban} \qquad (1)$$

This chapter focuses on the calculation of Potential Urban harvest for water in the Netherlands and an estimation of Urban Max Tech Harvest. We assumed no restrictions due to technological factors, $Ø_{tech} = 1$. As mentioned in the introduction, several technologies are available to upgrade water quality to a certain desired level.

3.2 Average urban water tissue (Water-UrbAT)

In search of an accounting and planning methodology specifically for urban water metabolism, the urban water tissue was developed. Water-UrbAT measures the maximum potential for harvesting water within a given urban system. The Average Urban Water Tissue matches the available resources with the existing demand, in terms of quantity and quality requirements. Water-UrbAT systematically investigates the potentials for multi-sourcing, re-using and cascading water within the system and aims for a more efficient use of water resources. The Dutch urban water tissue (Water-UrbAT-NL) builds upon the Dutch Urban Average Tissue (UrbAT-NL) of Rovers (2007) and Leduc et al. (2008). This approach relates urban typologies to water harvesting potentials, thus aiming to foster a re-thinking of our current urban water systems. The approach can be used by urban planners and decision makers to understand the urban system and the internal flows within the same system and provide smart, customised solutions for existing and new urban areas. It also facilitates benchmarking processes because of the standard functional unit. Costs are not calculated; the methodology is resources driven.

3.3 Urban water tissue development

To apply the Urban Harvest approach for the water flows within the urban tissue the following steps are required:

1. Demand inventory: Hierarchical identification and quantification of water use activities based on water quality requirements and volumes within the urban tissue.

2. Supply inventory: Hierarchical identification and quantification of available water sources based on quality and volumes. Identification of hidden flows and possible new water sources. And calculation of the Potential Urban Harvest and Max Tech Harvest.

3. Couple Supply – Demand: Try to ensure that the quality of the water is as high as required for the use but not higher by using the principles of multi-sourcing and cascading.

4. Optimise Supply – Demand Apply quality upgrading and recycling principles by including treatment steps. Calculation of the Urban Max Tech Harvest by scenarios development.

4. Results

Urban areas are complex systems, where different activities and functions are mixed. To define an average urban area the concept of the urban tissue for mapping the water harvesting potential has been used. The average urban tissue has been defined for the Netherlands by Leduc et al. (2008). First, the total urban surface of The Netherlands was determined; then the different functions that are part of the urban area were identified with their area. Consequently, the researchers recalculated all function surfaces to m² per hectare (a hectare is the functional unit used in this approach). Then, the researchers created a visualisation that shows all the urban functions, fitting onto an average Dutch hectare. "The 'Dutch Urban Average Tissue'[13] (UrbAT-NL) provides insight in the distribution of functions in an urban area, percentage-wise and building-wise" (Rovers, 2007). Figure 3 shows this Dutch Urban Average Tissue.

[13] The total Dutch surface is 4,150,000 ha; the Dutch urban surface is 507,020 ha, or 12 % and the other 88% corresponds to rural surface (Leduc et al., 2008).

Urban function	Area(m²)
Residential	4,415
Social/cultural	305
Shopping & hospitality industry	129
Public services	240
Sport facilities	635
Industrial/business	1,400
Recreational	735
Urban food gardens	79
Semi-built up area	647
Roads	1,415

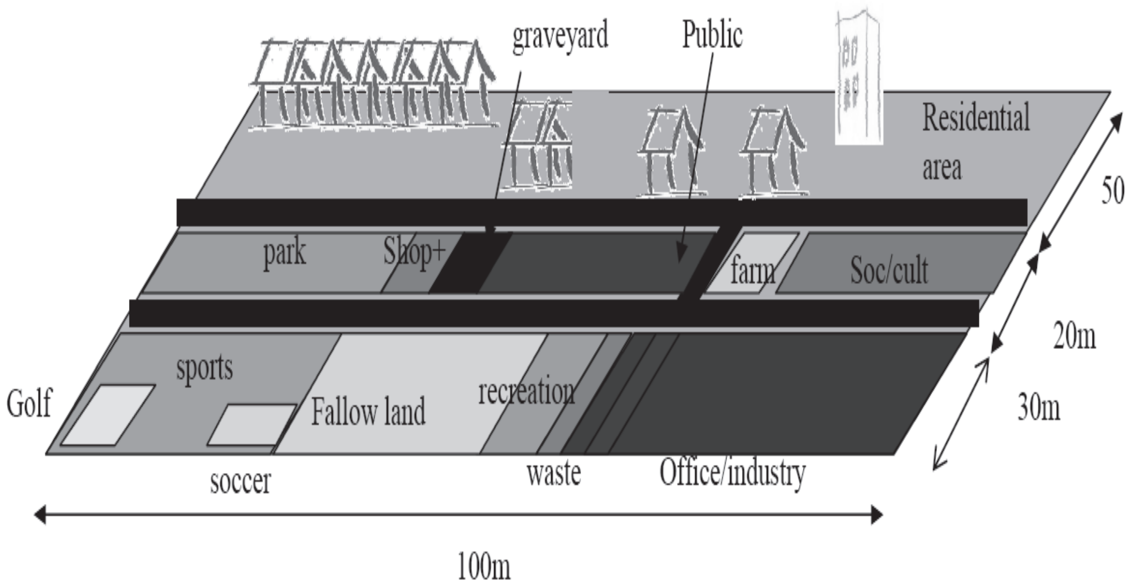

Figure 3 Dutch average urban tissue (Rovers, 2007; Leduc et al., 2008)

4.1 Demand inventory

For the demand inventory, domestic and industrial consumption were discriminated. The domestic demand was calculated based on the Dutch urban average tissue occupancy, 13.5 persons per hectare, and the domestic water use per person in the Netherlands. For the water industry consumption, the total water consumption was divided by the number of urban hectares in the Netherlands, 507,020 ha. Table 1 shows the water demand inventory for the UrbAT-NL

Table 1 Water demand inventory for the UrbAT-NL. Source: cbs. 2001

Quality	**Demand at HOUSEHOLD level**	**m3/ha -year**	**Quality**	**Demand at INDUSTRY level**	**m3/ha -year**
	Food preparation	8.3	**Q1**	Total tap	785.0
	Coffee & Tea	5.9	**Q2**	Total fresh groundwater Production A	555.4
	Drinking water	2.9	**Q3**	Total fresh surface water Production B	16956.6
	Bathroom sink	26.1	**Q4**	Total salt or brackish roundwater Production C	14562.1
	Bath	12.3	**Q5**	Total water from other companies Production D	456.9
	Shower	245.3			
	Washing hands	18.7			
	Dishwasher	14.7			
	Other kitchen	26.1			
Q1	**Drinking water, kitchen use, personal hygiene**	**361**			
	Washing machine	76.3			
	Washing by hand	8.3			
Q2	**Washing clothes**	**85**			
Q3	**Toilet flush**	**183**			

Table 2 Supply inventory for the UrbAT-NL

Quality	Sources	Current harvest[14] m³/ha - y	Potential harvest[15] m³/ha - y
Q_1	Tap water*	1413	
Q_2	Rain water		3810
Q_3	Direct ground water	555	
Q_4	Surface water	16957	
Q_5	Salt-brackish water	14562	
Q_6	Household grey water		408
Q_7	Industrial wastewater		32859

4.2 Supply inventory

The supply inventory (see table 2) was based on figures of extraction of water resources in the Netherlands. For the potential rain water harvest the roof area available within the UrbAT-NL was taken into account and the grey water production suitable for cascading was calculated.

4.3 Couple supply - demand

When the sources and demand have been identified, the shortcoming of the existing resources management becomes evident. Analysing figure 4, in the case of households there are quality losses due to different factors. Firstly, the quality surplus of the influent that drops drastically after the use and unused remaining quality. Two measures can be taken. First: multi-sourcing and using a source with a lower quality to fulfil some of the demand. And second: cascading or recycling grey water outputs. In the case of industry multi-sources that supply water for different processes are already present. Nevertheless, remaining quality of the effluent is lost when is diluted in the sewer and transported to the wastewater treatment plant.

[14] Source cbs, data correspond to the year 2001.

[15] Feasibility of these implementations depends on the exact urban typology.

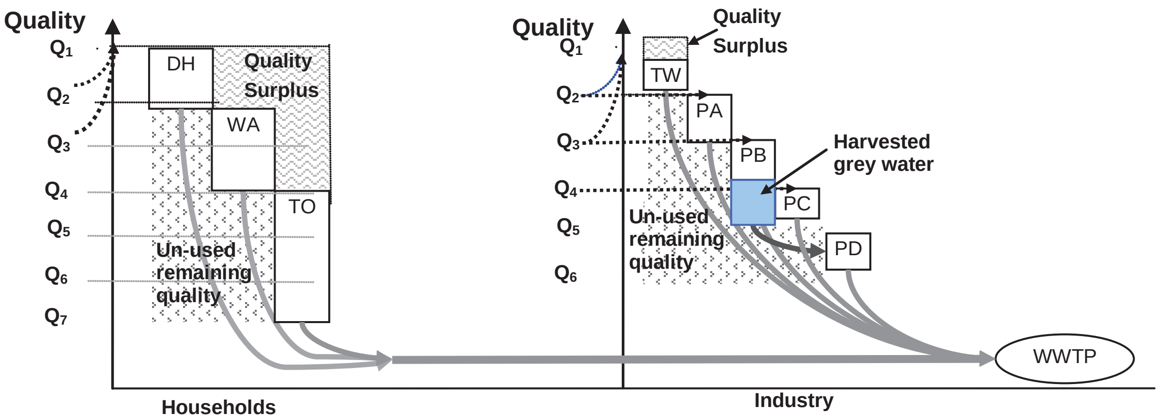

Figure 4 Visualization of existing demand – supply water qualities in households and industry for the Netherlands

Taking into account only the first two steps of multi-sourcing and cascading we can analyse the potential for water resources management, without extra treatment. This will be the more straightforward scenario, because when including recycling a broad range of possibilities are feasible and other criteria, such as energy consumption and use of chemicals, should also be included in the selection of the most appropriate treatment. For the purpose of this chapter, an industry water-cascading percentage of ten was assumed for the calculations. In order to precisely quantify the potential of re-use more detailed cases should be studied

Table 3 Potential water supply-demand for the UrbAT-NL – Only addressing multi-source and cascading

Sources	**Primary resources (m³/ha year)**				**Secondary resources (m³/ha year)**		
	Tap water	**Rain water**	**Direct ground water**	**Surface water**	**Salt-brackish water**	**Household grey water**	**Industrial waste water**
Current	1413	0.0	555	16957	14562	0.0	457
Potential Max		7800				408	32859
Max Tech Harvest	1413	3810	555	16957	14562	408	32859
Urban Max Tech Harvest	361	1425	0.0	16901	12647	408	3467
Savings	**74%**		**100%**	**0.3%**	**13%**		

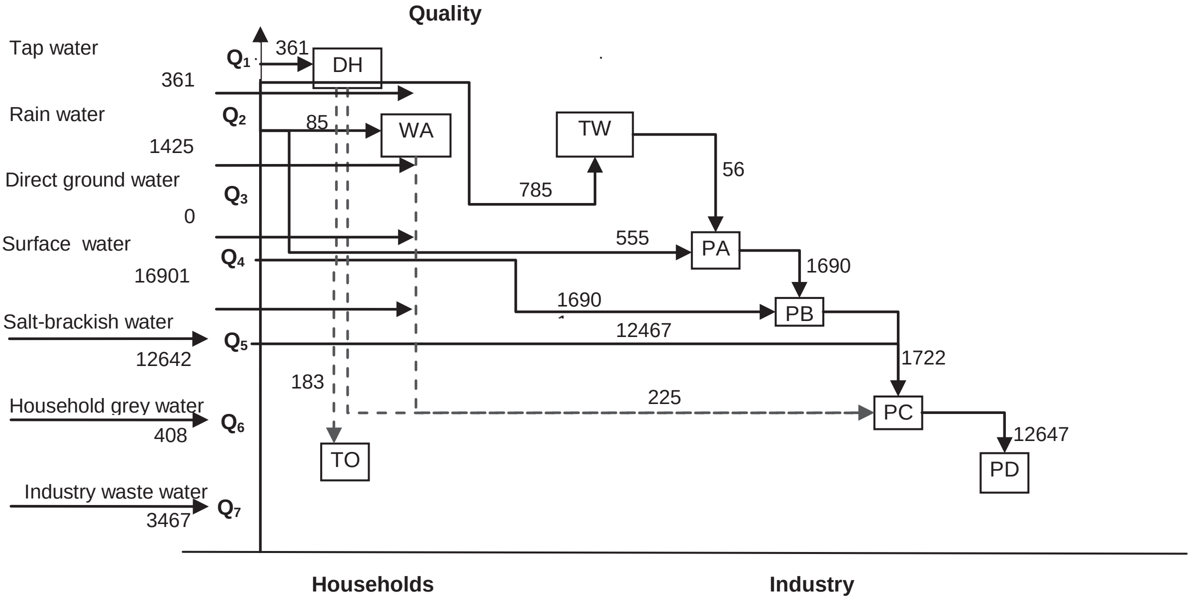

Figure 5 Visualisation of the urban max tech for the Dutch urban average tissue (UrbAT:NL)

Analysing the scenario addressing only cascading, the results show that 11.8 % of the water demand can be fulfilled by rainwater collected only from residential roofs. Tap water consumption can be minimised down to 74%. And wastewater can be reduced by 8%. The scenario can be seen in figure 5.

By studying the urban tissue, it is possible to calculate the potential resources that can be captured and transformed into new sources to remain into the urban area. For a more specific case, city or district level, the urban tissue will display the spatial distribution of flows, hierarchy of activities and uses to improve water management and also providing guidelines for urban planning.

5. Discussion

In this paper we have presented an approach towards a more efficient urban water system by implementing cascading, re-use and recycling. The analysis shows that water self-sufficiency is feasible for the studied case. We have not addressed the technical systems (dual pipes networks, rain water harvesting and storage systems) that should be implemented to realise the efficiency gains. As a final step within the developed approach further studies will have to be conducted to address these issues further and judge the technical and operational feasibility.

The approach also shows that, in theory, all wastewater within the city can be collected and treated and thus upgraded to a high quality level that is fit for each purpose of use. This will require space to build wastewater facilities, energy inputs to treat the flow(s) and chemicals input. The feasibility for wastewater treatment facilities will be based on local conditions. For this, more specific cases should be analysed. Further research will focus on application of the developed approach in specific areas, in order to validate its applicability.

The approach presented in this paper has focused on water flows. Within the urban water system there is also urban harvest possible. One of the important functions of water is its function as a carrier. As such it has various other potentially interesting components (harvest) attached to it as shown in table 4 below. Heat contained in urban wastewater flows can be harvested, e.g. by water pinching or heat exchange. Nutrients and organic matter can be harvested as well. In the next steps of our research approach towards urban harvest, the different urban flows will be combined and multiple criteria will be used for harvesting urban resources. This will involve application of presently available technologies as well as completely new concepts in urban water and solid waste management (Wilsenach et al., 2003). The way by which other resources within the system are valued will indicate the feasibility of the options. For instance, upgrading of resources need energy and material inputs. Whether these resources are available or scarce will be determined by the local setting characteristics. Moreover, water reused or recycled within the urban tissue minimises costs regarding water extraction and transportation. Moreover, if qualities are better matched, savings in water treatment will be achieved.

Table 4 Different flows that can be harvested from urban water flows

Urban flows	*Water*	*Heat*	*Nutrients*	*Organic matter*
Rain water	●			
Urban Wastewater (mixed)	●	●	●	●
Urban Wastewater (separated)				
Grey water	●	●		
Black water			●	●
Urine			●	

Cities are complex entities, and multiple flows are present to maintain all of their functions. When optimising water flows it is necessary to study the interrelation with other flows. For instance, implementation of more solar panels cause a reduction in the volume of water used for electricity generation. More efficient systems of cooling use less water; dry toilets for faecal matter used for urban farming as well diminish water consumption. A further step is to analyse how to address the relation among the different flows within the urban tissue. For this purpose the same functional unit and principles will be used, also to address competition regarding the spatial claims by the different flows. Further research will focus on the relation among the different flows and the relation between urban tissue and rural tissue.

6. Recommendations for further development of the approach

Further research should be conducted to develop rules regarding recycling feasibility according tissue characteristics. As well, a collection of case-specific tissues is recommended in order to validate the methodology and to identify the main characteristics that influence the urban water cycle, and how urban water management can be related to urban typologies. Also linkages with other flows will be developed to identify and visualise the complete metabolism of the tissue. In adition, further research should address development of guidelines to implement technologies and their implications in the built environment.

Acknowledgements

This research has been carried out within the framework of the European project SWITCH - Sustainable Water management Improving Tomorrow's Cities' Health-, supported by the European Commission through the 6th Framework Programme.

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Urban Surface Water Application for Climate-Robust Cooling of Buildings with Aquifer Energy Storage

Kees Wisse, PhD MSc[16]

1. Introduction

1.1 Urban surface water as an energy collector

There is increasing attention for sustainable cooling and heating systems for the built environment. An higher comfort level, zero-carbon and energy-neutral buildings are challenging engineers and architects to develop new concepts for buildings and installations. HVAC consultants and building services engineers often evaluate heating and cooling systems from the viewpoint of a stand-alone building. However, the entire urban environment contains many energy sources. One of them is urban surface water, another example is asphaltous pavements. In this chapter we consider urban surface water. During summer, it can be used as a large scale solar collector, while during winter it can act as a collector of energy for cooling.

1.2 Integrated concepts with aquifer energy storage

The temperature cycle over the year of urban surface water is such that seasonal heat storage is required. In the Dutch climate, most of the buildings ask energy for cooling during summer. The energy demand for (space) heating occurs during the period of October until May, depending on the thermal insulation of the building and the internal heat gains. For residential areas, heat is also required for tap water heating during the entire annual period. Applying urban surface water, seasonal heat storage is necessary to tune the energy supply and demand. Seasonal heat storage is possible using aquifer systems as well as underground heat exchangers. This chapter concerns the use of urban surface water together with an aquifer

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system. In ATES (Aquifer Thermal Energy Storage) systems groundwater is used to carry the thermal energy into and out of an aquifer. During summer operation, water from the cold well can be used for cooling applications. At the same time, the return flow of the building system provides energy for heating which is stored in the hot well (Fig. 1). Using urban surface water, additional heat can be stored in the hot well (Fig. 2). During winter operation the hot well can provide heat at a low temperature level as a source for a heat pump. At the same time, the heat pump provides cold water for the cold well. The energy for cooling, which can be captured from urban surface water during winter, is also stored in the cold well.

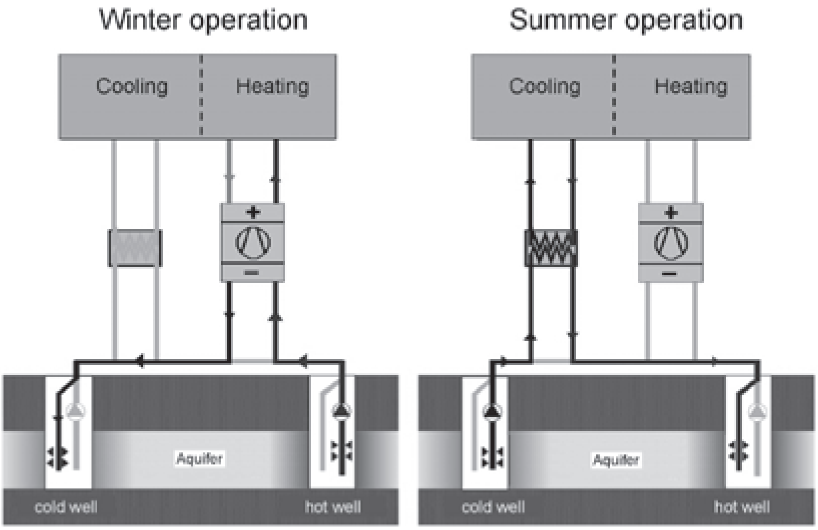


Figure 1 Energy flows due to heating and cooling by a heat pump and aquifer.

Currently, it is common that the concepts of Figure 1 and Figure 2 are operating as parallel systems. In that case, urban surface water is used to restore the energy balance in the aquifer. Working towards passive and zero-energy architecture, the challenge is to develop building concepts without heat pumps and just using the energy potential of urban surface water. However, the heating temperature of buildings is higher than the temperatures that can be obtained from urban surface water. Therefore additional heating will be required if no heat pump is applied. Using industrial residual heat, biomass or geothermal energy, it is possible to develop sustainable concepts without heat pumps. In an aquifer concept without heat pump, 100% of the cooling energy can be provided by the urban surface water.

The focus of this paper is energy capture for cooling of office buildings. For case studies of the energy capture potential for heating of a residential area, we refer to Graaf (2007) and Aparicio Medrano (2008). We present data for the required water surface for cooling of buildings with and without heat pumps. Additional to a specific example, we provide more generic design charts which can be used for manual calculation, as well as rules of thumb that serve architects and urban planners. The results are valid for shallow surface water (ponds).

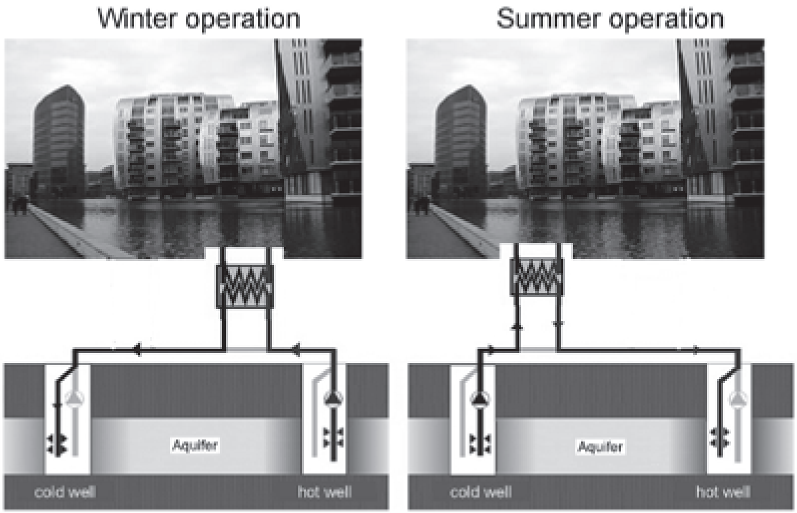


Figure 2 Energy capture using urban surface water and an aquifer

1.3 A changing climate

The energy capture potential of urban surface water is strongly influenced by the outdoor climate. A changing climate with higher temperatures during summer and winter will require an greater water surface. On the one hand this is due to the lower energy capture for cooling in case of higher outdoor temperatures during winter. On the other hand the cooling demand of buildings will increase, due to the higher temperatures during summer. For a climate-robust design, it is important to incorporate these effects. In previous work, we considered the impact of a changing climate on zero-energy office buildings using aquifer systems with heat pumps and so-called dry coolers (Wisse & Spek, 2008). For the energy capture potential of urban surface water, we consider climate change scenarios as developed by Hurk et al. (2006).

2. Urban surface water: modelling and in-situ measurements

2.1 Modelling

For the computational model for pond temperatures we used a one-dimensional model for the heat balance of the pond. The heat balance was determined on an hourly base, using ten sub-sections in the longitudinal direction (Figure 3). For the outdoor climate, the following climatic data were incorporated: air temperature, wind speed, solar irradiation and relative humidity. Data of the design reference year 'tempref' were applied (see Wisse et al. 2008 for further comments).The heat

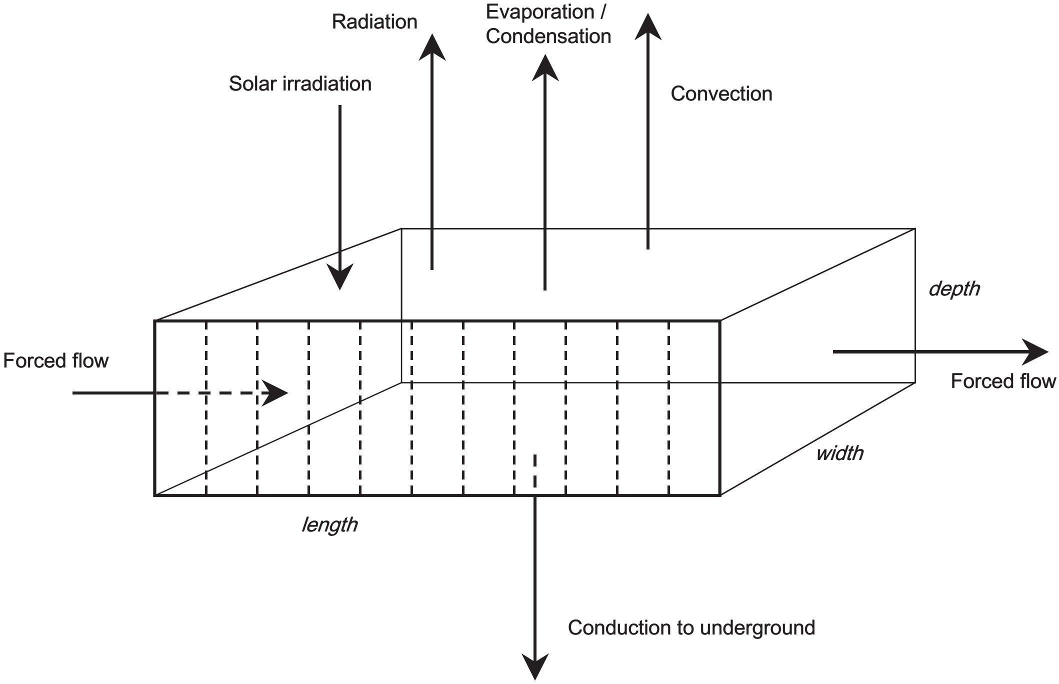


Figure 3 Computational model of the pond

balance consists of the following contributions: solar irradiation, evaporation condensation and convective and radiative heat exchange. Radiative heat exchange is determined using the law of Stefan Boltzmann, with an estimated sky temperature using the relative humidity and the air temperature. For the emission coefficient, a constant value was applied. For the effect of the evaporation and condensation, the free-field vapour mixing ratio and the boundary layer vapour mixing ratio were used, together with an empirical correlation that includes wind speed. An empirical correlation including wind speed was also applied for the convective heat exchange coefficient of the surface. Due to the 1D modelling, the results are only valid for shallow surface water. For a further comment and a more extensive description we refer to Aparicio Medrano et al. (2009).

2.2 Computational results and in-situ measurements

For an urban pond in The Hague (the Netherlands), in-situ measurements of the natural equilibrium temperatures were available for the period 1992–1999. The dimensions of the pond were as follows: length = 200 m, width = 50 m, while the depth equals 0.5 m. Figure 4 gives the results of the measured pond temperatures, as well as the computational results for this configuration using the model as described in the previous section. For the climate data we used the ’tempref’.

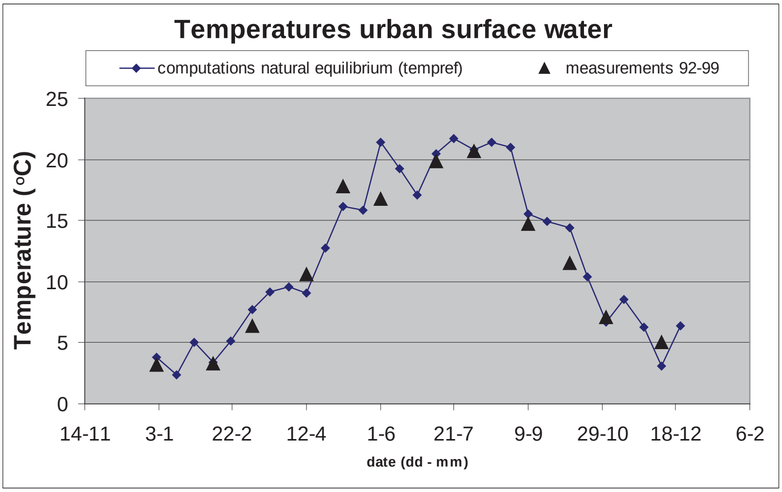
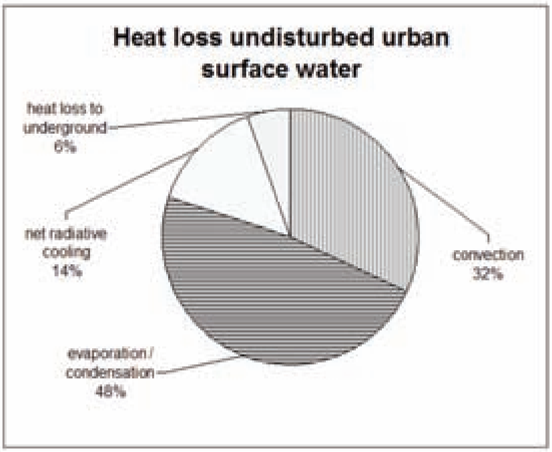


Figure 4 Natural equilibrium temperatures of a pond. LxWxD = 200x50x0.5 m. Climate conditions computations: current (‘tempref’ data).



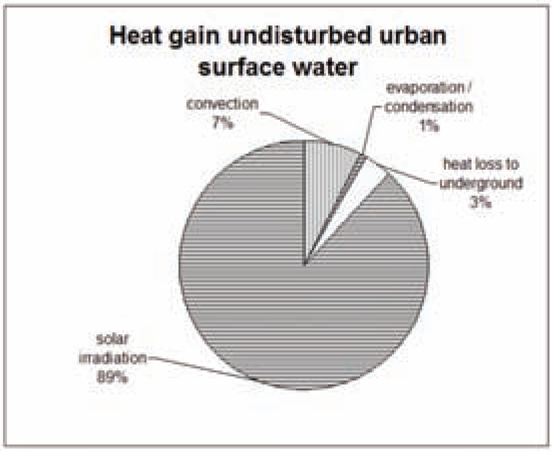


Figure 5 Energy balance of the natural dynamic equilibrium of a pond. LxWxD = 200x50x0.5m. Climate conditions computations: current ('tempref' data).

We consider the agreement between the measurements and simulations as sufficient for deriving general guidelines for the energy capture potential. Figure 5 gives the computed annual energy balance of the pond. This is important to understand the effects of a changing climate. The energy gain of the pond is dominated by the solar irradiation. The energy loss is dominated by the convective heat transfer and the evaporation. In a changing climate, outdoor temperatures, wind speed and the relative humidity are important factors that determine the energy capture potential for cooling.

3. Energy capture potential for cooling

3.1 Computational example

The urban pond as presented in Figure 4 was a point of departure for a sensitivity study of the energy capture potential. The computations were performed for a flow rate of 800 m^3/h. Charge and discharge of the pond only takes place when the temperature of the pond is below 5.5ºC. With equal flow rates in both circuits and a temperature difference of 1.5ºC over the heat exchanger this means an injection temperature in the cold well of 7ºC. For the temperature of the hot well, we assumed 14.5ºC, which means that a water flow of 13ºC is supplied to the pond.

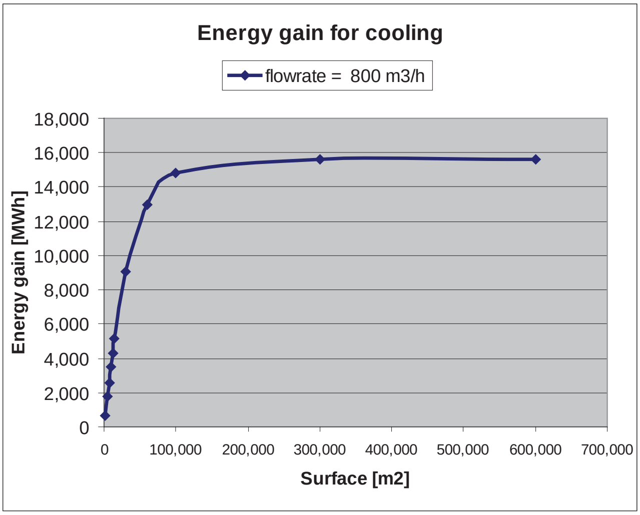


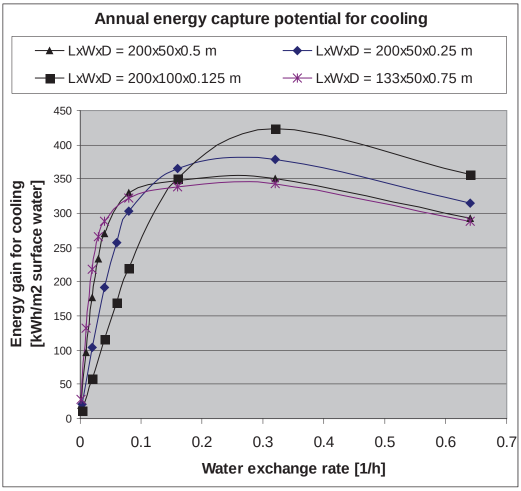
Figure 6 Energy capture potential for cooling depending on the pond surface. Depth = 0.5 m.

In the latter case the temperature difference of 1.5ºC is also due to the heat exchanger. The mentioned temperature levels are typical for aquifer storage in the Netherlands. Figure 6 gives the energy capture potential for energy supply to the cold well during winter, depending on the water surface. Using a constant flow rate, the energy capture shows a maximum as function of the water surface. This is due to the fact that at lower water exchange rates, the natural equilibrium will become dominant.

3.2 Design charts

Water exchange rate of the pond

The results as shown in Figure 6 give a first insight into the key parameters for optimisation of the energy capture potential. We derived more generic results using the water exchange rate as a key parameter. The water exchange rate is defined as the ratio between the exchange flow rate and the volume of the pond. The computations were performed for pond volumes in between 2,500 and 5,000 m^3 and exchange flow rates in-between 10 and 3,200 m^3/h Figure 7 (page 86) gives the results for depths in between 0.125 m and 0.75 m. The maximum energy capture per m^2 surface occurs for exchange rates in between 0.1 and 0.4, depending on the depth. These exchange rates correspond to the length of stay of water in the pond: in-between 3 and 10 hours. This can be explained by the fact that most of the energy for cooling can be captured during the night, when solar irradiation is zero and low air temperatures can be expected. The length of stay should not exceed the nocturnal period. When the water is staying in the pond longer, it will be heated up again by the solar irradiation. The results of Figure 7 are derived for a mix of pond volumes and surface areas in order to investigate the size dependency. This can be confusing for design applications. Future work is planned to develop more user-friendly and generalised design charts.



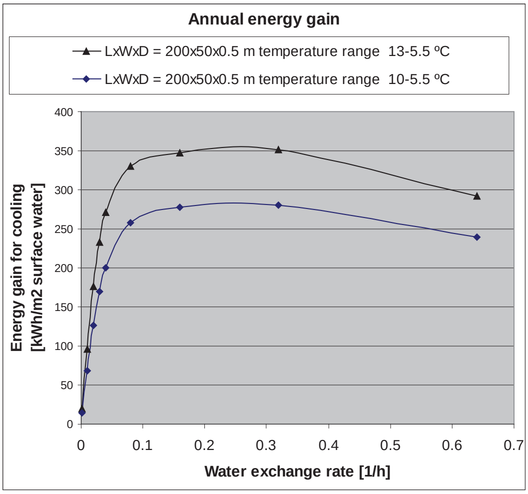


Figure 7 (top) Energy capture potential as function of the water exchange rate.
Figure 8 (bottom) Energy capture potential as function of the water exchange rate. Influence of the aquifer temperatures. Climate conditions: current.

Storage temperature

The results of the energy capture potential depend also on the temperature levels of the aquifer. Starting up an aquifer system, the hot well temperature will be equal to the free field underground water temperature. In concepts without heat pumps, the return flow of the cooling system of the building determines the temperatures in the hot well. In order to incorporate these effects, we performed also computations for a hot well temperature equal to 11.5ºC. A comparison with the previous results is given in Figure 8 for a depth equal to 0.5 m.

Effects on water temperatures

At a significant water exchange rate, the energy exchange with the aquifer leads to increasing water temperatures in the pond. From the viewpoint of water quality, the temperature rise must be limited. Some Dutch water boards limit the acceptable temperature rise to 1ºC (related to the natural equilibrium). Figure 9 gives the average temperature increase between November 1st and March 31st as a function of the water exchange rate. High exchange rates during the nocturnal period give a limited temperature rise and a relative high energy capture potential.

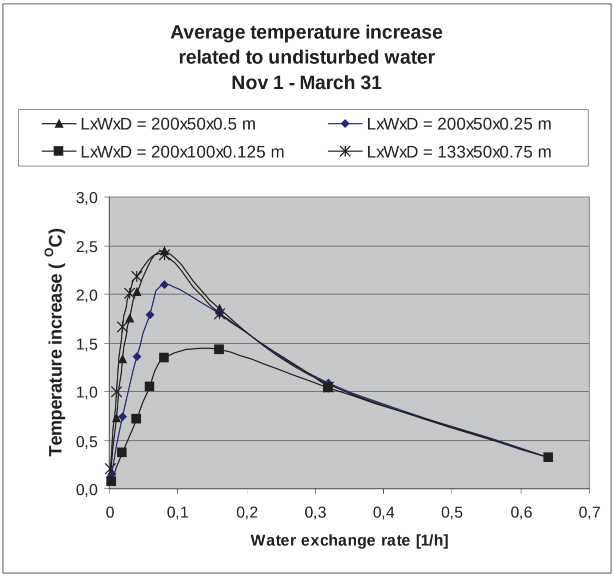
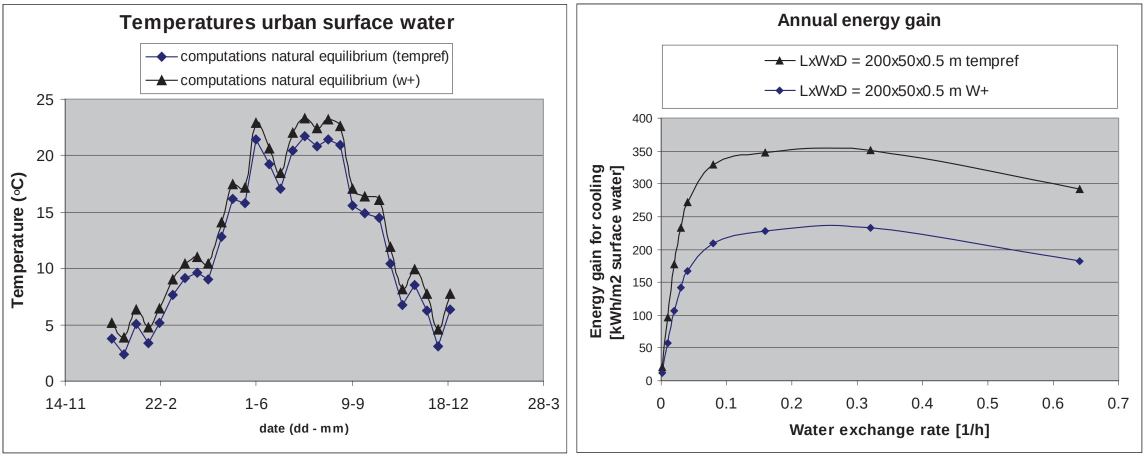


Figure 9 Temperature rise of the pond due to energy exchange with the aquifer. Climate conditions: current.

4. Climate-robust design of urban ponds for cooling

Using global climate models, regional climate models and Dutch historic measurement series, the KNMI developed four scenarios (Hurk et al. 2006): G and G+, W and W+. The G scenarios correspond with a global temperature rise of 1°C in 2050 with respect to 1990, while the W scenarios correspond to a global temperature rise of 2°C in 2050 with respect to 1990. In the '+' scenarios, a change occurs in the global air circulation above Europe. For the 2030s, we derived design reference years using these scenarios (Wisse et al. 2008). Using these scenario design reference years, the natural equilibrium temperatures of a typical pond as given in Figure 4 were recomputed, as well as the energy capture potential. The results are given in Figure 10. Hurk et al. (2006) only presented data for the temperatures; no data were provided with regard to humidity and solar irradiation. For these parameters, we used the 'tempref' data. Future work is required in order incorporate also the effects of a (possible) changing humidity and solar irradiation.



(a) (b)

Figure 10 Impact of a changing climate ((a): natural equilibrium temperatures (b) energy capture potential)

5. Meeting the requirements of office buildings with aquifer storage

For building service engineers who are familiar with the energy demand of buildings, design charts as given in Figure 7 to Figure 10 allow them to estimate the required water surface using hand calculations. For architects and urban planners, further simplified guidelines can be derived using the heating and cooling

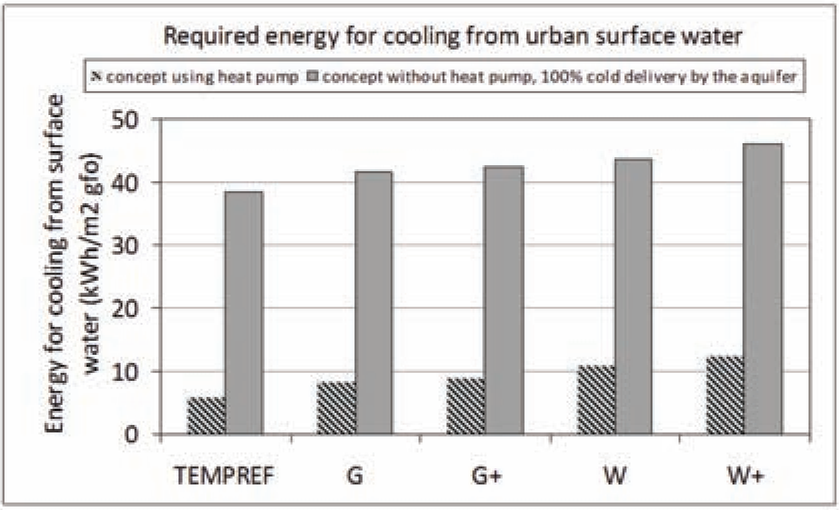


Figure 11 Energy demand for cooling per m² gross floor area. Current and future climate conditions (scenarios 2030s).

demand of a reference office building. For a typical Dutch office building of 20,000 m^2 gross floor area, Wisse & Spek (2008) presented the energy demand for heating and cooling. Figure 11 presents the energy demand for cooling that can be provided by urban ponds. Data are given for concepts with and without heat pumps. The impact of four climate scenarios is also given.

For the 'tempref' and 'W+' we derived the area potential of office buildings which can be cooled using 1 m^2 of urban surface water. For a maximum average temperature increase of 1ºC, with respect to the natural equilibrium, the energy capture potential of 1 m^2 of surface water is equal to 350 kWh/m^2 for the 'tempref' conditions. For the 'W+' conditions, 230 kWh/m^2 is feasible. Following the energy demand as given in Figure 11, values presented by table 1 (page 90) are valid. Suppose we have an office building of 2.000 m^2 gross floor area, divided over 3 storeys, the footprint of the building is about 667 m^2. For the ‘tempref’ climate conditions the required pond surface corresponds to 219 m^2 for a concept without a heat pump. For the ‘W+’, a pond of 400 m^2 is needed. In case of upscaling to whole urban area, a factor of 0.3 to 0.6 times the footprint of the buildings has significant impact on the urban planning. For a concept with a heat pump a factor of 0.05 to 0.2 times the footprint is sufficient (‘tempref’ – ‘W+’).

Table 1 Area potential for cooling of office buildings per m^2 surface water

Climate conditions	with heat pump	without heat pump
	(m^2 gross floor area / m^2 surface water)	(m^2 gross floor area / m^2 surface water)
Tempref	62	9.1
W+	18	5.0

6. Conclusions

Using a one-dimensional model for the heat balance of urban surface water, the energy capture potential for cooling of Dutch office buildings has been assessed. The results are limited to shallow urban surface water (ponds). The annual energy loss of the assessed Dutch pond is dominated by evaporative and convective heat losses. The energy gain is dominated by the solar irradiation. The computed annual temperature cycle is in agreement with the measured cycle for the natural equilibrium condition. For the current climate conditions, the maximum energy capture potential for cooling is about 350 kWh/m^2 (derived for depths in between 0.5 to 0.75 m). This gives a temperature increase of the water during the winter of about 1ºC (with respect to the natural equilibrium). A first evaluation of the impact of climate change shows that a reduction of 34% is possible for the energy capture potential. For a final assessment of the impact of a changing climate on the energy capture potential, climate scenarios are required which include the relative humidity and solar irradiation.

Using installation concepts with heat pumps, the required area of urban surface water is in the range of 2 to 5 %. This range is related to the gross floor area of the buildings and incorporates the effect of increasing outdoor temperatures up to the 2030s. Without heat pumps and 100% cooling supply by the surface water, this range is equal to 11 to 20%. From the viewpoint of urban planning the latter requirements are quite ambitious in the case of up-scaling to a whole urban area. For a specific situation the presented rules of thumb can be used in an early design study by architects and urban planners. The design charts in this paper can be used for further hand calculations. Future work is planned in order to develop more user friendly and generalised design charts. For final design studies, more advanced simulation models can be used in order to incorporate stratification effects, the impact on the water quality, urban heat island etc.

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PART B

BUILDING, SKIN AND TECHNOLOGY

One Planet Architecture

Thomas Rau[17]

1. Introduction

The RAU architectural team, based in Amsterdam, adopts a particular attitude, defined by the term 'one planet architecture': RAU designs buildings with a strong emphasis on sustainability. For 16 years now the practice has been working for the public and private sectors, maintaining an approach that is conscious of planet earth and that uses an integral methodology. RAU is actively involved in the current international discussion on sustainability and in developing energy-saving technology and energy-producing building concepts. In a world where so much nature is threatened by human activity, RAU considers its mission to make a positive contribution through its presence and work.

Our work: Designs by RAU are characterised by a proficient level of sustainability. Some even set new standards, such as the headquarters of the Dutch WWF, completed in 2006: a building that was partially a renovation project, one of the first such commissions to achieve a neutral CO_2 balance. More recently, RAU calculated all international environmental labels and criteria for the design of Carré de Soie, a large office and retail complex in Lyon. Without exception the design scored in the absolute top league. According to the American LEED certification method the complex scores 'Platinum', according to the European EPBD-code an A++, and to the accepted German code the design is a so-called 'Passivhaus'. According to the British BREEAM - which considers the urban embedding as well - the building was awarded the highest category: 'excellent'.

Our clients: Among other projects, RAU is currently developing a generic concept for energy-efficient full-service stores for an international supermarket chain; a design for a 40.000 m^2 college building with a series of public spaces for

[17] Thomas Rau is director of RAU architects, Amsterdam, the Netherlands

educational purposes; an energy-neutral hotel in a complex urban situation; a highly efficient laboratory on a university campus and self-sufficient mixed-use complexes with offices and housing.

Other projects include residential and tourism developments for unusual locations, from earthquake areas to ecologically sensitive nature reserves. The work has a diverse expressive language, following diverse briefs, similar to each other only in their active engagement towards the context and environment.

Integrated designs: Committed to the long-term interests of the planet and its inhabitants, RAU buildings feature smart heating, cooling and ventilation systems, advanced integration of structure and mechanical services, the use of human energy as a power resource, hyper-efficient plans, reuse of materials, `bird-friendly roofing tiles' and ‘bat basements’. Often high-tech results are achieved using low-tech solutions. Although material quality, structural and mechanical design are considered vital elements for achieving physicality in design, the incorporation of the human factor is what distinguishes RAU’s work.

Working methods: Intensive collaboration is a key element in the relations with project partners. RAU encourages diversity of input and opinion throughout the design process. With the intention of exploring new ways of synergy between technology and architecture, RAU has developed an integrated design methodology. Both the client, the users and the project team are closely involved, and the physical context of the site and the building itself are strongly united

Not just 'sustainable': Communication with all prospective users is vital, for they really ‘inhabit’ their future building. And in our view, a sustainable building not only reflects state-of-the-art technology. In fact, these considerations go without saying. To us is it self-evident that since architecture is increasingly required to meet stringent sustainability criteria, it will have to do so without sacrificing other standards, such as budget or aesthetics.

Social awareness: RAU's sustainable entrepreneurship results from a specific attitude towards the world. Working and living in the constant awareness that any action ultimately produces significant effects in the world at large: ecological, economic and social. This way of working creates healthy, energy-producing buildings that have a people-oriented approach and enhance awareness of our planet.

2. Case Studies

2.1 Case study 1: Carre de Soie - Lyon

Lyon, the Carré de Soie: where once the silk industry was located, a model neighbourhood will be developed between the city centre and the airport. Accreted housing will be demolished to make way for a sustainable urban concept.

Lyon's great ambitions for sustainable technologies and low-energy use must become a reality here. This first location-defining office complex with a shopping centre, a car park and 92 social housing apartments will set the standard for the whole city district, acting as a central hub. It will be located at the end of the metro line to the centre, immediately adjacent to a Park & Ride facility and on the tram route to the airport.

The design involves various aspects. Sustainable use of materials, such as walls of recycled glass and recycled glass-reinforced concrete. Low energy consumption (class A EPBD), using only infinite energy sources and self-generated energy. And, in order to get as close as possible to our self-imposed additional objective: an entirely self-supporting and – autonomous – CO_2 neutral design.

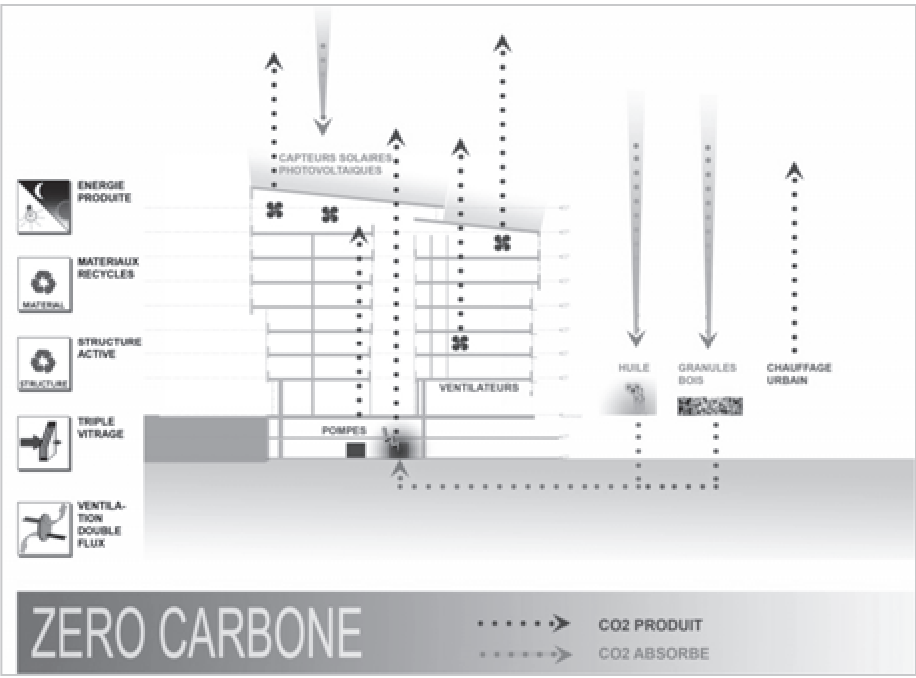


Figure 1 CO_2 neutral building

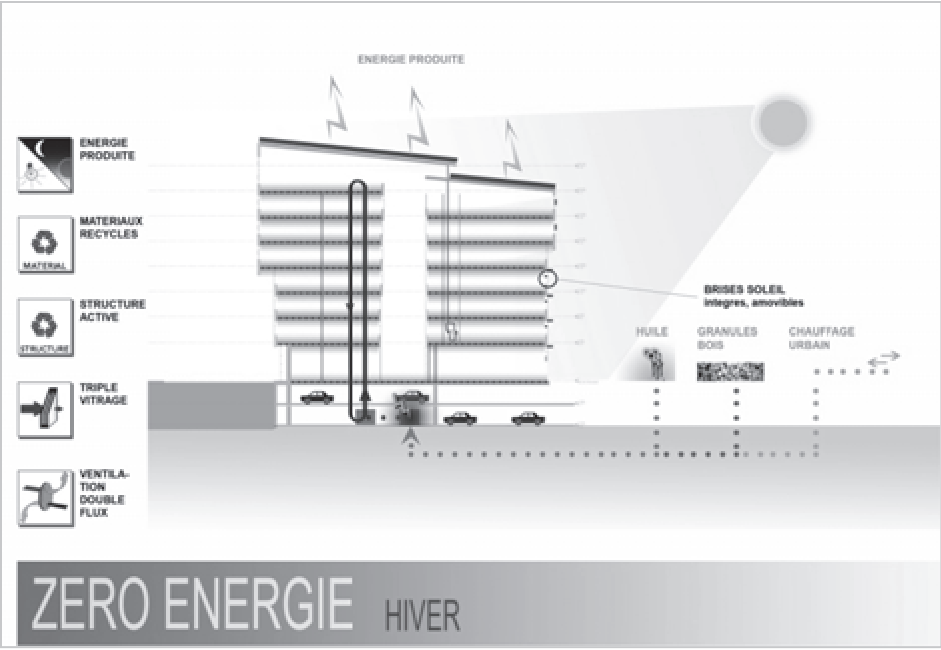


Figure 2 Winter situation

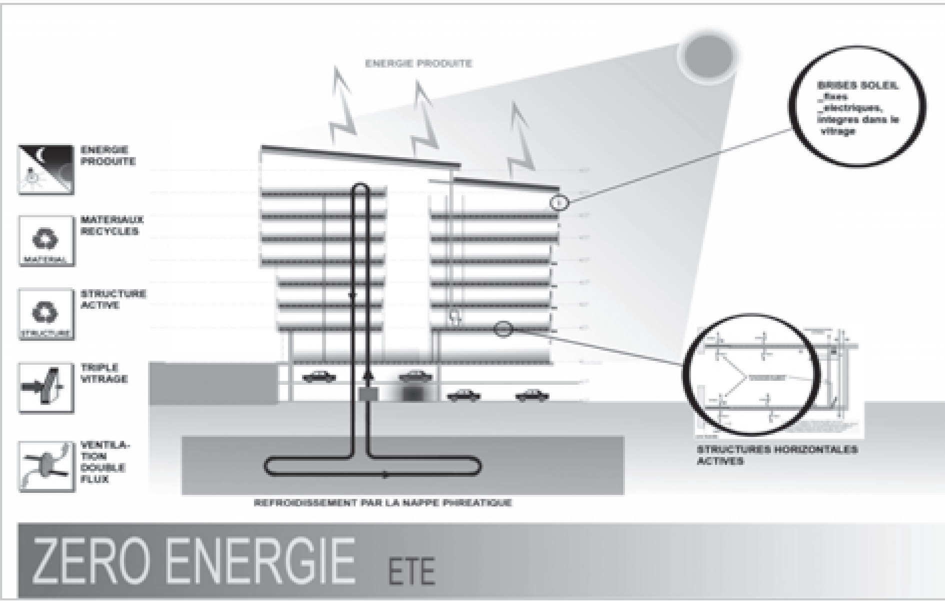
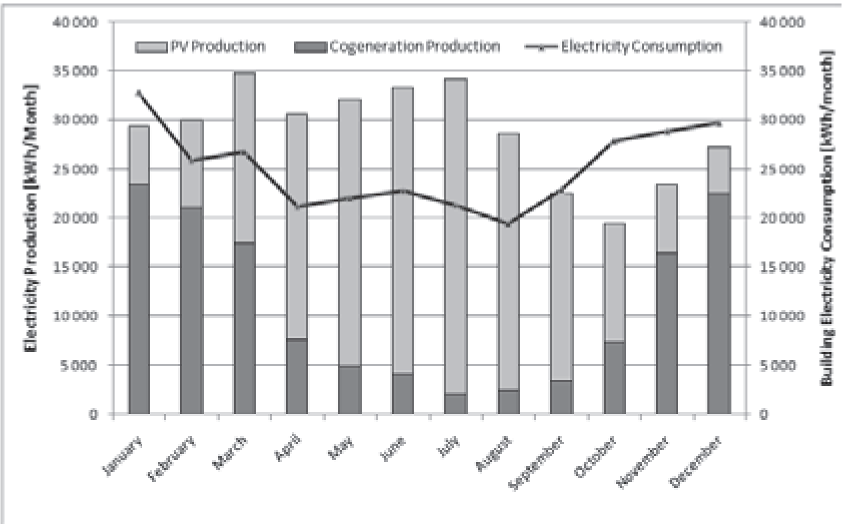


Figure 3 Summer situation

Table 1 Energy management



The building contains high-graded insulation through which the energy use can be restricted. It has 1600 m^2 of solar panels on the roof. The low-temperature controller is integral engineered by the design team. The floor contains cooling, heating, air handling and electricity supply. And the energy demand of the user is restricted by local controlling. This is translated into lighting by controlling each workplace individually. The energy controller shows the energy use per floor or division. The user appliances are fuel efficient, such as computers. They are ordered in big amounts and require less energy.

Table 1 shows the energy management of Le Carre de Soie. The light grey bars indicate the output of PV cells and the dark grey ones the production of sources on wood chips and gas. The line, i.e. electricity consumption, depicts the demand of the user. On average the building produces more energy than it uses. The remaining energy can return to the energy grid. Because of this the building can be seen as a power station.

2.2 Case Study 2: Headquarters WWF – Zeist

The Dutch branch of the World Wildlife Fund moved into its new premises. A former agricultural laboratory had been transformed into a most energy-efficient building. On the balance it is self-sufficient and CO_2 neutral.

The WWF, one of the world's largest non-governmental organisations, aims at the preservation of the natural flora and fauna, and the use of renewable energy fuels and raw materials. In Zeist, not far from a nature reserve, this organisation built its new headquarters in the Netherlands. The WWF decided against a new building, and instead for renovation of an agricultural laboratory complex from 1954, and to meet the challenge with the surrounding industrial and agricultural buildings.

After a design competition the building order was given to RAU. With its integrated concept for the renewal of the existing buildings RAU carried through energy efficiency and sustainability, transparency and modern workplaces, in harmony with landscape, nature and building. The crystalline uniformity of the existing buildings entailed the need for a dynamic enlargement. The middle part was broken away, and a new amorphous building block was put in, providing space for the main entrance, which was removed from north to south. A bridge crossing a pond leads to the main entrance.

The dominating new middle part, opening itself to the light and the landscape, forms the heart where all specific WWF functions come together – reception office, reception and consulting rooms, exhibition space and call centre. This middle part is connected through bridges with other working spaces. A big winding staircase runs through the amorphous building block, which on the outside is coated with natural brick materials and on the inside with loam. The northern building block – among trees, reposing on supports and coated with shingles of wood – accommodates the press and conference centre. The offices are centred in the east and west wings, and constructed on the south with boards of Oregon Pine and permanent blinds to admit the sun during winter.

Ceiling strips of felt provide agreeable and satisfying acoustics. The materials applied come from all over the world: e.g. the free-standing sanitary blocks are furnished with a colourful African plaster, tadelakt, and the banisters consist of bamboo stems. All horizontal elements in the adopted concrete skeleton are covered with capillary networks wrapped up in loam, which are used for heating and cooling. A solar energy power station on the roof provides energy and all installations run on vegetable oil. All together this warrants that the building is energetically self sufficient and CO_2 neutral. By replacement and extension of the middle part and an efficient internal arrangement, it was possible to demolish part of the old complex and give it back to nature.

Figure 3 Headquarters WNF Zeist

2.3 Case Study 3: Nijlân

Nijlân is an expansive, calm district, on the south-western outskirts of Leeuwarden, the Netherlands. It has both post-war housing and sixties developments, both low- and high-rise. Bordering on the ring road and on the Van Harinxma canal, this district has a view of the wide and open Frisian landscape.

Piter Jelles Nijlân is a large secondary school for 15,000 students, spread across four locations. Its senior staff has redeveloped the school’s educational concept: departments with 100 students each, compiling their own timetable. In this concept, teachers reside in their own room, while students are moving around the building, thereby learning to work independently.

At the end of 2003, an urban study by RAU showed that an entirely autonomous, compact building would offer the best solution in economic, environmental and functional terms. In order to achieve this compactness, a four-storey volume at the core of the building accommodates all class rooms for practical lessons. Grouped in circles around this core are the rooms for theoretical education, thereby enclosing the core like an arena. The lowest circle accommodates rooms for ‘commercial use’, facilitating students to sell their services to the outside world.

The building’s shape metaphorically reflects the process of peeling a fruit. A transparent unity of theory and practice makes the fruit, the pupils are the seed. Like half-peeled paring spiralling around the fruit, the facade partially opens up

Figure 4   Piter Jelles Nijlân secondary school

towards its surroundings. The facade is transparent where contact with the outside world is encouraged and alternately open and closed where pupils are working independently. As a token of appreciation and respect, pupils (and teachers) enter the building via a red carpet covering the stairs leading up to the building's main entrance.

The core of the building is home to practical subjects: mechanics and construction (ground level), kitchen and bakery (first level), electronics (second floor) and the building's technical facility room (third floor). It was a conscious decision to keep technical installations, such as ducts, visible for pupils, in order to reveal the complexity of and to stimulate curiosity for the functioning of the building. Located around this core are the shops on the ground floor, with class rooms for theoretical lessons and offices above.

The area surrounding the green campus is very diverse: semi-detached houses to the north, apartment blocks to the south, a shopping centre to the south-west. The volume of the school is too small to be an effective mediator between its urban surroundings. For this reason, the school's integration into its social environment is achieved by a sculptural statement embedded into a miniature park.

The extremely compact rounded form allows the extensive use of glass while keeping heat and energy consumption to a minimum. The shape also minimises the required space for traffic flow and ensures short access routes.

The Well-Tempered Envelope: A Prototype as a Sustainable Residential Building

Agnese Ghini, Dr.Eng.[18]

1. Introduction

1.1 Cultural background

Gaining indoor comfort in a virtuous manner under an environmental point of view – the thermal-hygrometric, light and acoustic comfort in full respect of the environment, in its individual components of energy, matter and eco-system relationships – is turning out to be of primary importance in architectural design. Not only on a governmental – and therefore regulatory – basis, but also on the basis of social consciousness it is possible to feel strong needs aimed at the nearly obsessive respect of natural heritage. The world's community suffers from a rooted sense of guilt towards the planet, which has been exploited without the awareness of the limit and of its capability to offer resources and, simultaneously, receive the waste of human activities. From the need to save non-renewable energy and matter connected to the economic disease of the western world, to the will to avoid further damage to ecosystems, the behavioural line in managing anthropogenic activities is going towards the maximum containment of non-renewable resources and minimisation of polluting emissions.

Within this framework, Climate Responsive Design apparently is a good way to tackle issues of indoor comfort connected to the containment of non-renewable resources. Here, the reduction of importance of heating and cooling systems, which are currently energy-devouring, and the simultaneous recourse to renewable energies are associated with the design of technological and architectural systems strictly based on the climate of the place and aimed at the

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best indoor comfort. Climate Sensitive Building is characterised by a reactive and sensible behaviour based on the changing of climate conditions, as well as active or passive control of thermal and light energy transfer, which is capable of guaranteeing an comfortable indoor well-being.

Over the last decades, architectural design has been suffering from a kind of moving apart from the purely technological dimension: architectural choices on shape and function have been made, in most cases, in total abstraction from environmental and technological issues: the indoor comfort issue has been completely performed by heating and cooling systems. In the current building practice in Italy, design is never of an integrated type. Each problem is faced almost totally independently of the whole, thus compromising the wholeness of the architectural body. In particular, the indoor comfort issue is badly managed and committed to heating and cooling systems that are completely independent of the technological systems selected to make the building. Specialists' analyses carried out throughout separate phases must be replaced by integrated design analysis and development, which are capable of resulting in the so-called Function Integrated Systems – i.e. systems where plants and building works in strict synergy and in relation to specific climate conditions, with a view to obtaining pre-fixed levels of indoor comfort with the least energy consumption.

Nowadays, the need is felt to bring the design back to its original function so as to take the technical and architectural conditions to the very centre of the indoor comfort issue. In the past, spontaneous architecture developed through millenary heritage of vernacular experiences and knowledge of building, architectural and urban systems sensitive and reactive to the environment and local climate, and able to determine spontaneous comfort of rooms.

If, on the one hand, going back to the same bio-climatic patterns would mean a regressive step, on the other hand it is possible to start a neo-vernacular tier, which is no longer based on a material culture that has layered through the centuries, but on a new culture ruled by science and engineering (the so-called Building Science: environmental physics, science and technology of materials, tools for modelling and precasting the behaviour of working systems and components), and their gradual progress, consistently with the sustainability and behavioural variability goals required by the local microclimate context.

Figure 1 Virtual view of the prototype.

In the specific case of Italy, where due to a number of sociological aspects a dwelling mode has developed that gives priority to rooms strictly connected to the exteriors, for long periods of the year, the development of new architectural and technological systems has to be mostly characterised by management based on the free floating building, on the direct control of overheating and underheating, and on the prevailing contribution of natural ventilation. Unlike German low-energy systems, where air-conditioning depends on ad-hoc heating and cooling systems, and consistent with the results of recent research dedicated to the study of comfort associated with natural ventilation, which results in higher appreciation and adaptation to the variability of environmental conditions (Brager, 2001), the residential building in the Mediterranean climatic area needs a closer relationship between the external microclimate and its interior. Or, as an alternative, mostly in buildings destined for service industry, recourse should be had to hybrid ventilation systems, where mechanic-type ventilation can be interrupted, under certain external climate conditions, in favour of natural ventilation.

2. Hygrothermal comfort

2.1 Hygrothermal comfort and climate sensitive building

ASHRAE 4055 and ISO 7730 standards define the performance goals of interior spaces. Yet, which standards should be applied to buildings that are not artificially conditioned such as Climate Sensitive Buildings (Croce 2007)? Humpreys and Nicol (Nicol et al, 2002) developed a method aimed at the evaluation of comfort conditions in non-conditioned buildings. Such a method, of an ‘adaptive’ type, is based on the human capability to respond to the climatic condition changes, both through physiological reactivity (thermal-hygric adjustments of the body) and behavioural adaptability, which occurs by adjustment of the building envelope, clothing and type of activity. In buildings that are designed in such a way as to take advantage of human adaptive capability, it is possible to make reference to less strict performance goals, without reducing the current quality expectations. Such goals are based on the non-perfect regularity of the natural world’s environmental conditions.

Research sponsored by ASHRAE in 2000 (Brager, 2001) about naturally-ventilated buildings has highlighted three types of adaptation: physiological, related to acclimatisation (which is linked to physiological reactivity such as vasoconstriction, vasodilatation, breathing, perspiration and transpiration); psychological, linked to unconscious availability to adapt one’s expectations to the context (repeated exposure to a new signal tends to reduce the extent of the initial response of senses); and behavioural, which is linked to behaviour reactions that can be intensified by the availability of more or less sophisticated devices, even of building type, to control external climatic conditions.

In naturally-ventilated environments, 90% of the individuals consider a temperature to be comfortable increased or decreased by 5°C in relation to the reference that is considered an optimum, therefore with an extension of the tolerance range compared to the results obtained with air-conditioning.

Encouraged by data produced so far by the scientific community, the research group of the Technology of Architecture from the University of Parma - consisting of B. Bertozzi, B. Gherri, E. Mazzadi, G. Michiara and the author - is devoting itself to the study of performances of the Climate Sensitive Building. These are extremely low energy consumption buildings, which are sensitive to a specific climate, namely characterised by a tendency to manage the indoor comfort for long periods of the year, throughout the alternation of seasons, through nearly automatic reactions to the external environment stimulations, realised through the technological and architectural properties of the building itself.

In such buildings, use of plant and system devices is limited to very reduced time slots, to coincide with climate critical situations that could not be managed otherwise, for example in the presence of the so-called ‘heat waves’ coming from Africa.

The choice of an hyper-insulated envelope typical of the Passivhaus is to be considered essential even for Mediterranean climates, but not sufficient: the control of solar contributions and internal loads during summer and the modes for their immediate dissipation – through ventilation and underground heat exchangers – or delayed dissipation – through inertia factor and underground heat exchangers – get a fundamental importance in our context, to such an extent as to have a deep impact on designing solutions. While in the case of the Passivhaus technological solutions are not much different one from the other, due to a certain climate homogeneity, the varied climatology characterising the Italian regions does not allow any homogeneous spreading of standardised building solutions.

In such contexts, it is advisable to adopt a complex, Climatically Conscious Design, which can manage more or less spontaneously the external inputs determined by the climatic and microclimatic local condition. If in such buildings, the building system is entrusted with the primary function of control internal climatic conditions, heating and cooling systems are assigned the task of controlling, in very limited time slots, the most critical climate conditions, as well as supporting the working of low-energy devices for the control and regulation of energy flows. The high reduction of energy flows, outwards in winter and inwards in summer, leads to the adoption of special low-power heating and cooling systems characterised by high performances, based on the use of renewable resources that can manage low quantities of energy: heat pumps, cogeneration and regeneration pumps, heat exchangers, geothermal probes.

A good example of Climate Sensitive Building is the BEDZED settlement, near London, which thanks to high inertia factors is able to control indoor conditions, on a natural basis and as a function of adaptive behaviours of its inhabitants.

To sum up, we can conclude that Climate Sensitive Building is not characterised by a specific high-tech or traditional technology, yet it aims at performance goals based on the adaptive theory; it reduces the total energy consumption by using renewable alternative sources; it controls free contributions through inertial systems, heat exchangers or phase-change materials; it uses natural ventilation systems; it adopts high-performance low-maintenance plants, strongly integrated with the architectural and technological system, in line with the

Table 1 Actions influencing the indoor natural climate

Positive actions for winter	Negative actions for winter
High solarization	Low solarization
Geothermal availability	Windiness

Positive actions for summer	Negative actions for summer
Winds and breezes	Low windiness and absence of breeze
High range of temperature between night and day	High solarization of the envelope due to natural or artificial factors
Geothermal availability	Low range of temperature between night and day
Absence of prolonged periods with critical temperature	Prolonged periods with critical temperature and high humidity
Presence of vegetation and trees	Absence of vegetation or lack of trees

spontaneous building behaviour, based on the use of renewable energies, mainly solar and geothermal energy.

The choice of the best technology for the envelope, the internal partition systems and heating and cooling systems, as a function of the pre-fixed indoor comfort standards, is strictly linked to the microclimate and local climate conditions. In this respect, any evaluation of all ‘actions’ that may influence the indoor natural climate is necessary.

2.2 Performance modulation of the climate sensitive building technical elements

Outside, walls delimiting interior spaces, as they mediate the signals coming from outside, become sources of signals which, as a whole, define the quality of comfort indoors. The quality of a Climate Sensitive Project is determined by the ability to modulate such signals on a streamlined basis. To face precise microclimate conditions, the project should include envelope solutions that can modulate, in a structural and interactive way, the signals coming from outside.

Modulation may be of a static or dynamic type. Static modulation, which is typical of the current buildings, is referred to non-changeable behavioural patterns of the technical element, independently of the level and quality of environmental stimulation. This modulation is managed by the project once and for all. Dynamic modulation coincides with the possibility to change the behaviour of a technical item of the envelope when a special external environmental condition occurs, through configurations that may change on a daily and seasonal basis. The latter type of modulation is fundamental in Italy, where the envelope is required to have a different behaviour in summer and winter. Today, dynamic modulation is committed to heating and cooling systems. In a spontaneous climate-controlled building, the envelope must react, too. Dynamic modulation can be either active, if committed to automatic actions, or adaptive, if committed to the users' actions.

2.3 Environmental thermal quality in winter

The temperature is the main parameter for controlling thermal comfort. It is due to the air temperature and radiant temperature of the surfaces delimiting the internal space. Relative humidity has little impact on thermal comfort, and a slight impact on hygienic-type aspects. In current buildings the dynamic modulation is committed to heating and cooling systems that supply the energy required to take air temperature to a fixed value upon external conditions change while, at the same time, the building is entrusted with static modulation, i.e. it passively reacts to thermal inputs generated by heating and cooling systems. Internal surface temperature varies upon change in the external temperature, not as a result of the heating system.

The current trend of ongoing research induces the building design to aim to regulate the surface temperature of the envelope intrados[i], not to control the internal air temperature. Wall or floor radiant systems, by adding or subtracting energy, can compensate for the poor thermal inertia of the contiguous technical element; this is a case of active inertia.

The intrados surfaces have a different behaviour, depending on their being opaque or transparent. In opaque elements, surface temperatures can be either passively modulated by special thermal resistances, efficient inertial masses, by the use of phase-change salts, or actively modulated through energy contribution. Modulation may be rapid or inertial. There are radiant floors with inertial performance and other ones with rapid-response.

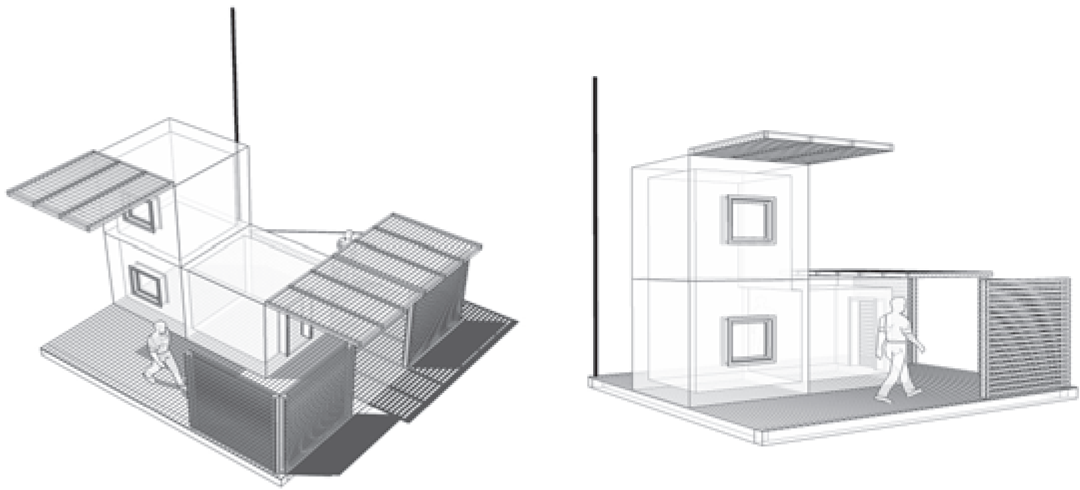
In transparent elements, modulation of the internal surface has to be accompanied by modulation of energy contribution due to solarisation. The surface temperature can be statically modulated through the thermal resistance of the set of windows, and actively modulated through dynamic insulation, just like Air Exhaust Windows, or even by overnight integration of more or less insulating darkening systems. For example, the double-skin envelope of an active type integrated with air-conditioning where the exhaust air is conveyed through the air gap to recuperate the heat. Opaque envelopes almost completely adiabatic tend to assimilate their thermal status to that of internal partitions, thus reducing radiation heterogeneity.

This way, we pass from Skin Dominated buildings to Internal Load Dominated buildings, and the building or plant system design logic completely changes. Internal loads become significant in percentage and give great contribution, along with solar contributions, to energy supplying for heating purposes.

In cases of hyper-insulated envelopes, it is not necessary to turn to solar gain enhancing systems, since this could bring about overheating, both in winter and summer.

Managing the thermal transient situations, that may come both from variable conditions of the external environment and from thermal variation due to exceeding internal loads or solar gain, is increasingly important. The control of thermal variations at low temperatures can be obtained through mechanised air changes; incidental opening of windows is not advisable, since it could unbalance any thermodynamic functioning of the building. Any addition of heat exchangers to recover thermal energy is recommended.

The changeability of external thermal conditions can be modulated by heat absorption or transfer, either delayed or postponed, aimed at the control of the building cooling times under free running conditions. For example, when the heating is switched off overnight, a good inertia factor, linked to internal inertial masses, may be somehow useful. Based on these last remarks, a building with Passivhaus characteristics finds no hindrance when carried out with a low inertia factor lightweight technology, since energy needs are extremely reduced, even during poorly sunny days. Experimental trials showed that under conditions of free floating, reduction of internal temperature from one day to the other is moderate.



Figures 2 and 3 Perspective views of the prototype with its mobile solar screens.

It can be noticed that in hyper-insulated systems – such as Passivhaus – the inertia factors required to compensate for transient situations need lower efficient accumulation masses than would be required in current buildings, thanks to the fact that the thermal variations are contained. In such conditions, utilisation of phase change materials (PCM) is economically feasible.

In a lightweight building, the presence of a massive layer in the intrados of the opaque envelope can only be useful to calculate the internal environment inertia factor, but the same effect can be more easily obtained with the internal partition mass.

2.4 Environmental thermal quality in summer

In summer, hygrometric exchange prevails over thermal exchange. As the internal temperature increases, the difference between the body epithelial temperature and the temperature itself decreases; at the same time, the thermal flows that can be transferred for thermal exchange are reduced. Therefore, hygric exchange becomes the only possibility of regulation, when the internal temperature is higher than the epithelial temperature. Due to thermal exchange, in this case, heat is transferred to the body. Since the evaporation process depends on the relative humidity of the indoor air, low values favour the body heat transfer.

Natural ventilation is an important element to manage indoor conditions directly generated by the building and its technological components. In fact, ventilation serves not only to discharge the incoming thermal energy and reduce the relative humidity produced inside the building, but also to facilitate thermal transfer, under conditions of free floating, both by convection and through hygrometric exchange. This means removal of the body heat is favoured by the flow of air, which – touching the human body – facilitates evaporation and removal of vapour produced by the human body.

In case of natural ventilation, it is not possible to manage the level of relative humidity, which may bring about conditions of discomfort or condensation of steam on non-insulated retaining walls – if it exceeds the external level.

It can be advisable to act on the temperature of surfaces delimiting the internal spaces, by using fluids cooled down by geothermal devices. In this case, the control of the temperature of the internal air occurs through the control of surface temperature; this one must be kept above the saturation temperature, to avoid events of superficial condensation. Sensors will be necessary, that activate the controls of adduction flow rate of such fluids on which the surface temperature regulation depends.

To sum up, to regulate the internal climate it is necessary to adopt envelopes that can retain heat inputs, radiant heating and cooling systems or night ventilation - which is suitable when there is a good range of temperature and the incoming air temperature is lower than the internal surface one.

3. Prototype

3.1 Environmental thermal quality in summer

Within a research project financed by producers of boards for closing systems and vertical partitions and a pool of local building firms, and concerning the study of dry technology solutions for residential buildings, it was possible to realise, on the University Campus, a small prototype that constitutes an important opportunity for a scientific in-depth analysis as well as support to teaching.

The prototype, which is made up of three rooms of approximately 9 m^2 each, two of which are on the ground level and the third one on the second level (see figure 2 and 3), is carried out with a wood-frame structure (9/14 cm), closed with entirely dry envelopes. Floors and covering are carried out with hybrid technology, partly wooden and partly with reinforced concrete. In the part of the prototype that develops over two levels, for a total height of 769 cm, natural ventilation walls have been built, with a 3-cm air gap.

Stratification of vertical envelopes, designed in synergy with producers, is carried out with a sequence of wood-wool or rock-wool insulating boards, vapour-proof membranes and water-proof on extrados, plaster and fibre internal finishing boards, concrete and glass fibre boards for outdoors (see fig. 4).

The small building has a rotation around a central axis to allow studying the most correct envelope solution according to sun orientation. On top, in proximity to the second level covering, mobile screens are applied, realised with 45° inclined lamella, to study shading on the windowed surface of the second floor.

Subject of the research, currently ongoing, is defining which are the most correct envelope systems in ‘stratified’ dry technology, under the point of view of the thermal-hygrometric and acoustic performance with regard to the sun orientation of surfaces, to the environmental impact of the materials used and especially with regard to the energy consumption required for cooling and heating system, in winter and summer.

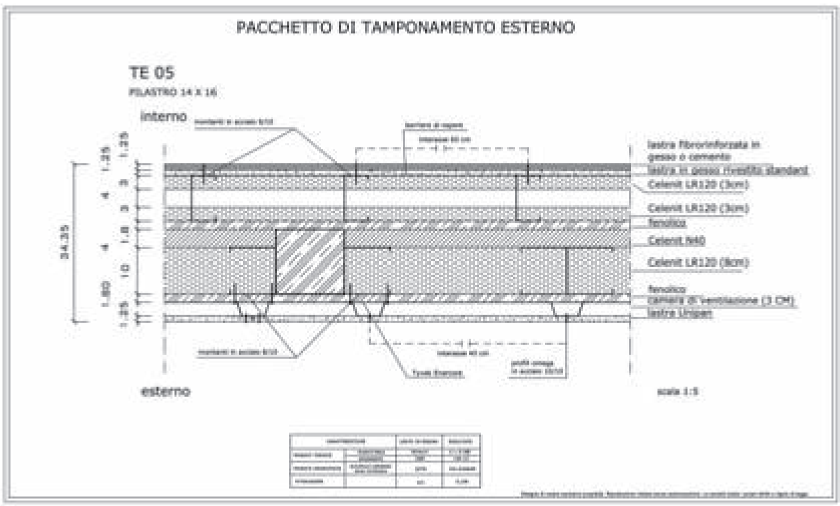
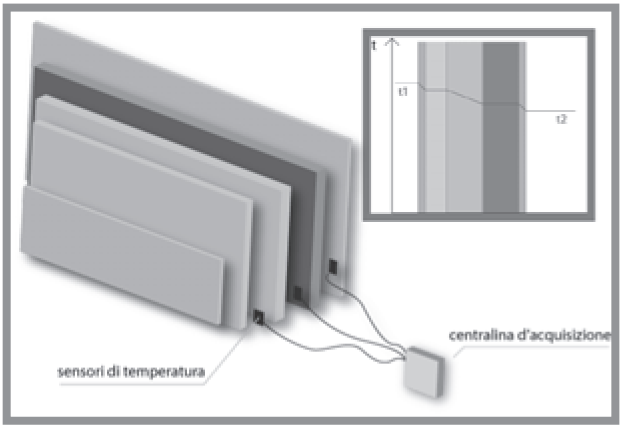


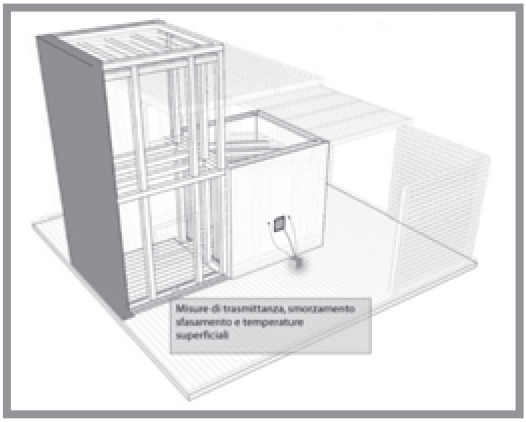
Figure 4 Technological detail of the ventilated envelope of the prototype.

In fact, the building will be tested in summer and winter, during the first phase, without any cooling or heating system, to evaluate the ability of the envelope to interact with climatic factors by measuring the corresponding internal parameters; during the second phase, with the inter-relation of the heating and cooling system to evaluate the ability of the envelope to keep the prefixed indoor comfort conditions. The goal is identifying, once the external climate conditions are known, the thermal-hygrometric performance limits, under the static winter conditions and the dynamic summer conditions, of the opaque envelope systems in terms of thermal transmittance and inertia, attenuation and phase shift of the thermal wave, internal and superficial condensation, in order to define enhanced technological systems. These ones can be subject to redesigning of layers and their sequence, by also using innovative materials other than those used in the first realisation of the building. In fact, thanks to the versatility of the dry technology it is made by, the prototype will be modified – during the research - in its opaque envelope and vertical partition system, to evaluate the best performing technological solution, not only through theoretical modelling, but also through on-site experimentation. The choice of the technological solution will also be helped by a series of case studies, which made the object of a previous research phase, relevant to residential buildings realised in Europe with the use of dry technology, analysed under the theoretical point of view, therefore already known in terms of performances.

The realisation of a part of envelope with natural ventilation allows calculating also the contribution of the air knife under dynamic summer conditions, where the greatest contribution is foreseen in terms of reduction of heat contribution from outdoors to indoors. In the warm-humid climate characterising our region's summers, the ventilated wall constitutes a fundamental system for the thermal dispersion of the heat that can possibly accumulate from the wall and be transferred into the internal spaces.

More precisely, the thermal-hygrometric and acoustic investigation of the envelope is carried out both through theoretical calculations and provisional models in course of project, and through an on-site experimental verification protocol, upon completion of the building.





Figures 5 and 6 Temperature values of the wall are obtained with thermometers collocated inside and on its surfaces.

In particular, the thermal-hygrometric verification protocol, which is applicable to other case studies and existing residential buildings that need a retrofit of energy and indoor comfort, is made up of two separate paths for summer and winter. In summer, monitoring of the relative humidity and internal air temperature is carried out for at least one month; monitoring of the wall temperature, attenuation and phase shift of the thermal wave on significant parts of the envelope for at least five days in a row; analysis of thermal bridges by thermal camera.

In winter, monitoring of the relative humidity and internal air temperature is carried out for at least one month; monitoring of the wall temperature, air thermal stratification and thermal transmittance on significant parts of the envelope for at least five days in a row; analysis of thermal bridges by thermal camera.

Monitoring as envisaged by the verification protocol, besides highlighting any faults and potentials of the envelope during the analysis, will facilitate the operations of performance modulation of a dynamic-adaptive type of the envelope technical elements during the phase of prototype use. For example, activation of the covering horizontal screens will occur upon reaching the preset values of the thermal parameters involved; or activation of natural ventilation will be brought about by an increase in the wall temperature.

Table 2 Comparative theoretical and experimental transmittance and phase shift values

Orientation	**not vent. wall**	**not vent. wall**	**ventilated wall**	**ventilated wall**
	Transmittance U[W/mqK]	phase shift S [h]	Transmittance U[W/mqK]	phase shift S [h]
South	0,44	6	0,25	8
North	0,22	9	0,19	n.d.
East	-	-	0,15	10
Theoretical Values	**0,19**	**16**	**0,17**	**13**

The final research results will be available at the end of 2009. The prototype will have been subject to experimental verifications and used for teaching demos to students of the Faculty of Architecture and Civil Engineering of the University of Parma.

At present, the first checks about the wall's thermal behaviour during the winter season has been concluded. Temperature values inside the wall stratification – using thermometers collocated inside and on surfaces (see figures 5, 6) – thermal wave values, – using a heat flow meter – and phase shift values have been obtained. Through further processing, from these values we determined the thermal behaviour of the examined wall and, in particular, calculated the experimental transmittance.

From a first reading of the data, it has been observed a strong deviation between theoretical and experimental values about phase shift of thermal waves, and, especially, in non-ventilated walls. It has also been observed that experimental transmittance values are significantly worse than theoretical ones in the non-ventilated south wall.

Figure 7   Virtual view of the prototype.

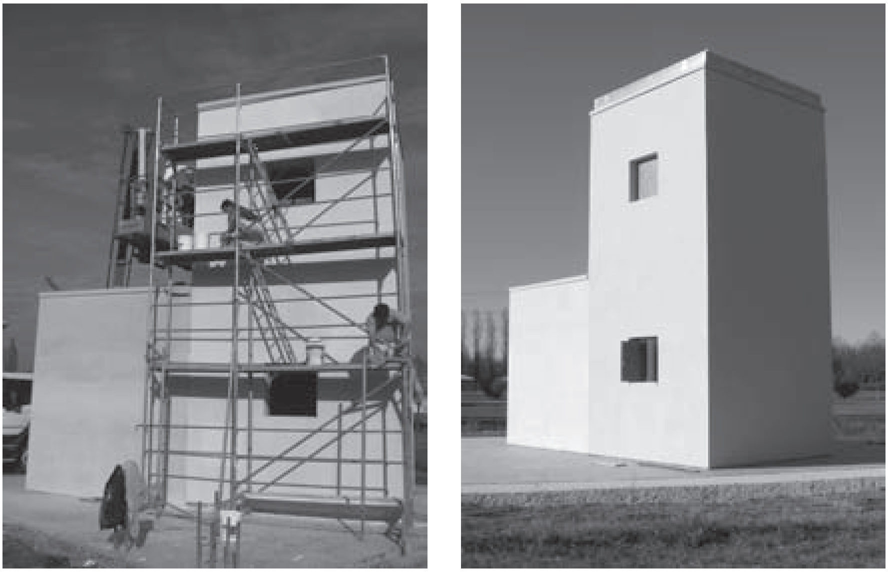


Figure 8   Construction of the prototype.

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Zero Carbon Building Methods: The Case of Hempcrete Projects

Prof. Tom Woolley, B.Arch, PhD[19]

1. Searching for low carbon building

It has long been recognised that buildings and their use contribute significantly to CO_2 emissions, perhaps more than 50% of total emissions. Finding ways of meeting our housing and building needs while having a low impact on the planet has been the aim of many self-builders, architects and environmentalists. However there are two main differences in approach. There are those who have focused on getting the main stream construction industry to make buildings more energy efficient even though they rely on petrochemical based insulations, cement and concrete. Others have tried to search for lower impact alternatives that also are healthier and less polluting. There is now a range of building methods and materials derived from natural low impact sources such as earth, straw, recycled materials and so on. We first learned about hemp and lime construction from pioneering Suffolk architect Ralph Carpenter (Modece Architects) and soon realised that this was a form of eco-construction that could achieve low-energy buildings using low-impact materials. While it was a natural alternative material, it clearly had great potential in mainstream construction.

Hemp-lime construction is a composite construction material and building method that combines fast growing renewable and carbon sequestrating plant-based aggregates (hemp shiv) with a lime-based binder to form a lightweight material that is suited to solid walls, roof insulation and under-floor insulation and as part of timber-framed building. It also offers good thermal and acoustic performance and the ability to regulate internal relative humidity through

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hygroscopic material behaviour, contributing to healthier building spaces and providing effective thermal mass. It is formed by mixing together hemp shiv and a lime-based binder. The lime binds the hemp aggregates together, giving the material modest structural strength and stiffness. Lime also protects the shiv from biological decay, mainly through its ability to wick water away from the hemp shiv and its high alkalinity, as well as providing essential fire resistance. Hemp lime can be used to form solid non-load-bearing panels or blocks, typically as part of timber or other framed buildings. By varying the mix design, hemp lime materials may also be used in denser or lighter composites for floor insulation and roof insulation.

Hemp lime has been under development since the early 1990s, mainly through work in France and Belgium, but also including research work in the UK, funded by DEFRA (Department of Food and Rural Affairs) through the NNFCC (National Non Food Crops Centre). There are over 50 hemp lime building projects in the UK, including houses and even large industrial buildings. All have attracted considerable attention from professionals and the media. A particular benefit of hemp-lime construction is its capacity to sequester CO_2 into the building fabric. As government policy becomes increasingly concerned with reducing carbon emissions and finding more efficient ways of meeting current targets, it seems possible that hemp lime can make a major contribution to this offering a genuinely zero-carbon solution to sustainable construction.

2. Non-food crops

Natural fibres and crop-based materials are being widely used in building construction today. Timber is a natural crop-based material, but good-quality construction timber takes a long time to grow. It has been recognised, for some time, that the forests of the world are vital in terms of maintaining ecological balance so timber should be used sparingly. However composite engineered timber, wood fibre and wood waste products are becoming more and more important and we try to use these with hemp lime.

Hemp is mainly grown for fibre, which is used in bio-composites and insulation with the manufacturing of these products taking place mainly in UK, Germany and Poland. It is also used for seed to produce oils that are used in a number of applications including cosmetics and foodstuffs. The stalk of the plant, normally known as the hurd or shiv, was seen as a waste by-product and has been sold for many years as horse bedding to stables and farms. However, it was realised that the shiv could be used to produce a unique building material.

When hemp is harvested the plant is left to 'ret' on the ground for three to four weeks. The stalks are baled and taken to the processing factory where the fibre is stripped off (de-cortification) leaving the woody core or stalk behind. This can be chopped up into small lengths and used as an aggregate. Mixing the hemp shiv with lime-based binders produces a form of lightweight concrete.

Crops like hemp can be grown in rotation with food crops to improve the soil and reduce weeds and thus they should not be seen in the same terms as food crops grown for bio fuels. Hemp instead can be grown as a food crop with only the left-over hurds used for construction. Even if we built all the new houses in the UK from hemp this would only require farmers to use a tiny proportion of available land. Hemp assists food production rather than competing with it.

Processing hemp is an important issue. Currently it is grown throughout southern England but has to be transported to a large new factory in Suffolk for processing. In the long term there could be more regionally based hemp processing factories reducing transport costs and energy. Stripping the fibre from hemp and processing the shiv requires machinery to be economical. In the past hemp was processed by hand but this was extremely hard and time-consuming work, however there is a lot of interest in lower-tech methods particularly for use in developing countries where there is growing interest in hemp (especially southern Africa).

3. Hempcrete or hemp lime

Mixing the hemp shiv and lime with water creates a lightweight lime and hemp mixture that is sometimes referred to by the generic term hempcrete. The proportions of the hemp lime can be varied according to the density and characteristics required. Suppliers of proprietary hemp lime materials, such as *Tradical Hemcrete®*, will indicate the correct mix proportions of lime binder to hemp.

Once the material is mixed with a small amount of water it resembles a sticky porridge that can be cast into walls, roofs or floors to produce a solid insulating mass using shuttering or by spraying. This mass is solid enough to hold together quite quickly but then takes a while to dry out and cure. Drying and curing time will vary according to the mix, climatic conditions and so on, but is normally about four weeks. This may seem like a disadvantage when so many building methods offer quick-fix solutions. However, the hemp-lime mix is solid almost as soon as it is cast and shuttering can be removed immediately or after 24 hours.

When the material has dried out it becomes a strong and solid composite which creates a weatherproof mass providing thermal insulation, thermal storage and a substrate, which can take a variety of finishes. The normal practice is to construct a simple timber frame or sub frame which provides the principal structure of the building supporting any floors and roofs, the hemp lime is then sprayed or cast around the timber frame to provide solid walls, and possibly floors and roof.

As well as being used for new construction, hemp lime can be used for the renovation and repair of old timber-framed buildings as a sympathetic replacement for the original wall infill or as an insulating plaster on old masonry. It can be cast or plastered onto old masonry walls improving thermal performance whilst retaining the thermal mass.

The main advantage of using hemp and lime is that it simplifies construction. Most timber frame systems have quite complex build ups and often have difficulty in achieving target air tightness standards. This should not be a problem with hempcrete as it is a very simple building method that can be grasped by ordinary builders within a few hours of instruction.

4. Growing, production and supply

Both the hemp and lime are produced and processed in the UK. A consortium of companies has invested heavily in promoting a proprietary product called *Tradical*® which uses hemp from Hemcore and a lime-based binder manufactured in Abingdon in Oxfordshire. It is possible to produce hempcrete buildings using local grown hemp and other lime binders but the advantage of using the proprietary product is that it has been developed scientifically and also has building control approval for use throughout the UK. The Hemp Lime Construction Products Association (HLCPA) is affiliated and linked to other mainstream trade and industry bodies, such as the UK Construction Products Association and accredited companies that can spray hemp and lime into walls.

5. Hempcrete performance

Information about the performance of hemp and lime is growing as a result of a number of scientific studies that have been carried out in the UK, France and Belgium (University of Bath, Centre for Alternative Technology, Catholique Universite de Louvain, and the ENTPE in Lyon). Not all of this work has yet been published.. Because of the unique characteristics of the material and its unusual performance scientists have been fascinated to discover why a simple mixture of hemp and lime exhibits so many interesting beneficial properties. In particular the scientists have focused on thermal performance, the role of water and moisture in the material and its acoustic properties. Less has been done on structural issues as it is assumed that structural loads will be taken by a frame. The focus on water and moisture came about as the early pioneers of hemp and hydraulic lime soon realised that there was a competition for the available water between the hemp and the lime when mixed and this could cause problems. Because hemp is able to absorb a great deal of water, when the initial set is taking place it is possible that too much water is absorbed by the hemp and not enough is available to the lime to ensure proper setting.

In a similar way to timber, the cellulose material in hemp can absorb water without damage providing it is able to dry out again. In the past synthetic building materials have been developed to repel or not absorb water as it was thought this was the best way to ensure a longer life and avoid deterioration. Thus it involves a shift in thinking about building materials to welcome the ability of a material to cope with water. Once the hemp and lime composite has dried out and the lime has set the moisture content of the material will fluctuate as driving rain hits the outer surface or moisture is absorbed from the atmosphere or indoor humidity. Being able to absorb moisture, particularly internally, ensures a breathing wall and will reduce the relative humidity and improve the indoor air quality of buildings. The moisture content in the material also serves as a thermal buffer helping to store heat and improve thermal performance.

Work on hygroscopic performance has largely been in laboratory studies and computer simulations. The leading scientists in this area are Evrard and De Herde at the Catholique Université de Louvain. The work of Evrard and De Herde has confirmed that hemp lime is hygroscopic; absorbing and releasing moisture in response to changes in atmospheric conditions. This hygroscopic performance has beneficial aspects to prevent condensation and control internal relative humidity, with consequential health benefits for building occupants. It has been proposed that hemp lime absorbs and releases energy, as moisture is released or absorbed, giving the material a unique apparent thermal mass and latent heat energy not normally associated with such a lightweight material. The dynamic sorption tests showed that buffering of the LHC-wall mixture ('Lime Hemp Concrete') was high. Future experiments should also focus on a precise analysis of pore size distribution in LHC to go further in explaining why retarded sorption phenomena is more significant in this particular material than in other mineral materials.

Concerning the thermal conductivity and its relation to water content, it is interesting to notice that moisture induced variation on measured values could come from a latent heat effects due to moisture evaporating at the hot plate and condensing at the cold plate. The breathability of hemp and lime walls, floors and roofs allows moisture laden air to permeate the fabric and this helps with good indoor air quality. Humidity can be controlled by the moisture buffering capabilities of natural materials. This cannot be achieved with solid materials like concrete or synthetic insulations. Conventional buildings where ventilation is inadequate can develop problems with mould growth and this can be very damaging to health.

6. InsulationpProperties

From a wide range of literature the general consensus from various scientists and also the manufacturers of hemp and lime products used to be that hemp and lime composites have a thermal conductivity (lambda) value of around 0.09 W/mK. This is a conservative figure, which is being superceded as more scientific tests are carried out. For instance subsequent tests at the National Physical Laboratory indicate an improved figure of 0.07 W/mK.

Scientific work has also indicated that the thermal performance improves as the composite dries out. According to measurements made at the Fraunhofer-Institute for Building Physics, dry thermal conductivity of 'wall' mixture is 0.115 W/mK at 65%. It changes to 0.137 W/mK (Evrard, 2006)

Tests of the thermal conductivity of walls at Ralph Carpenter's house in Suffolk by Plymouth University led to an agreed reading of 0.08 W/mK. These were taken on a wall which was 200 mm thick and had been constructed a number of years ago so the walls could be assumed to have fully dried out and the lime carbonated. Based on this we calculated the R value (thermal resistance) to be 2.75 with plaster and surface resistances taken into account. The team at Plymouth

University agreed that a U value derived from this would be in the region of 0.36-0.37 W/m^2K. This empirical work confirmed a lambda value of 0.08-0.09 for hemp and lime and as this conservative figure has been repeated by so many authorities that it seems reasonable to accept this when making building regulation applications.

If a wall of 300 mm were constructed using these figures, this would have a U value of approximately 0.26 W/m^2K to 0.28 W/m^2K. This would be quite adequate to meet the new building regulations thermal standards. However experience has taught us that the actual thermal performance of hemp and lime buildings is much better than might be predicted by crude U values. More recent (unpublished) work suggests that a 300 mm wall could have a U value of 0.23.

In order to achieve much higher levels of insulation it would be logical perhaps to increase the wall thickness. Tests at the Milton Park building indicate that increased thickness will give better U values but there may be a number of reasons why it is not practicable or desirable to use very thick walls. The walls at Milton Park are nearly 500 mm thick and have an internal permanent shuttering and plaster. As we know that hemp buildings perform better than a theoretical projection it may not be cost effective to use substantially more material to achieve a further improvement in thermal resistance. The insulation performance is also related to density and thus the placement of the material by spraying or tamping can affect the thermal performance. If too dense a mix is used or the material is too heavily tamped in shuttering then the insulation value may not be as good. Spraying the material onto permanent shuttering should generally give a lower density and thus better thermal performance. The mix proportions of hemp and lime can also be varied so that by reducing the amount of lime a less dense mix will be achieved. This is normally done where hemp is used in roofs, so that it is both lighter and a better insulator. On the other hand a denser mix will be preferred in floors for greater mechanical strength. We are still learning about this. There is scope for a great deal more research on these issues, both on the theoretical aspects of thermal mass and retention and also on the performance of hemp lime structures in use.

7. Thermal mass and comfort

What the building regulations and conventional methods of measuring thermal performance do not do, is to take account of thermal mass and the ability of insulating materials to store heat and release it into the building. Thermal mass is a complicated issue because it operates in a number of different ways in buildings. Lightweight timber and steel-frame buildings, insulated with lightweight synthetic or mineral materials, may have little thermal mass and thus the fabric cannot store heat. If the building is designed to make use of passive solar gains through south facing glazing then there needs to be enough thermal mass to absorb and store this heat. However heavy construction may retain too much heat or, when the ambient temperature is cold, take too long to heat up, to ensure good thermal comfort. It has been argued that heavyweight construction will mitigate the effects of climate change (Arup and Dunster) but simply including a lot of heavy concrete in walls or floors does not necessarily guarantee success.

Heavyweight materials like solid concrete are not able to absorb and emit heat quickly and cannot buffer moisture. Other heavy low-impact materials, such as unfired earth cob or straw-clay can also provide better than expected thermal performance, though generally additional insulation is needed in order to comply with the building regulations. (Goodhew & Griffiths, 2005)

Hemp and lime on the other hand provides a happy medium of being a lightweight material with the characteristics of a heavier material which both insulates and stores heat. This allows it to respond to ambient conditions much more effectively and it balances thermal and humidity variations as required.

Lightweight synthetic insulation materials cannot store heat at all and if subject to thermal shock (sudden changes of temperature) will allow heat to flow surprisingly quickly, however good their thermal resistance. Hygrothermal materials like hemp and lime will slow down these changes (decrement factor) and thus can maintain much more stable conditions.

Thermal comfort is a key factor in how people experience buildings and even slight changes of temperature can make people feel colder or hotter if other factors come into play. For instance even in a warm building, cold drafts can make people feel cold. Humidity levels also have a very significant effect on people's comfort and if humidity is too high or too low, then people will also feel that the temperature is not right.

The BRE study of the hemp lime houses at Haverhill showed very clearly that even though the predicted U values for the hemp houses were not as good as the comparable conventional hoses, heating bills in the hemp houses have been lower. The tenants have not complained about being too cold or too hot. The BRE calculated the SAP rating for the hemp lime houses to be 77 and that for the adjacent brick houses as 87. The lower the SAP rating the poorer the theoretical thermal performance.

"Looking at the data collected by BRE using thermal and humidity loggers we find that the temperatures maintained in the hemp houses have been consistently one or two degrees higher than in the brick houses for the same amount of heat input. At a temperature of 19^{o}C people can be very sensitive to even half a degree difference and once the tenants are familiar with the way their houses work it is likely that they will start to adjust their radiators to deliver comfort conditions more efficiently. This should reduce the overall energy consumption in the hemp houses. The hemp houses constructed of "Isochanvre" (hemp) and lime should be consuming more energy than the brick control houses, which are constructed with 2 leaves of masonry separated by 100mm of blown fibre rockwool cavity fill, with 50 mm Styrofoam insulation to the suspended concrete floors and with 200 mm rockwool insulation to the roofs. This is not the case. It is interesting to note that the brick control houses meet the revised standards in part L of the Building Regulations, introduced in April 2002. It can therefore be assumed that the hemp houses satisfy the new part L of the Building Regulations." (BRE 2002)

8. Life cycle issues

The following list sets out claimed advantages of hemp and lime that have been evaluated in various Life Cycle analyses:

- Hemp does not require agrochemicals in its cultivation. Some nitrogen fertilizer may be used but there is no need for pesticides or insecticides.
- The growing of hemp is beneficial to the land and agriculture an should no detract from food production.
- The hemp fibre and seed has a number of high value uses whereas hemp and lime building is making use of a low value by product by using the shiv or woody core of the plant.
- The energy used in planting, harvesting and processing the plant material is quite low.
- As an 'aggregate' it is replacing quarried minerals thus reducing the environmental damage of stone extraction.
- As an insulation it is replacing synthetic fossil fuel based materials which consume energy and emit toxic chemicals during manufacture.

- As an insulation it does not require the addition of toxic chemicals used as fire retardants such as phosphates or PBDE's (bromine based materials).
- Carbon sequestration - Hemp, in common with all similar plants, transforms carbon dioxide during its rapid growth and captures carbon, releasing oxygen to the atmosphere. This has a positive effect in achieving the sequestration of the principal greenhouse gas CO_2 that is absorbed by the plant. Using the plant in construction "locks up" this carbon dioxide in the fabric of the building.

9. Carbon sequestration and CO_2 emissions

Calculations carried out by Lime Technology Ltd suggest that CO_2 sequestration can be estimated using the following formulae (*see below*).These formulae provide a method for calculating how much CO_2 is absorbed during the growing of the hemp plant. All plants absorb CO_2 and emit oxygen and this is essential for human life on the planet. This makes it possible to calculate the amount of carbon dioxide saved by the hemp, which can then be stored in a hemp-lime building.

Lime however emits CO_2 during its manufacture as fuel is burned in lime kilns. This must be deducted from the CO_2 saved by the hemp. All CO_2 emitted from the calcination of the limestone can be re-absorbed upon full carbonation but the CO_2 emitted by the burning of the fuel is not re-absorbed. During the life of a building any lime uses slowly carbonates (absorbs CO_2 from the air) however this does not offset all the CO_2 used in the original manufacturing. Thus it is necessary to allow for CO_2 emissions from manufacture and transport of the lime binder. Taking this into account with the sequestration of the hemp gives and overall figure. It is claimed that **approximately 110 kg of CO_2 can be sequestered into every cubic metre of hemp and lime walling material**. This figure will be higher if a smaller proportion of lime is used in a less dense mix such as for roof construction.

Lime-based binders are formulated with materials that have lower energy demands in manufacture compared with materials such as cement. The lower kiln temperatures and lower density of air limes make the products less energy intensive than other common alternatives. However lime is still responsible for some CO_2 emissions. The Tradical proprietary lime binder for use with hemp does contain some cement and other additives, but the energy used in this manufacture has been taken into account in these calculations.

Photosynthesis:		
$6H_2O + 6CO_2$	→	$C_6H_{12}O_6 + 6O_2$
6(18) + 6(44)	→	180 + 6(32)
Glucose to cellulose:		
$C_6H_{12}O_6$	→	$C_6H_{10}O_5$ + H_2O
180	→	162 + 18
$\frac{6CO_2}{C_6H_{10}O_5}$	= $\frac{264}{162}$	= 1.63 (actual figure 1.84)

Formulae calculating CO_2 absorption by hemp plants during their growing

The following table shows that, having carried out these calculations, it is possible to state that a cubic metre of hemp-lime wall can lock up over 100 kilos of CO_2 whereas conventional building wastes a similar amount. There are very few building materials that can make this claim. There are those who have questioned these calculations but however they are carried out there is little doubt that hemp-lime structures act as a carbon sink. Independently compiled figures at Bath University also show Hemp Lime to have a relatively low embodied energy.

Table 1 Summary of carbon sequestration for hemp-lime

1m^3 of wall mix contains:	
110 kg hemp shiv	202 kg of CO_2 is absorbed
220 kg lime binder	94 kg of CO_2 is emitted
Net sequestration	108 kg CO_2/m^3

Table 2 Embodied energy of insulation and other materials

Insulation and other Materials	Embodied energy MJ/kg
Cellulose	0.94 to 3
Fiberglass	28
Mineral Wool	16.8
Woodwool Board	20
Hemp	15
Hempcrete	21
Recycled Wool	20.9
Expanded Polystyrene	109.2
Polyurethane	72.1
Lime	5.3
Fly ash cement	2.43
Based on figures published in the Inventory of Carbon and Energy (ICE) by Prof. Geoff Hammond and Craig Jones (SERT), University of Bath, 2008. Version 1.6 (ref)	

10. Conclusions

Much work is still to be done to understand exactly how hemp lime construction works and to validate figures for thermal performance, embodied energy, life cycle performance etc. However architects and specifiers are increasingly attracted by its characteristics when they are trying to produce greener buildings. A massive out of town retail store for Marks and Spencers has been submitted for planning approval in Cheshire, England. It is proposed to construct most of the walls out of hempcrete. Demonstrations of the use of the hemp lime material have been sufficient to convince many skeptics as to the value of natural materials.

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Further information

Information about hemp and lime construction can be obtained from www.limetechnology.co.uk or www.Lhoist.co.uk. The Hemp Lime Construction Products Association (HLCPA) (www.hlcpa.org.uk) provides a source of information, education and performance standards.

Development of a Membrane Roofing System with Integrated Climate Control for Community Shelters

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Peter Kok, Harm Hulsbergen

1. Introduction

In case of calamities and emergencies, such as wars or natural disasters, shelters offer great relief to large groups of survivors within a relatively short period of time. However, the commonly applied tent structures for sheltering generally only have a lifespan of one year, they can only offer a limited amount of space and they perform poorly on indoor climate. When sheltering of refugees is needed in an emergency situation, a large number of the small family shelters are indispensable. In addition, in the first phase of emergencies there is also a need for medical and organisational facilities as well as facilities for food distribution. In the following semi-permanent phase there is a demand for social, educational and religious facilities. For these functions the current sheltering solutions are not satisfactory due to the short lifespan and the limited amount of space. Meijers et al. (2007) observed that a solution should be developed to fill this niche. In 2005 a low-cost, low-material and flexible building system was developed for the Dutch agricultural sector by the research group of Product Development (Gijsbers, 2005). This system proved to be the starting-point for the development of a Community shelter. In fact a reverse engineering trajectory started from that point, with the aim to develop a Community Shelter which would meet the requirements of multiple stages in emergency relief and which would adopt the proven qualities of the already developed system.

In the next paragraph a description is given of the existing building system. This will be followed by the explanation of two spin-off developments, including the

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Emergency Community Shelter. The next paragraph will describe the concept for active climate control, followed by a conclusion.

2. Starting-point: Arched stable for dairy cattle

Over the last ten years the agricultural sector of livestock breeding suffered from economic and environmental concerns and issues on animal welfare. It is understood that the conventional building types cannot function properly during their long lifespan of 40 to 50 years, because of changing regulations and requirements. In addition, the widely accepted standards for buildings for dairy cattle suffered from poor indoor climate conditions, high building costs and a very low level of flexibility that makes it difficult to implement changes during the lifespan of the building. Therefore, the Eindhoven University of Technology developed a low cost and flexible building system for dairy cattle in cooperation with a coalition of leading consultancy companies (Gijsbers, 2005). This so-called Boogstal®, in English: Arched Stable, was created within the SlimBouwen® approach for building technology and product development (Lichtenberg, 2005) and was enthusiastically introduced as a pilot project in October of 2006 in Dieteren in the south of the Netherlands. It proved that a rather slim and low-cost construction, covered with a double-layered membrane, can be assembled and installed within a relative short period and it makes it possible to offer the cattle and the farmer a high level of comfort. The building has been developed to deliver a stable indoor climate of 0 to 20°C, which is the thermo-neutral zone of dairy cattle.

Figure 1a & b   Pilot project Arched stable for dairy cattle in Dieteren (The Netherlands)

Figure 2 Detail of the roof: truss structure, upper and lower membrane and ventilation openings

2.1 Modular structural system

The basis of the modular structural system exists of straight steel truss elements with a triangular cross section. By adding specific angled connection elements to the system, the trusses can be assembled to a number of arches with a span varying from 30 to 50 meters. The building height can be chosen from 6 to 12 meters, depending on the size of the span. Building length may vary from 20 meters to any desired size by the addition of more arches to the structure. The foundation of the arches is created by two relatively small reinforced concrete beams that are as long as the total length of the building. Bracing elements in between the arcs provide cross directional stability.

2.2 Passive climate control

In-between two adjacent arcs, a double layered membrane is placed as roof covering and to create a natural ventilation system that can be adjusted depending on the amount of ventilation needed.

The roof is primarily designed to keep the indoor temperature low in case of high outdoor temperatures. Dairy cattle are able to withstand cold temperatures easily; therefore the building is not insulated. However, they are highly sensitive to temperatures above 25 °C, which cause heat stress and lower the production of milk drastically.

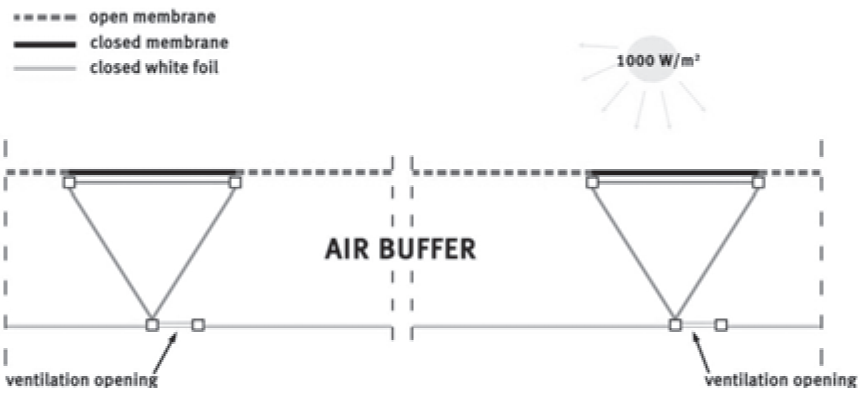

Figure 3 Detail of the roof, on top a windbreak mesh and below a semi transparent foil

The double-layered roof (see Fig. 3) consists of an outer layer of 55% open windbreak mesh which tempers the wind speed, but more important it blocks the major part of sun radiation. Subsequently, a part of the collected heat in the membranes will flow away through the air buffer in between of the two layers because of convection. Heat from inside the building can get out through the large amount of ventilation openings by buoyancy induced flow (stack effect) and because of air movement at wind speeds over 3 m/s.

The lower layer of white foil keeps rain outside. Underneath the truss elements, which are closed on top, there are small open strips for ventilation purposes that have the total length of the structural arc. This results in a homogenous and sufficient ventilation flow through the building, which is proven by the lack of condensation and the stability of indoor temperature and humidity during the monitoring phase of one year (Gijsbers et al. 2007). The white foil prevents direct sunlight from entering the indoor space and creates a diffuse and natural transmission of daylight. This results in a light intensity that is generally comparable to outside conditions on a cloudy day all year round that is an enormous improvement on indoor comfort compared to traditional housing for dairy cattle.

In comparison to a normal single layered roof without insulation (for example sheets of corrugated iron, fibre-cement corrugated sheeting or a single layer of foil), there is approximately 75% less heat flow during a sunny day (T_a = 30°C; sun load = 1000 W/m^2) on the inside of the building. The surface temperature of the roofing material is also significantly lower: 85°C in the case of a single layered roof and

35°C in the case of a double-layered roof. These numbers result in a large increase of indoor comfort during hot temperatures.

2.3 Results and conclusions

The development and realisation of the arched stable produced new and valuable information on: modular and flexible arched structures with large spans, availability and usage of membranes, passive climate control and a general impression of the atmosphere within a large membrane covered space. The system has been monitored for a year and it proved to be technically and financially feasible (Gijsbers, et al. 2007), Therefore it was chosen to be translated for the use for other purposes.

The most important benefits of the arched stable compared to an ordinary stable for dairy cattle are: up to 30% decrease of building costs, 50% less weight and use of materials, a short and efficient building process, flexibility on the product and building level and a significant improvement of indoor climate conditions.

3. Case developments

Most functions demand higher indoor thermal qualities than dairy cattle. To make the Arched Stable concept suitable for functions like a Community Shelter, the membrane roofing system has to be further developed into a system for active climate control. A newly introduced concern in this development, in comparison to passive climate control, is energy efficiency. Consequently, the building has to be conditioned with a minimum of building services.

Beside the development of the Community Shelter, a parallel spin-off project is being developed based on the Arched Stable for dairy cattle, which concerns an Arched Stable for pig breeding. The developments in these two projects run alongside because both are in need of active climate control. The two cases set the boundary conditions for the development of the active climate control of a multilayered, energy-efficient membrane roofing system. The Community Shelter will be described first, followed by the Arched Stable for pig breeding.

Figure 4 The Community Shelter during the phases of emergency relief

3.1 Emergency Community Shelter

Tents and other forms of easy-to-install lodging are often used in the case of direct aid and relief after calamities and wars. However, as explained in the introduction, the commonly applied tents fail in providing long term facilities that are necessary for community purposes, while most refugees spend a number of years in refugee camps. Refugees are in desperate need of medical and organisational facilities as well as facilities for food distribution on the short term, and social, educational and religious facilities on the long term. For these functions the current sheltering solutions are not satisfactory due to the short lifespan and the limited amount of space.

The Community Shelter is a newly introduced concept and is developed in association with a humanitarian organisation. The aim of the development is a lightweight, demountable building system with integrated climate control which can be deployed quickly and easily after and during calamities. The system should be able to undergo functional changes during different phase of emergency relief. Figure 4 gives an overview of the phases of emergency relief provided by the Community Shelter.

The different steps and requirements of the Community Shelter in figure 4 can be described as follows:

1. Transport: 30 ft container, basic layout of 4 segments, operational within 24 hours
2. Assembly: intuitive and logical assembly of light weight elements by handcraft, clever connection techniques, easy to understand (picture) manual, colour coding
3. Point of recognition: span of 20 m, height of 5 m, bright colour use, pictograms printed on skin
4. First Aid facilities: instruction of aid workers, registration of refugees, hand out of family shelters, acclimatised medical facilities, food distribution
5. Extension: beginning of refugee settlement, extending of system, flexible division of indoor spaces
6. Community Centre: centralised social function
7. Long-term facilities: flexible change of functions, space for religion, education, sanitary, trade and other social functions
8. Disassembly: back to storage or direct re-use in other places for emergency relief

In an emergency situation there is a limited amount of energy available for conditioning of the indoor space. Therefore, the building climate has to be controlled without the input of energy (Meijers et al., 2005; Kok et al., 2008).

The reliability of the system is one of the most important properties in developing of a shelter. The system must be 100% fail-proof and able to be easily assembled by refugees. The shelter will be firstly developed according to a combination of shelter standards (Shelter Centre, 2007) and the Dutch building regulations. For example, the Community Shelter has to resist a wind load up to 120 km/h and the shelter must be able to provide an adequate indoor climate at extreme outside conditions (-10°C).

3.2 Arched stable for pig breeding

The second case in development is Arched Stable for the breeding of pigs in the Netherlands. In this case the indoor climate demands are also high because of growth rates. A stable climate of approximately 20°C has to be realised the whole year round, regardless of the outside climate conditions (Haas, 2008; Hoeve, 2007).

The pig breeding industry is a traditional industry that relies on existing and proven technologies. Another important characteristic of the industry is the high indoor heat generation caused by the metabolism of the animals that leads to high indoor temperatures and a surplus of warmth. However, cooling concepts are rarely applied because of the high initial investment. As with dairy cattle, this sector is also under pressure because of environmental and economic issues and regulations. Therefore a low cost and flexible building could be a solution, but only if the indoor climate will be sufficient to preserve the economic standards. Here also lies a chance for energy-efficient active climate control.

3.3 Case comparison

The internal climate conditions for both cases are, oddly enough, nearly alike. Both applications demand a stable indoor temperature of 20°C and a high level of indoor lighting (minimum of 200 lux) in spite of varying outside conditions. The main difference between both applications is the ventilation rate. The ventilation rate inside the pigsty is substantially larger than the ventilation rate in the case of human inhabitants because of air pollution, although both are high, compared to normal dwellings (see Table 1).

Table 1 Comfort conditions for humans and pigs

Condition	Humans	Pigs
Comfort temp.	20°C	19 - 22°C
Ventilation min.	3,2 $m^3/h/m^2$	8 $m^3/h/m^2$
Ventilation max.	35 $m^3/h/m^2$	80 $m^3/h/m^2$
Air speed max.	0,20 m/s	0,20 m/s
Humidity	40-60%	60-80%

4. Climate control

The concept for climate control of both cases can be divided in two parts. First, to minimise the loss of energy that is already inside the building, a layer of insulation will be integrated into the roofing system. Second, to ensure a stable indoor climate, heating and cooling have to be applied. In addition, the measures to condition the indoor climate have to be energy-efficient, preferably self-supporting zero-energy solutions. Therefore, a solution is found in an integrated heat recovery roof, where the heat generated inside the building will be efficiently reused for the heating of the ingoing ventilation flow. In this section the insulation solutions and the heat recovery roof will be explained.

4.1 Insulation of roof

One of the advantages of the roof of the Arched Stable is the large amount of daylight entering the building that gives the inhabitants a day and night rhythm. By adding a layer of insulation like mineral wool to the roof, the advantage of daylight will be undone. For some purposes that is not a problem, for example where artificial light will do, but when issues like day-night rhythm (pig breeding) or energy-efficiency (Community Shelter) are concerned, direct daylight is definitely preferred.

In situations where daylight is needed, a layer or cushion of air can be added simply by tightening an extra layer of foil to the structure. When heated or cooled off, the air is able to freely flow in between the foils. Therefore, the insulation value is not very high. The layers of foil need to be applied in an airtight manner, to reduce the airflow inside to a minimum. The maximum leakage rate is restricted to 500 mm^2/m^2 according to DIN EN ISO 6946 (2003). Secondly it's important to know that a layer of 'standing' air above 15 mm of height will never result into a larger heat resistance. The distance, therefore, may be chosen on practical grounds. However, when the layer of air becomes too large, the air flow inside only decreases the thermal resistance.

A single layer of 'standing' air of 50 mm results in a thermal resistance of 0.16 m^2K/W. For example in the Arched Stable for pig breeding a roof layout is chosen of 2 layers of 'standing' air, see Figure 5. This results in a total thermal resistance of 0.50 m^2K/W (U_{tot} = 2.0 W/m^2K), comparable to 20 mm of mineral wool, which is satisfactory for this purpose. The foils are fixed under high tensile strength.

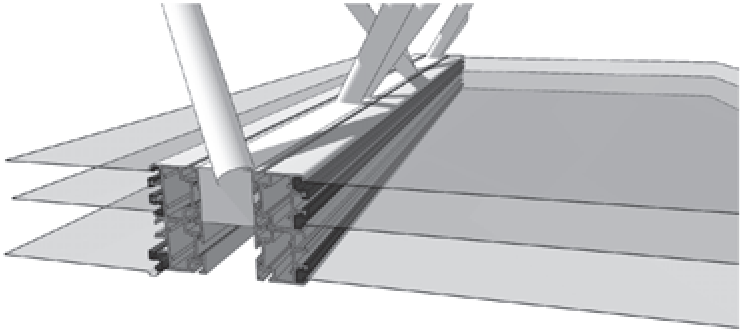

Figure 5   Membrane roof with 2 layers of 50 mm of 'standing' air, U_{tot} = 2.0 W/m^{2}K

Field tests have shown that if the tension in the foil is high enough and the air tightness is sufficient, the layer of air will always remain approximately 50 mm, independent of pressure differences (wind, indoor ventilation) over the roof. This is due to the stability of air pressure in between the foils.

In case of the Community Shelter it is possible that a thermal resistance of 0.50 m^{2}K/W will not be sufficient. For example when a value of 1.0 m^{2}K/W is compulsory it may be possible to add a layer of 10 mm Pyrogel (λ = 0.012 W/mK) or 30 mm mineral wool (λ = 0.04 W/mK). However, this will diminish the amount of daylight entering the building drastically.

4.2 Heat recovery roof

In the described cases where energy is limited or not available (Community Shelter), or where energy use has to be limited for economical reasons (Arched Stable for pig breeding), heating up and ventilating large spaces are the main problems. The shelter roof may be able to integrate three functions in this case. The first is weather resistance as building envelope, the second one is active climate control and the third is energy-efficiency. Because a substantial amount of ventilation is needed for emergency shelters and pig stables, that air must be fresh; the air is most likely to come directly from the outside. When outside temperatures are lower than the demanded inside temperature, heating is necessary. In emergency situations this will most likely be in the colder areas around the globe and during night time in the majority of possible locations. Therefore, the following concept has been developed, which is based on the technique of heat recovery units as used for residential purposes.

The concept

The concept of the roof consists of the integration of the existing roof and the principle of a heat recovery unit. To make active climate control possible using this combination, the solution is sought in the application of multiple horizontally distant layers of semi-transparent membranes, because of its ability to preserve the entrance of daylight.

Underneath a layer of insulation (Fig. 6: (1)) heat recovery by large turbulent counter flows will provide an energy-efficient pre-heating of indoor air. Extra layers, for instance made of foil, can be added to the roof so room for the airflows can be realised (Fig. 6: (2,3)). By using a small and energy-efficient ventilator, for example on solar power, these flows can be put in motion.

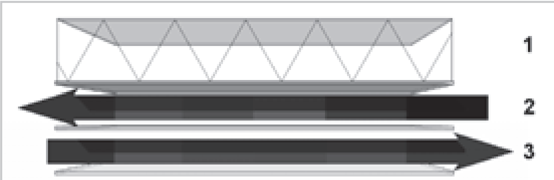

Figure 6 Concept lay up; insulation layer (1), outdoor air (2), indoor air (3) (windbreak mesh on top not displayed)

Calculation

For the determination of design parameters of the system, a model has been made to estimate and validate the efficiency of the design principle. The model is set up by the serial calculation of a large number of simplified cells (see Fig. 7). In this calculation the influence of temperature, transition coefficient, air speed and specific measurements have been implemented.

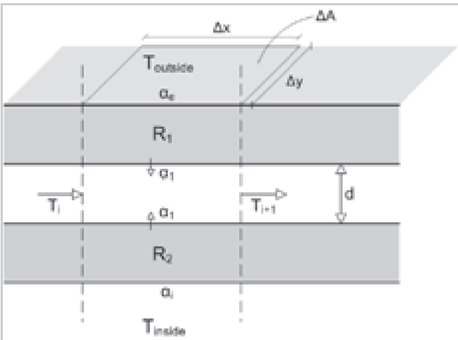

Figure 7 Calculation model with simplified cells

In the calculation, in contrast to a heat recovery unit, only one layer of flow and counter flow are applied. In practice this is not a problem because the whole roof can be used, which provides enough surface area for the exchange of heat. The main characteristic that determines the efficiency of the principle is the transition coefficient concerning the exchange of heat in between of the counter flows. To achieve the best performance (largest transition coefficient), the flows should be turbulent, not laminar. In addition, the height of the channels should be as small as practically possible and the air speed must be as high as possible. Calculations prove that the principle is efficient in consideration of the boundary conditions. Figure 8 shows an example of calculated air temperatures of the inward flow at a variety of flow lengths and different outdoor temperatures. The indoor temperature (outward flow) is set at 20°C. In this case a channel height of 30 mm has been applied. After setting the right basic measures and needed values, the model provides valuable information about possible materials to use and airspeeds that are feasible according to design parameters

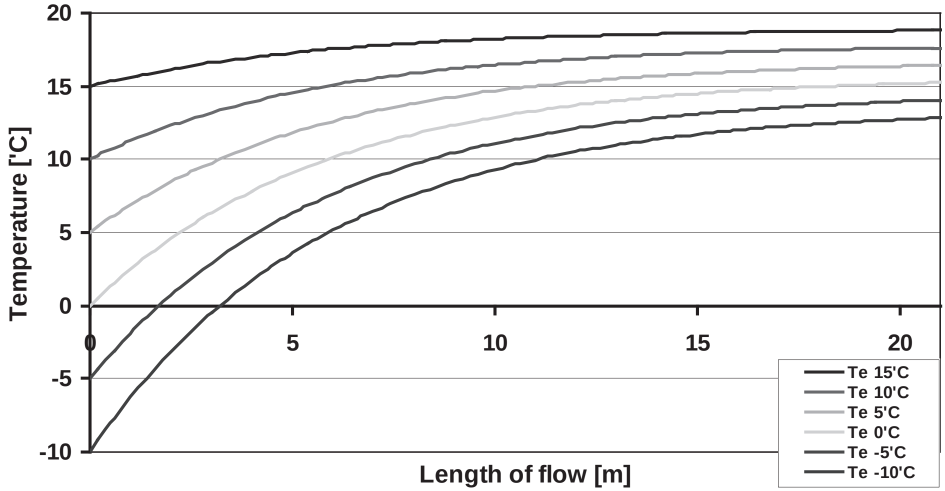

Figure 8 Results of inward flow temperatures at different outdoor temperatures (T_e) and flow lengths

Materialisation

After calculation, the earlier suggested use of foils for the channel walls was found to be a problem. The distance between the foils must be around 30 mm to function properly. However, when the air flows create under-pressure in the channels, the foils will most likely collapse towards each other. This problem can be solved by replacing the channels of foil by a triple walled semi-transparent polycarbonate panel with channels of 26 mm high (see Figure 9).

The daylight advantages as mentioned before will be preserved when using this materialisation. On top of the polycarbonate panel, an insulation layer will be applied that exists of three layers of PE foil that close in two layers filled with ‘standing’ air.

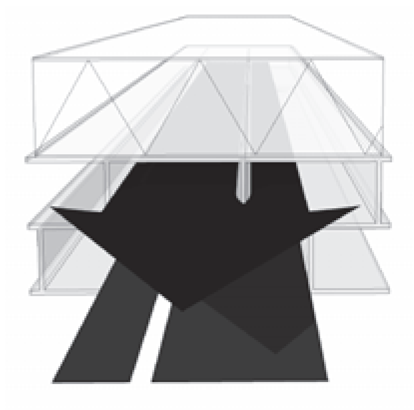

Figure 9 Final lay out of the heat recovery roof (windbreak mesh on top not displayed)

4.4 Practical solution for the Community Shelter: low-cost high-volume heat recovery unit

When outside temperatures reach far below zero the heat recovery roof can not provide a comfortable indoor air temperature by itself. Because of the high ventilation capacity needed in emergency shelters (approx 30.000 m^3/h), a special heat recovery unit is preferred. Regular heat recovery units are made of aluminium and are, therefore, very expensive and quite fragile. To solve this problem, a low-cost high-volume heat recovery unit made out of foil is developed at the moment within the chair of Product Development.

5. Conclusion

Calculations proved to be promising; therefore, the next step is to build a prototype in order to validate the calculation model. At the moment, a scale test of the emergency Community Shelter is in preparation. When scale testing proves to be satisfactory, plans are to start a pilot model for 1:1 model tests in association with an international aid organization. Not only technical and financial aspects are reviewed, but also the logistic part will be considered. Furthermore, a demonstration project of an Arched Stable for pig breeding will be built in 2009, based on the Arched Stable with an insulated roof. This stable will again be monitored; in the future the total concept can be optimized and the calculation models can be refined.

The most important conclusion of this research project is that it proves to be possible to develop comfortable and low-cost buildings for emergency situations, which include added values like flexibility, climate control and energy-efficiency at very competitive price levels. It results in a humane solution without the use of energy consuming techniques and with respect to the requirements of the refugees in need of relief.

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PART C

MANAGEMENT AND TRANS- FORMATION

The Promising Combination of Sustainable Housing Transformation and Industrial, Flexible and Demountable Building

Prof. Anke van Hal, PhD MSc[21]

1. Introduction

The existing housing stock is extremely valuable and challenging, not only because of the social vulnerability but also as a result of the European CO_2 emission goals. These goals, a reaction to climate change, demand a totally new approach of the renovation of existing houses. A total renewal of techniques, procedures, regulations and financial systems is necessary. Creativity is essential as well as design, technical and process knowledge. An industrial, flexible and demountable (IFD) approach seems promising.

The goals set in reaction to global climate change are extremely ambitious. The overall European goals state that by 2020 the CO_2 emission must be reduced by 20 percent compared to 1990. Several national governments set even higher goals. The Dutch, for example, raised this standard to 30 percent. However; with the current economic growth the CO_2 emission shall, without any restraints, grow by 20 percent. This means that in Europe the goal is not a 20 percent reduction against 1990 but a reduction of 40 percent. The Dutch even strive for a halving.

The European government also wishes for 2020 that 20 percent of the energy used is produced sustainably. At this point in time in the Netherlands only two percent of the energy is produced sustainably, mainly through sun and wind.

A large part of these goals needs to be met with the existing housing stock. Dutch housing is responsible for 20 percent of the national CO_2 emission. On top of that, houses built each year account to only a little over one percent of the 7 million existing ones. Until 1995 just a few requirements were set for energy-saving

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measures and therefore a great part of Dutch housing does not meet recent criteria. Almost seventy percent of the Dutch housing stock needs extra insulation, such as insulated floors, insulated roofs, insulated fronts and double glazing to reach the recent standard of newly built houses. To make everything even more ambitious: there is an immense time pressure. 2020 is only 11 years from now. Taking the described goals into account the world must look totally different by then. To be able to reach these goals using high-efficiency boilers and insulation is just a first step.

In theory the easiest approach to tackle this challenge is demolition and reconstruction. In practice however, demolition is not an option in the Netherlands. Only 0.25 percent of existing homes are replaced each year. This means that houses should endure almost 400 years instead of the assumed period of 50 years (the calculated economic lifespan of a house).

Another argument for avoiding demolition is that people find existing things valuable. Existing housing is different from new housing by the fact that people already live there. These people have come to love their homes and neighbourhoods. This love does not disappear as soon as technical and social problems appear. The human factor plays an important role in the approach of housing. Plans for demolition may be met with great resistance. Based on these facts it may be concluded that instead of demolition and reconstruction, Sustainable Housing Transformation (SHT) should be the goal.

2. Sustainable Housing Transformation (SHT)

Sustainable Housing Transformation addresses sustainable transformation of existing housing and neighbourhoods. The interpretation of the term sustainable has broadened with time. The environment used to be the focus point of attention. Following Elkington’s introduction of the Triple-P approach the environment (Planet) still has attention, but now completely in correlation with the interests of man (People) and the economical interests of all parties involved (Profit).

Concerning the interests of people with Sustainable Housing Transformation: they wish foremost to live comfortably at low costs in attractive and safe neighbourhoods. The economical interests (Profit) are less easily summarised since they may vary considerably. Think of lowering the costs of living for residents thanks to energy-saving systems. But also business benefits for market parties reside under profit. For example, the rising real estate rates or competitive advantages for market parties. Especially this P of Profit entails an immense change. In the past, taking care of the environment was considered opposed to successful business dealings. Fortunately that opinion is no longer held. Making money is allowed, as long as the environment also profits from it.

Two extremes of Sustainable Housing Transformation are ‘stripping’ and ‘pimping’. Stripping is removing everything until only the structural frames of the houses are left and floor plans can be newly arranged. Such an approach may be well combined with the installation of new techniques. However, people have to move, which is an enormous social disadvantage of this approach. It must be possible to make extensive changes while homes are occupied. At Nyenrode, the Dutch business university, in the innovation lab for building renovation, it is investigated how houses can be made more sustainable without forcing a move. ‘Pimping’, this approach was called. Especially houses built in the sixties and later are very standardised. For that reason an industrial, flexible and demountable (IFD) approach seemed promising.

3. IFD

Industrial, Flexible and Demountable construction principles are not new. For some time now, innovative designers and suppliers have been active in developing new industrial concepts and products for the construction industry which could justifiably be included in the IFD category. The use of industrial building methods for offices, schools and factories has become more or less common practice. In circumstances leading to pressing demands for temporary accommodation, as the result of natural catastrophes or war, IFD construction methods have proved to be a natural choice because of the speed by which buildings can be erected and the fact that a uniform solution can be offered in response to tremendous volume requirements. In the conventional market, uniformity becomes a less valued factor; ‘modules’ and ‘industrial products’ are anathema to the companies and organisations commissioning constructing work. They want the building to reflect their own identity, not just to be one of many. A solution to this dilemma can be found in flexible product automation whereby standard basic modular products can be adapted to the customer's specific requirements and desires from project to project.

To date, however, developments seem to come to a halt after the one-off application of an IFD concept or product in a single project and it has not proved possible to take the next step to products which are totally unrelated to a specific project. The construction world is not used to abstract innovation and co-operation. Compared to other industries, the construction industry spends no more than 10% of its annual turnover on R&D, and even then most of that investment can be attributed to the suppliers. The fragmented nature of the construction sector, with many small businesses, and the way in which tendering is mainly concentrated on cost-based competition, provide little incentive for innovation.

In short, while there is plenty of interest in IFD construction products and ideas from the supply side, there is little interest from the market, and IFD construction principles are still far from being daily practice in the construction industry. In recent years, however, the users of buildings have become more outspoken, and the requirements and wishes they are now expressing display far more dynamism and variation than ever before. At the same time, the market is changing from one which is supply driven to one which is driven by demand, and the principals are compelling their contractors to seek alternatives. And this is where IFD construction techniques can offer many advantages.

4. Three examples

The combination of IFD and the existing housing stock is promising. Especially the combination of IFD and the standardised existing housing stock that became common after the rising popularity of reinforced concrete. In several countries and in several projects the combination of IFD and the existing housing stock has been tested. Sometimes high goals related to sustainability have been taken into account too. Three recent examples will be shortly described; the practical 'backpack bathroom' of Heijmans Services, the energy-efficient approach of the French architectural office Lacaton & Vassal, designed by demand of the Housing association OPAC de Paris and the ambitious sustainable approach of the Dutch architectural office 2012 and building waste specialist Caroussel called (no) Flat Future.

Example I Heijmans servicebouw won the Innovation Award 2008 in the Dutch province Zeeland. The building company earned it for the 'backpack bathroom'. This is an IFD bathroom, installed through a hole in the facade. The backpack bathroom increases the floor space of the bathroom and changes the architectural performance of the houses.

Figure 1 The practical backpack bathroom. Source Heijmans Services and www.PZC.nl

Example II Two-thirds of the work of the Paris Office Public Patrimoine Construction Réhabilitation Aménagement Politique, or OPAC, is infill. In 2005 Lacaton + Vassal and architect Frédéric Druot beat competitors to reshape the Tour Bois le Prêtre, a 17-story housing tower on the city's northern edge designed by architect Raymond Lopez in 1957. The team cuts away most of the thick concrete facade's partitions, installing balconies and large sliding windows in their place. Beside opening the apartments to more natural light, the units are being significantly enlarged and opened, and new heating, ventilation and electric systems are installed.

Figure 2 Source: http://www.lacatonvassal.com/index.php?idp=56#

Figure 3 Source: 2012-architecten

Example III (No) Flat Future of the Dutch architecture office 2012 and building waste specialist Caroussel is a study focused on creating architectural quality and energy efficiency of high-rise apartment buildings of the period 1960-1970 by the re-use of demolition waste . In the proposal the project will be stripped. The approach of the façade however is an interesting point of view in relation to the discussion about IFD and SHT.

5. Conclusion

Initiatives like the three projects presented show the challenge and 'fun' of the combination IFD and SHT. This combination requires a totally new way of working and thinking but also the indispensability of the input of the skills of innovative architects. In the Netherlands, Nyenrode Business University and the Delft University of Technology cooperate closely to meet this challenge.

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Transformation of Monofunctional Office Areas

Hilde Remøy, MSc[22], Prof. Hans de Jonge, MSc[23]

1. Introduction

Building transformation is a well-known phenomenon: inner city buildings loose their function, and adapt to new use. In the Netherlands though, the scale on which since 2001 office buildings have lost their function is so far unprecedented; at the end of 2007 about 6 million square metres, equalling 13% percent of the office space in the Netherlands, was vacant. From a study of the Amsterdam office market, we found that 60% of the vacant office space is structurally vacant, meaning vacancy of the same square metres for three or more consecutive years with no perspective of future tenancy. Structural vacancy of office buildings is a problem on different levels and to different actors in the real estate market. For the owner of a building, structural vacancy means no income while the expenses of maintenance, insurances and taxes still have to be paid. Socially and on an urban level, structural vacancy is a problem of location decay and dilapidation and initiates downgrading of complete areas, a downwards movement that may be hard to turn. Building transformation is a way of coping with structurally vacant office buildings.

1.1 Objective

Former research has focused on the transformation opportunities of office buildings into housing by studies of completed transformations. Also, instruments were developed concerning the transformation potential of office buildings and the functional and financial feasibility of these transformations.

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In the Netherlands, transformation of structurally vacant office buildings into housing is interesting since the housing market is tight; there is a high demand for housing. Also, the office building typology and the typology of apartment buildings share several characteristics that - generally speaking - make transformation from offices into housing technically and functionally possible.

However, in the Netherlands 70% of the structurally vacant office buildings are situated on monofunctional office locations. These are not considered suitable for housing (Geraedts & Voordt, 2007). In our research we focused on the Amsterdam office market, the main market in the Netherlands with approximately 6.5 million square metres of office space. Also, the vacancy in the Amsterdam office market is at a high level compared to both other European main markets as well as other Dutch cities, e.g. Frankfurt and Rotterdam, both with 12% vacancy, while the vacancy in Amsterdam is approximately 20% of the total office building stock! Furthermore, some areas mainly accommodate offices, and in these areas office building vacancy of 20% implies 20% vacancy of the total building stock (*Figure 1*). Is transformation of office buildings within these areas still possible? Can urban renewal be initiated through the transformation of structurally vacant office buildings into housing? And, vice versa, what is the impact of urban redevelopment on the transformation potential of office buildings?

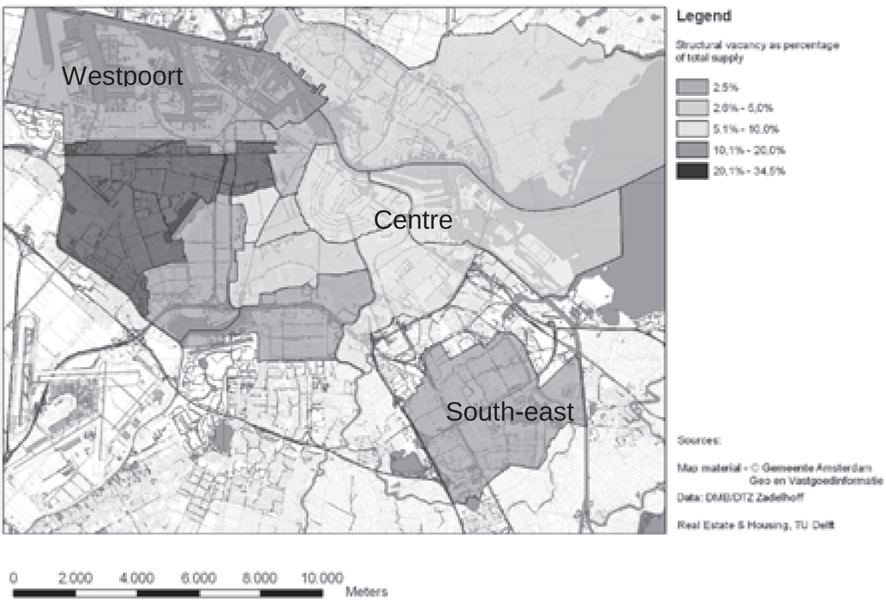

Figure 1 The level of structural vacancy of office space in Amsterdam per area

1.2 Methodology

In this chapter we present empirical results of still ongoing studies as well as theoretical background studies. We studied 220 office buildings in the Amsterdam office market to describe the building and location characteristics of structurally vacant office buildings and reveal causal relations between structural vacancy and these characteristics (Remøy et al. forthcoming). We chose a sample in which 50% of the buildings had a registered level of structural vacancy of more than 50%. Henceforth we studied the transformation potential of the location of structurally vacant office buildings in this sample using the 'transformation meter', a tool for measuring the transformation potential of office buildings by their location and building characteristics (Geraedts & Voordt, 2007). In this study we considered the location characteristics of the structurally vacant office buildings.

Finally, we interviewed 30 property developers and housing associations and asked them under which market conditions they find transformation interesting, and to which extent location and building characteristics influence the initiation of a transformation. We also asked them to assess the transformation potential of two office buildings on two different locations in Amsterdam, one situated in the centre of Amsterdam and the other in a monofunctional office area outside the centre. During these interviews photos and drawings of the buildings and locations were shown to the interviewees, who were consequently asked to consider and argue for or against transformation of both buildings.

2. The development of the office location

The industrial revolution triggered the need for office employees, migration to the cities, and urbanisation and led to spatial problems and challenges that were addressed by the modern movement: The health of citizens was threatened by the many industrial developments taking place inside the pre-industrial cities and the growing working class was accommodated in small, unhygienic and unsafe housing. As a solution, industry, offices and housing for the workers were neatly divided and connected by infrastructure and green zones, at the same time letting more light, space and air into the urban fabric. The functional zoning would not only literally provide distance between the factory smoke and the workers' homes, but also figuratively in the sense of separating work from leisure-time and recreation. The same ideals were visualised in the architecture of the time; by being spacious and admitting sunlight and air the buildings would also contribute to the health of its inhabitants. Architects at that time were fascinated by machines and designed houses as ‘living machines’, the exterior expressing the explicit function of the interior, and ‘ideal’ buildings were designed to fit the accommodated function as precisely as possible.

The ideas of the modern movement were presented in the ‘Charter of Athens’, a report on the 1933 CIAM (Congrès Internationaux d'Architecture Moderne) meeting in Athens, though not published until 1943 (Frampton, 1992). Their ideas were radical and foresaw the complete demolition of historic cities; comprehensive redevelopment was seen as the one possible solution for dealing with obsolete historic legacy, as in Le Corbusier’s Plan Voisin for Paris (Le Corbusier, 1931).

In the Netherlands, as in the whole of Europe, the ideas of the modern movement, though developed in the 1930s, were not introduced in the urban development until after the Second World War, when large scale reconstructions and extensions of the existing urban fabric were needed after years of low construction activities. In the Netherlands, post-war developments were mainly extensions to the existing cities, also comprising the first office areas that were developed near the urban centres. The functionalist scheme was applied to the urban design and architecture until now, resulting in functional segregation and monofunctional urban areas. Already in the sixties Jacobs (1961) and others warned against the continuous application of rigid zoning plans and comprehensive redevelopments so offensive to the working class, and disruptive to the small firms and organisations that add up to the liveability of urban areas.

Whereas the industrial city was dominated and developed by the industrial sector and the administration of it, the post-industrial city provides services for itself and for industry that has moved to other areas, regions or countries. Therefore, in the post-industrial city the functional zoning is not any more functional; the idea itself has become outdated (Tiesdell et al., 1996). According to Florida (2004), the new large working class is the creative class, consisting of knowledge workers and employees or independents working in the traditional creative industries such as architecture, (graphical) design, arts and crafts, but also comprising engineers, university personnel and employees at software or internet development companies. While the offices of the post-war years were classified as white collar factories, the creative class of the 21st century are highly skilled. They are working more or less independently, have flexible working hours, and are often able to perform their work from home, just as well as from behind their desk at the company they work for. According to Rodenburg (2005) the location is regarded an important factor by highly qualified professionals when applying for a job; the city centre or multifunctional locations are far more popular than monofunctional office locations. These employees do not work 8 hours a day, they have no need for a separation between their working environment and the place where they live: they demand functional integration.

3. The case of Amsterdam

Amsterdam, as many other European cities, faced an interrupted growth as a result depression of the 1930s and the Second World War. From the sixties onwards growth was concentrated in monofunctional office parks, and even though office workers express their preference for working in multifunctional urban surroundings and the most structurally vacant office buildings in Amsterdam are found on monofunctional office locations, office buildings are still being developed on these locations (Bak, 2008).

Since 2001, the office market can be characterised as a replacement market, meaning that since new office buildings are continuously added to the office market, the available supply of office space grows and lower-quality office buildings are pushed off the market by new, high-quality office buildings – new buildings drive out bad buildings. These older office buildings become part of the stock of structurally vacant office buildings, most of which were constructed between 1970 and 1990 and situated on monofunctional office locations. Examples of such locations in Amsterdam are Westpoort, situated north-west to the centre, and Amsterdam South-East (Fig 1). Both are examples of urban areas developed according to the functionalist ideals of urban planning, where office and industrial locations are separated from other urban areas by roads or railways. In the case of Westpoort, much has been done to redevelop the area and renovate the office buildings, but the functional zoning of the area has not been altered. Renovations of this kind seem to be of short-term influence, making a first five years lease possible, after which the buildings again become vacant. In the northern part of Amsterdam South-East, around the Amsterdam Arena and the Bijlmer train station has been redeveloped, adding shopping malls, a concert hall, a cinema and cafes, but this has not influenced the southern part of the area. On the contrary, the relatively new developments close to the Arena are now also experiencing vacancy after the first lease-periods ended. The structural vacancy of buildings within other locations in Amsterdam is less problematic and can be solved by dealing merely with the building, for instance by transformation.

The ideas of the malfunctioning single-use office locations were confirmed in interviews that we held with office market experts in 2006 (Remøy, 2007), and by Rodenburgs study of the Amsterdam Zuidas (2005). The reason for malfunctioning was sought not so much in the organisations' appreciation, but in the employment market and the employees' appreciation. Well-educated employees are scarce, and a good salary is not enough to convince employees to take on a job; hence, secondary benefits are important. One of the secondary benefits that are important to young, highly educated employees is a safe working environment, accessible by public transport and with urban facilities such as cafés, shops and restaurants within walking distance.

3.1 The transformation potential of office buildings

Office buildings on monofunctional office locations are seen as unsuitable for transformation. Geraedts & Voordt (2007) mention several criteria that need consideration when transforming offices into housing, of which some are classified as 'veto criteria'. If these aspects are found in the building or on the location of the building, the building is unsuitable for transformation. Serious health risk is a veto criterion and considers air pollution, noise and stench. Furthermore, the properties of the building frame need to allow for housing; the Dutch building decree demands a free height of 2.6 m from floor to ceiling. Using our sample of 220 office buildings, we checked the main properties of the buildings. However, none of the buildings had floor heights lower than 2.6 m, and the structural grid of office buildings is usually larger than for housing.

Using a GIS application, we produced a map of Amsterdam showing structurally vacant office buildings as dots, and then projected noise contours from industry, the airport, railways and ring-roads onto it (Figure 2). Additional to noise nuisance, we mentioned air pollution and stench as veto criteria. Since all are caused by industry and traffic, it was no surprise that both stench and air-pollution were found within the areas with too high a noise-level. Most offices that are not suited for housing (according to the veto criteria we used) are located within Westpoort. The structural vacancy is 15% (approximately 150,000 m^2), but as offices are mixed with industry, transformation into housing is not a possible way of

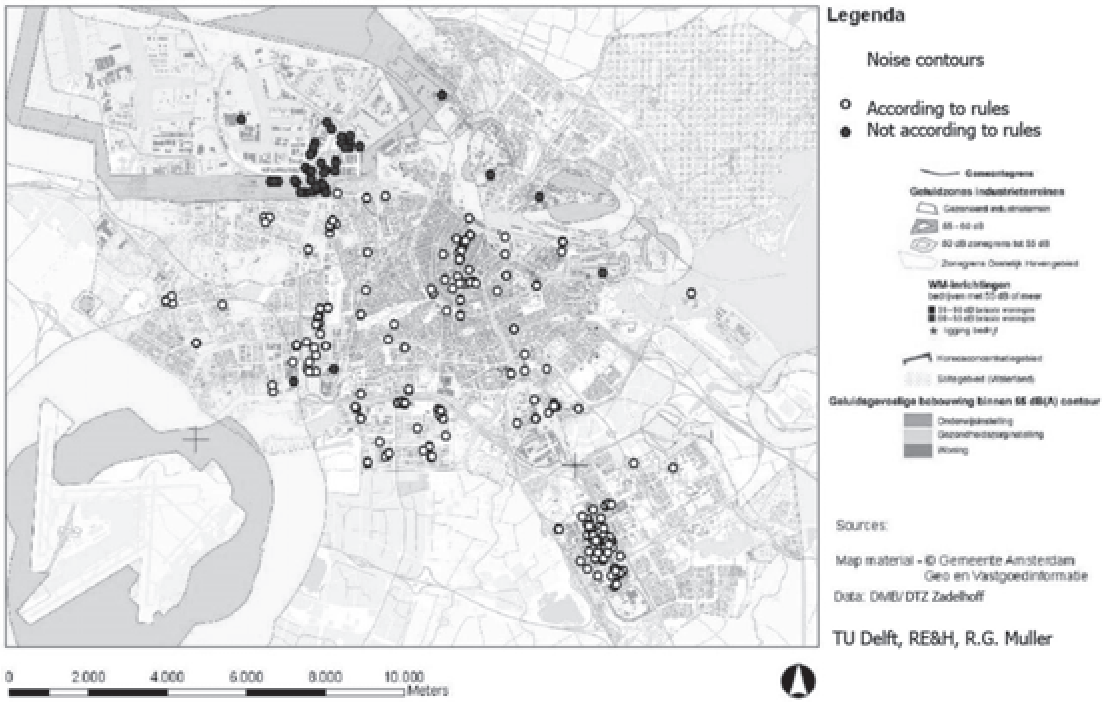

Figure 2   Inventory of structurally vacant office buildings and nuisance patterns in Amsterdam

coping with this vacancy. According to our veto criteria, the monofunctional office location in Amsterdam South-East seems to be a more interesting area for transformation. The first office buildings in this area were built around 1980 and new buildings are still under development. However, this area has a structural vacancy of 17%, and in total 200,000 m^2 of office space is structurally vacant.

3.2 The interviews

We discussed the possibilities for transformation of buildings in this area in the interviews using photos and floor plans of a typical office building on this location, comparing it to an office building in the centre of Amsterdam. We then asked whether or not the interviewees would be interested in transforming one or both of the office building into housing. Of the 30 respondents, 5 thought the *location* in Amsterdam South-East to be interesting, although 2 of the 5 expressed that functions such as a long-stay hotel or a health clinic would be more interesting than housing. All interviewees thought the *location and building* in the centre of

Amsterdam to be interesting let alone two, two took into concern that the purchasing price of the building would probably be high and form an obstacle to the financial feasibility of the transformation. The respondents' first reaction was not to be interested in transformation of the building located in a monofunctional office area, i.e. the building in Amsterdam South-East. Since their first reaction was based on both the building and the location, we asked them to be specific and first argue their view on the building, then on the location.

Figure 3   The two buildings and locations discussed in the interviews. Left the building in the centre of Amsterdam; right (two pictures) the building in Amsterdam South-East

The responses to the buildings were mixed, and could partly be explained because of the background of the interviewees. To small-scale developers the building in South-East was interesting because of its scale, while the sheer size of the building in the centre of Amsterdam was seen as an obstacle. Also half of the housing associations reacted positively on the building in South-East, seeing a potential for transformation into student-housing. For the same reason, the larger developers considered the building in the centre more interesting. While all respondents had the idea that transformation of the building in the centre will be functionally, technically and financially feasible, given that the purchasing price would be ‘reasonable’, some respondents questioned the feasibility and sustainability of investing in the transformation of the relatively small scale building in South-East. As it would need a new façade in order to be suited for housing and as problems were foreseen with regard to the adaption of building services to a housing scheme, the transformation costs would probably be high. Some suggested investing in a new building with high initial quality rather than a less strict functional scheme.

The location in the centre did not trigger much discussion. All interviewees would consider the location a scoop, though some again opted that the owner of the location – given that they know the real estate market – would ask a high purchase price. The location in Amsterdam South-East generated more discussion. Few of the interviewees were initially interested, but discussing the possibilities for transformation, three approaches were opted for, all three starting with the outlook that the whole area will be transformed. One option mentioned was to first transform some buildings into shops, gyms, restaurants and other services, then in a second phase adding housing to the program, partly by transformation and partly by demolition and new construction. A second option mentioned was to start transformation of buildings adjacent to existing housing, facilities or public transport, applying the so-called ‘ink stain method’ to slowly improve the quality of the area. The ink stain method departs from the idea that transformation of one office building into housing may inspire other actors to transform or redevelop buildings in the vicinity, so leading to transformation of a whole area by small means. However, the risk is high that the redevelopment takes a long time and investors drop off along the way. The third and most preferred option would imply an urban area development, considering the whole area as one development. Regardless of the preferred solution, transformation of one building in this area is not seen as feasible. The area lacks facilities, public transport and is not regarded socially safe. One interviewee made a point, representing the meaning of most other respondents: “Look at it this way: organisations don’t want to locate their offices here. Why would anyone want to live here?”

4. Reflections and conclusions

Our study of the Amsterdam office market shows that structural vacancy is foremost a problem in monofunctional office areas, having the highest level of office building vacancy and also with the highest impact of structural vacancy. According to the set of interviews we conducted with 30 developers and housing associations, transformation of these office buildings is only possible as part of a larger urban area development. Also, the question is whether the existing office buildings can be transformed as part of such an urban redevelopment. Many of the buildings are of low technical quality and have been designed according to a functional scheme for offices that is so tight that any adaptation or transformation is unfeasible: the facades need replacement, there are few shafts and services and a minimum of space for entrances, stairs and elevators. Though part of a larger redevelopment, the physical building characteristics would cause transformation to be unfeasible and redevelopment would be more interesting, both financially and from a sustainability point of view.

There are different ways of initiating an urban area redevelopment. However, it is a challenging task and is much more complicated than transforming one office building into housing. An urban area transformation requires cooperation from the actors with interests in the area. In the case of Amsterdam South-East the actors involved are several investors who own one or two properties. The municipality seems to be the logical initiator and coordinator of the transformation, although it has no ownership in the area. Nevertheless, it is in the interest of the municipality to transform the urban area into a sustainable one to avoid further disinvestment, downgrading and depreciation of the area. Therefore, the municipality at this moment is the only party with a ‘sense of urgency’ for intervening.

In our study we are focusing on the Dutch context and specifically the Amsterdam office market. The findings as such cannot be generalised. However, throughout Europe modernistic planning methods are still of great impact on the development of urban areas, as zoning plans with housing districts separated from office areas still dominate. When these monofunctional areas are at the end of their functional lifespan, change can only take place as part of wholesale renovations or transformations that are often just as expensive as redevelopment. The flexibility and adaptability of these areas and buildings are low, negatively influencing the urban durability and sustainability.

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Towards Economic Sustainability through Adaptable Buildings

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1. Introduction

A revolution in agricultural and industrial sectors in the 18th century wrought a remarkable change in social, cultural and economical life styles in the UK. As a result, major changes could be seen in patterns of land ownership and land use during the last century (Butlin, 1994). Today, the UK Government tends to promote optimum use of the existing building stock through mixed use in urban centres and encourages conversion of redundant office and retail space into leisure, service and/or residential uses rather than renewal. Pitts (2004) further suggests the promotion of mixed use developments in the UK will reduce the need for travel to work by private vehicles, make local facilities more viable, and encourage the community spirit helping to achieve sustainability goals. Therefore it is important to analyse ways of utilising the existing building stock as mixed or sole-use developments, because building functions have limited life, they are expensive to build, and the cost of replacement is high and clearly unnecessary where they are physically robust and adaptable. This is encouraging greater innovation in the design of new buildings to allow for change of use throughout the structure's lifetime. Recently there has been a growing need for adaptable building developments in the UK.

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Previous research has concentrated on innovations in information technology, new working practices, tightening of the environmental agenda (Kincard, 2000), and rapid change in private and public organisations, changing user needs and effects of obsolescence (Arge, 2005) as factors which influence the adaptability of buildings. Most of the conventional buildings are one-off and not designed for mass customisation. But adaptable buildings might focus on bespoke solutions which, wherever possible, are flexible to varying customer needs.

The purpose of this paper is to identify how the functional uses of buildings change over time using a morphological analysis within a semi-rural borough in UK over a 100 year time span. The study further investigates the factors behind those transformations and proposes how buildings could adapt for those changes without demolishing the entire structure. Moreover, a conceptual framework is developed to explore the economic impacts of adaptable buildings.

2. Research methodology

The town of Loughborough was used to represent the changes of buildings over the last century. It is a typical small rural town in the heart of the United Kingdom. The available historic maps and documents were collected from Leicester Record Office, and Loughborough public library. An extensive morphological analysis was carried out within the area to study how building functions have changed and to establish the factors behind those changes. A previous research study using morphological analysis was undertaken by Ariga (2005) on adaptable physical settings and flexible mixtures for liveable urban communities in the city of San Francisco. It focused on functional clusters and their adaptability with the changing conditions. Similarly, morphological analysis is used to identify the pattern of change in building functions in a selected building cluster in Loughborough during the last century. A morphological analysis is a general method for non-quantified modelling; consequently, it is considered as a classification system made up of categories that divide some aspects of the world into parts (Ariga, 2005). In this sense, the same method is used by the research described in this paper to investigate the space use pattern in buildings (either mixed or sole use) and their surrounding structures.

The main types of building were identified as residential, commercial, industrial, social and leisure categories. Residential included detached and semi-detached houses and apartment blocks. Commercial comprised offices, banks, public houses, hotels and retail categories. Industrial included buildings for manufacturing and warehouses. Social covered schools, churches, clubs, hospitals and buildings which were built for community wellbeing. Leisure included parks and other recreational facilities. Historic maps, to a scale of 1" = 88 ft, for the years 1886, 1901, 1921, 1968, 1970, 1974, 1981, 1989, were used to study the pattern of functional transformations of buildings over the years. Among those maps, critical differentiations of functional uses were identified from 1886, 1921, 1970 and 1989. Other historic documents were also accessed to identify the factors behind the transitions. A semi-structured interview was conducted with one of the development and control officers in the Local Authority (Charnwood Borough Council) to obtain the platform data for the study and to identify the economic impacts derived from the changes observed. The interview supported the selection of the specific case study area in the town. This comprised the area bounded by Market Place, High Street, Woodgate and South Street. The main reason for selecting this area was its frequent changes in space and its representation of all the functional units better than the other possible clusters. The selected cluster is located at the commercial hub of the town of Loughborough.

Moreover, direct observations of the existing building stock within the area were carried out to identify their most recent uses. This observation revealed which buildings had been replaced in recent times as the construction technology was clearly less than 60 years old and helped to estimate the percentage of alterations in buildings and their functions.

3. Data collection and analysis

The Industrial Revolution in the 19th century caused rapid developments in the town based on hosiery, other textile productions, and various manufacturing and engineering industries. It appears that the charter of incorporation in 1888 was largely the result of the industrial prosperity of Loughborough (Deakin, 1974). Although relatively undamaged physically by the First and Second World Wars in the first half of the 20th century, there was a disruption to the growth pattern of the town during these periods whilst the growth of public policies in the late 20th century has favoured changes in space: use patterns.

3.1 Case study

The case study was carried out to identify the pattern of building change in Loughborough. A cluster area was selected through a preliminary survey which identified the maximum number of multifunctional (residential, commercial, industrial, social, leisure) units within a single area. The cluster area referred to in this paper is the one surrounded by roads, which shows remarkable changes in both the functional and spatial transitions.

Table 1 : Pattern of Building Transitions

Year	Cluster Maps	Spatial Transition
1886		This is the base line map used for the study. The area is bounded by High Street to the north, Woodgate to the East, South Street to the south and Market Place to the West. Residential buildings were placed along Woodgate and South Streets as semi detached houses. Most of the detached houses were scattered over the middle part of the cluster. The town hall and police court can be identified under the Social category. There were commercial buildings, such as banks, hotels, small shops and a few public houses with Industrial buildings surrounded by the residential units at the centre. The variation of building type was highlighted on the location maps by assigning the following shades to each functional unit.
1921		Spatial extensions in social (Town hall) and commercial buildings (bank, hotels) could be easily identified through the 1921 map. A new picture theatre and National Westminster bank were added to the social and commercial building networks respectively. But no remarkable alteration to the remaining building stock could be seen in 1921. Impact of the First World War (1914 – 1918) was not noticeable.

1970		By 1970 many changes could be easily identified. Since 1921, new building and extension had taken place in all the functional categories. Specific new construction (Corporation Yard, Woolworths, Police Station) and conversions of existing buildings (Part of an existing police station becomes a Magistrate Court, Midland Horticultural Works become Clemerson's Storage), could be highlighted during this period. More spaces were also allocated for commercial, social and industrial buildings. Some of the Victorian residential buildings were demolished and some were converted to other functions. The cluster started to commercialise after the Second World War adding growing employment opportunities for the people at Loughborough. As a result, the town economically stabilised in 1970.
1989		It can be seen that more spaces were added to the existing commercial stock since 1970. All the residential buildings were replaced by the other functional units. A larger area has been allocated as open space in 1989 than in 1970. There is no evidence of significant development in the existing stock or new construction.
2008		This map illustrates the building change of the selected cluster in 2008. When analysing the historical plans throughout the last century, a remarkable growth in commercial, social and open spaces can be identified in 2008. Approximately half of the area is developed as commercial buildings and remain area is allocated for social and open spaces

3.2 Economic growth

The morphological analysis illustrates a demand for various buildings in different time periods. It is proposed that analysing the economic impacts from these changes will enable a framework to be developed that assists with the projection of potential future functional requirements of the built environment. To this end four economic indicators were identified (see 3.2.1 to 3.2.4) and analysed by considering all the clusters in general at Loughborough and their impacts on building transition.

Growth in the industrial/manufacturing sectors

A growing trend in the industrial sector a century ago demanded a change in building type to fit the new purpose. The historical maps indicate that in the 19th and early 20th centuries many of the buildings were utilised for manufacturing lace, bells, cranes and electrical products along with heavy industries such as iron foundries, corn mills, warehousing and goods handling on canal wharves. It seems that the Brush Engineering Company Ltd was Loughborough's largest manufacturing group in that era. Other employment opportunities were offered by John Taylor's bell-foundry in 1839, Ladybird Books Ltd in 1873, and Davy Morris's crane works in 1903 (Wix et al., 1994).

It would appear that these industrial buildings were very large, spacious and well engineered to accommodate the heavy machinery and large work force. By the turn of the 21st century however, it could be seen that most of these industrial buildings had been converted to other functional units such as residential, commercial, social and retail facilities with certain improvements (e.g. the Towles Mill building). However, designing buildings for adaptation is one of the present day's solutions for a knowledge based, profit-orientated economy with rapidly changing product ranges. Reusability created by adaptability of buildings will significantly contribute to economic sustainability.

Growth rate of population

It is obvious that the growth of population is one of the significant economic factors that drives the need for extra housing. So the changes in population growth in Loughborough compared to the English average during the last century has been calculated (Figure 1) in order to gauge its influence on the local built environment. The formula used to calculate the growth rate is:

Growth Rate =

$$\{(\text{Population in ending year}/\text{Population in beginning year})^{1/\text{Number of years}} - 1\}\%$$

Source : http://www.measuringworth.com/growth/#

The graph in Figure 1 shows the population growth of Loughborough to be largely higher than national growth rate only dropping below the national rate in 1845 and 1865. The local growth rate trend has followed the national one but the difference between the two growth rates has noticeably diminished over time. The local rate is more erratic although this is likely to be due to the increased sensitivity of the smaller numbers involved in its calculation. More recent digression in the trends occur in 1946/1956 caused by WW2 and 1970/1975 caused by the establishment of the university with its associated influx of employees.

The growth of population in Loughborough has been creating many challenges to the built environment and its policy makers. However the expansion of buildings to continue the existing functions, demolition of redundant buildings and functional conversion of most of the buildings in the cluster could be seen in parallel to the population growth with the space allocation for building developments rising. The high frequency of functional conversions rather the structural changes in the existing building stock can be further highlighted.

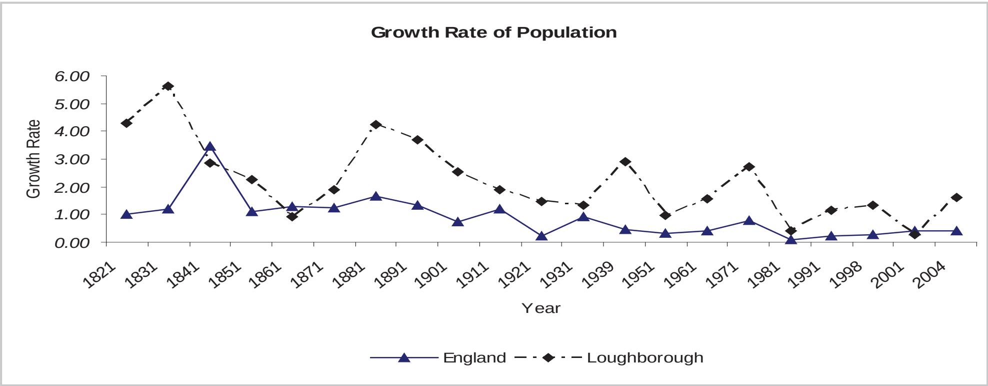
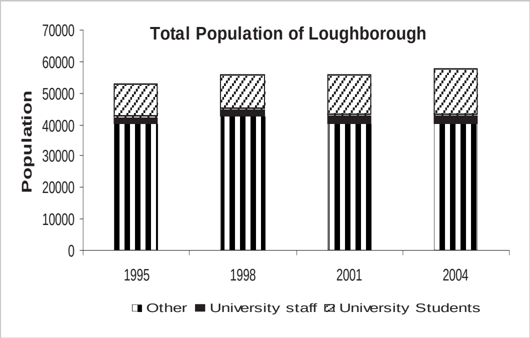


Figure 1: Growth Rate of Population. Sources: The office for national statistics, www.statistics.gov.uk/statbase/product.asp?vink=601&More=N, Atlas of the Borough of Charnwood, 1990 pp 51 and www.leics.gov.uk/,



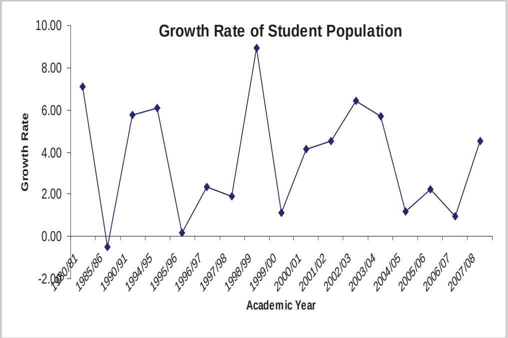


Figure 2 and 3: Population Distribution of Loughborough resp. Growth of Student Population in University of Loughborough. Source: Facts and Figures, University of Loughborough, http://www.lboro.ac.uk/admin/ar/planning/stats/factsfigures/index.htm

Growth of higher and further education

Significant development in the higher and further educational sectors in the town occurred in 1966 with the incorporation of the university charter. This placed the new university on one of the largest single site campuses anywhere in the UK and made it the largest employer in the town of Loughborough (Herbert, 1996). The growth rate of the student population during the last two decades is graphed in Figure 2. This growth has demanded additional space for student accommodation and associated commercial and leisure facilities within the selected cluster. Further is has outstrip the availability of existing facilities resulting in significant new build programmes to cater for the community needs and wants.

The increase in student numbers' growth rates in different periods (1988-1995, 1996-1997, 1998-1999, 2000-2003, 2005-2006, 2007-to date) is highlighted in Figure 2. Consequently, Figure 3 illustrates the population distribution of Loughborough in the last decade. The university population represented 23.75%, 23.42%, 27.52% and 30.11% of the total population in 1995, 1998, 2001 and 2004 respectively. Approximately, it is around 1/3 of the total population of Loughborough. According to the recent university publications the total staff and student population is 19,156 in mid May 2008 and was 17,334 in 2004. This growth might affect Loughborough's economic growth because of increase purchasing power of the students and staff. However, a lack of published data on student, staff, and other categories in remain years caused not to identify any link between the cluster development. But it appears in the continuous growth in university population as well as a growing demand towards commercial buildings with in the cluster.

Planning policies

Considerable effects from planning policies on building construction can be seen in Loughborough after the formation of Charnwood Borough council in 1974. All buildings are now to be constructed according to the county structure plan (Wix & Keil, 2002). The policies are derived from a two-tier activity. The national government policy statement sets the framework for the whole country and local authorities then apply it to work in their regions. Most of the policies are concerned with environmental sustainability.

The policies are biased towards increasing ‘brownfield’ development (reuse and redevelopment of previously developed land) and limiting ‘greenfield’ development (new construction on previously undeveloped land). Moreover, the policies favour an increase in housing to meet the fast expansion of the elderly, single parent and disabled population in the county (Wix & Keil, 2002). In seeming contradiction to this a critical growth and transition in commercial and industrial zones can be identified through historical plans. This has directly affected Loughborough’s traffic system, and new plans and regulations were developed to keep the market town away from the residential zones. It can be clearly seen through the above case study that there has been a shifting of residential buildings to locations away from the cluster area and that this part of the town has become a commercial hub for Loughborough.

4. Results and discussions

Geraedts (2008) states the current building stock is more towards long structural, short functional life and more concerned to fit the sustainable agenda. His evidence further illustrates the existing building stock is no longer meeting the present day user’s needs and this leads to an increasing the number of vacant buildings. As a solution for this dilemma he suggests an effective means should be found to incorporate adaptable, recyclable, sustainable, consumer-oriented, flexible and open building concepts. It is valid for the selected cluster too. The morphological analysis shows that most of the buildings, around 83%, faced functional transitions during their sole structural lifespan. However, the result further illustrates that approximately 30% of total demolitions were carried out in the cluster during the last century. From this it is obvious there is a need for designing buildings which can change without physical damage to the structure. It is also a way of optimising sustainable goals by reusing the existing resources.

All the functional mixes could be identified within the cluster during the 1886. However the cluster started to commercialise in 1970. Residential buildings were totally shifted away from the cluster and more commercial and social buildings were accommodated. Policy makers were strived to separate the residential sector form the market segment. As a result some of the existing residential houses were required convert offices, pub houses and some were totally replaced from 1970 map. The growth in local population, increase of spending power, implementation of new planning policies, sustainable concerns, changing user demands and building obsolescence can be identified as the key factors behind this transition.

In the aftermath of WW2 the sudden growth in all the sectors in Loughborough is highly remarkable. The shifting of houses to discrete residential zones and the mushrooming developments in commercial zones is significant. The improvements in spaces for banking show the growth in monetary transactions from the earlier periods. As one of a large prospective employer, the university plays vital role in this sense. Only Lloyds bank can be found on the map of 1886; in 1921 Westminster bank is added to the commercial network. In 1970 the expansion of both banks can be seen and another branch of Westminster bank is added to the cluster, and by 2008 HSBC, National Westminster and Lloyds bank have been placed in the cluster. So the growth in banking and some expansion in social structures could be highlighted within the cluster. Those improvements affected the economic booms in Loughborough during the periods.

The industrial diffusion in the cluster is significant when analysing the economic growth in Loughborough. The Midland Horticultural Works had provided more employment opportunities to people surrounding Loughborough in early years. Then this space was used as storage for Clemersons. Even though the function changed from industrial to commercial (retail) the same structure was performing the different functions. Moreover, a continuous growth in social and leisure buildings could be identified within the cluster. Extensions in the town hall building to receive a big crowd at once and construction of new police court - renewal and partially conversion of existing police court to magistrate court – is notable. The growth in population is one of the leading factors which drives expansions leading in the long term to social improvement, sustainable goals and community wellbeing.

It was derived from the interview and the observations that the economic, social, environmental parameters and obsolescence are the key demanding factors for building space. Either factor can create significant demand for space. However, new buildings which can be adapted to new functional goals have identified the solution to cater for growing demand. The term ‘adaptable’ is a multifaceted concept. It is about managing ‘change’ in the context of buildings which can occur as a result of either exogenous (external) or endogenous (internal) influences (Douglas, 2006).

The research study undertaken by ‘Adaptable Futures’ concerns the effective and efficient ways of delivering adaptable solutions to the UK construction. Moreover, the team identified flexible, available, changeable, moveable, reusable, refittable, scalable as the higher level strategies of adaptability, which incorporates with specified lower-level strategies. This study supports to the main research by identifying building changes, factors behind the change and to develop a framework for measure the economic feasibility of adaptable solutions over the new building.

4.1 Conceptual framework

Other than the above features, the performance criteria, in terms of economic concerns is linked to the conceptual framework illustrated in Figure 4 (next page). Through the morphological analysis they were identified the most significant driving factors, which lead for the functional transformation of buildings in the cluster. Around 30% of buildings were demolished and new construction was undertaken as a solution. The main reason was less physical robustness to accommodate new functions and/or failed to continue the existing functions. Hughes et al. (2004) identify that short lifetimes reduce a building’s value without reducing costs – simply, because there is no way of economically constructing a building for a short life. It is oblivious from the cluster that most of the buildings were belonging to long structural lives. In the sense, it is required to find the alternative means of adaptability which creates room for accommodating multi functional uses within a single structural tenure and drive towards the sustainable goals at the end.

The higher-level strategies developed by ‘Adaptable Futures[28]’ research team is incorporated to the framework as alternative means of deriving adaptable

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[28] Integrated research project, funded by the Research Council (EPSRC) through Loughborough's Innovative Manufacturing & Construction Research Centre (IMCRC),and industrial partners. www.adaptablefutures.com

solutions. However, multiple terminologies are used in the industry to define the term ‘adaptability’. These higher-level strategies almost blended with available terminologies and limited to a seven categories. At last, the decision will be based on the economic evaluation of proposed adaptable options over new construction.

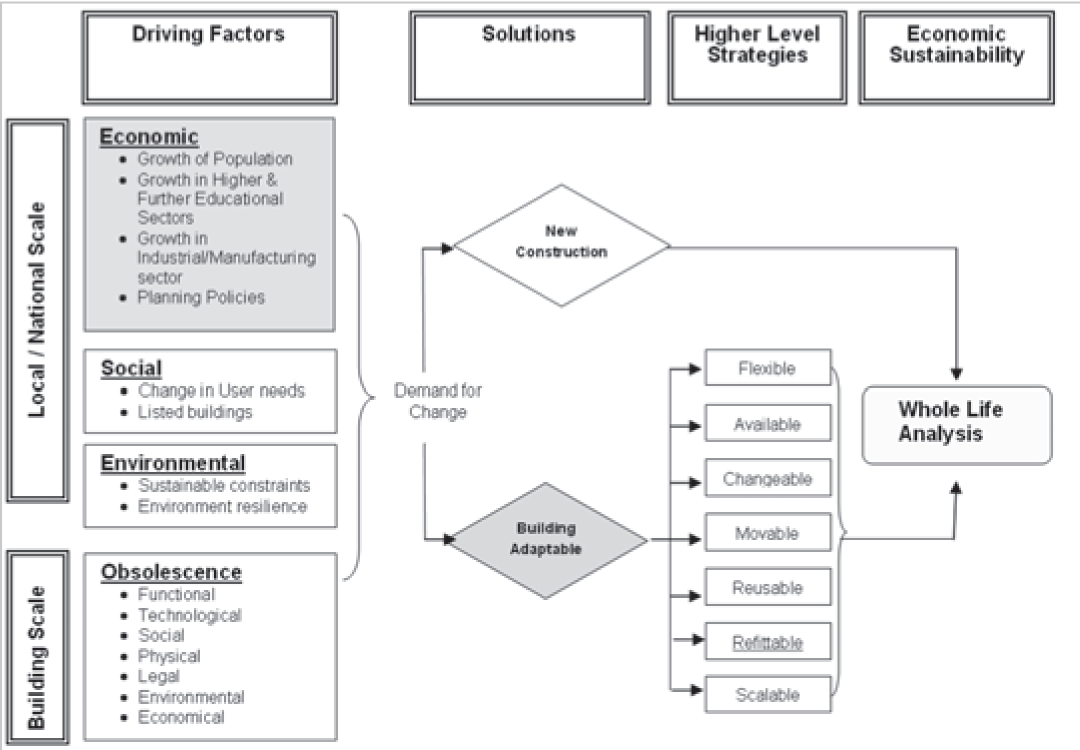

Figure 4 Conceptual Framework

Whole Life Analysis (WLA) is proposed by this framework as the technique to evaluate the economic feasibility of decisions. BSRIA (2008) defines WLA as a method of economic project evaluation in which all costs arise, as well as benefits accrued from installing, operating, maintaining and ultimately disposing of a project. This study focused to find the best economic decision on adaptable buildings based on the lowest whole life cost.

5. Conclusion

The demand for functional transformation of buildings rather than their structural transformation was identified from the morphological analysis. Most of the original structures have converted to alternative and/or multiple functions during the studied time spans. But it was found that some conversions were not fit for purpose and as a result they were demolished and new construction was undertaken. The main difficulty faced by practical changes/conversions arose because early design was not focused on future flexibility. This emphasised the importance of incorporating higher level strategies of adaptability in future new buildings which provide economically sustainable solutions for the whole country.

It was found from the analysis that the growth in population (residents and university students) has been a considerable driving force behind the economic developments in Loughborough and the demand for functional changes in buildings. Policy makers also play a vital role in functional change. Obsolescence with its effects on the economics of the development is identified as one of the critical areas to be studied further. However, a growth in construction and its contribution to the national economy can be measured by considering buildings as a unit of analysis. The trend towards various building functions and proper balance between supply and demand is of paramount importance in a profit-orientated economy. High frequency in changes of user needs and obsolescence are the most significant drivers for adaptability in the 21st century. However, buildings need to be designed to overcome those challenges in the future and they also need to become more economically viable than the renewal.

The conceptual framework developed identifies the driving factors for building space and evaluates the economic sustainability of adaptable solutions through whole life analysis. The framework needs to be tested and validated in the future.

Acknowledgement

The authors acknowledge the significant contribution of Mr. Peter Blitz, Development Control Team Leader, Charnwood Borough Council. Thanks are also due to staff members of Leicester Record office and public library Loughborough for arranging an easy access to the historical maps and documents.

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Knowledge on Urban Microclimates in the Urban Planning and Design Process

Marjolein van Esch, MSc[29]

1. Introduction

Many countries have policies to intensify urban land use to enhance the economical and social viability of cities and preservation (and viability) of farmland and natural areas. Existing city centres should be strengthened and the development of new - economical, industrial, knowledge and innovation - centres will be stimulated. On a larger scale infrastructure and urbanisation will be bundled.

These policies can be placed within a context of sustainable land use, in regard to which several design concepts exist. While these concepts differ in focus and approach, they consist of similar ‘design ingredients’: high building densities, mixed land uses, diversity and urban greening. These are (supposed) means to reduce the demand for energy by reducing the need for transport and to create beneficial conditions for combined heat and power systems. Furthermore, social interaction is facilitated by easy access to a vast variety of services within walking distance. Another benefit is the protection of rural areas to urban sprawl and fragmentation (Holden, 2004; Jabareen, 2006). A majority of the world’s cities are positioned in river deltas. Urban growth in these regions has a negative influence on our agriculture and natural areas, both limited sources.

Following from these policies and sustainability concepts densification is the most important strategy for urban areas. This leads to highly urban environments, in practice often in the form of multi-storey or high-rise developments, with an extensive mix of urban functions.

This strategy of densification can have a large impact on the urban microclimate and therefore on the physical wellbeing of humans in densely urbanised areas. Dense urban layouts can limit solar access, trap air pollutants and

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produce significant levels of noise. Outdoor conditions provide the basis for indoor conditions, so problems outdoors ask for interventions indoors, which in turn may lead to significant material and energy consumption. Waste heat exhausted to the outdoor environment contributes to the urban heat island effect, the phenomenon that an urban area is significantly warmer than is surrounding (rural) area (Oke, 1982; Kim, 1992). It may therefore be preferable to find passive building strategies that support physical wellbeing.

There is a significant body of scientific knowledge on the influence of urban geometry on the urban microclimate (Arnfield, 1990; Hunter et al., 1992; Knowles, 2003; Littlefair, 2001; Ng, 2005; Sini et al., 1996; Xiaomin et al., 2006). These studies however usually concern only one or two climatic elements. In order to make the studies useful for the design process their results should be integrated. Furthermore, the approach and results of most studies on the influence of spatial parameters on the urban microclimate are difficult to apply to urban designs and plans, since most of these studies are theoretical and scientific, rather than practical. Urban design needs to place al climate elements in perspective to one another and in relation to the urban form. There is a normative goal, whereas scientific studies are limited by their empirical form. An integrative approach is thus needed.

This paper proposes a framework for the translation of expert knowledge on the aspects of microclimates that influence physical wellbeing into a design tool. The aim is to support the planning process in general and the design process more in particular. This information prepared for the design process will enable designers and planners to estimate the influence of their spatial design choices on the (future) microclimate and also has the capacity to play a role as a communication tool in a multi-actor environment. This will help in creating conditions for urban microclimates that favour physical wellbeing.

In order to get to this framework, we will first address the topics of physical wellbeing and microclimates, and present some problems concerning physical wellbeing, presented by changes to both climate and urban environments. We will then move to design, and discuss issues that arise in the translation of expert knowledge to design information. We will also look into the role of information in the urban planning cycle, and the use of information with regard to different design styles.

2. The urban microclimate

2.1 Physical well-being and the urban microclimate

For the purpose of this study, physical wellbeing is defined as the state in which the body functions efficiently and effectively in rest and at work, is free of pain and disease, and experiences comfort. It is an important constituent of health, which is defined by the World Health Organisation as “a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity.”

Physical wellbeing can be significantly influenced by the meteorological climate in general and by the urban microclimate more specifically. An urban microclimate may be defined as the distinctive climate in a small-scale urban area (neighbourhood), and is constituted by the influence of the built environment on the larger scale climatic conditions of solar radiation, temperature, humidity, precipitation (type, frequency, and amount), atmospheric pressure, and wind (speed and direction). In other words: the spatial layout of a city and its neighbourhoods sets the conditions for their microclimates.

The various climate elements all act directly upon the human body, which may accept or counteract their effects by physical and physiological reactions, such as sweating, shivering, and the dilation or narrowing of blood vessels, in order to maintain a steady core temperature. When a minimum of energy expenditure is needed for these reactions the body is near biological equilibrium and feels at ease. There can however be significant stresses on the body, with discomfort or even health danger as a result. The amount of stress placed on the body is dependent on the climate: hot-humid, hot-arid and cold climates demand more of the human thermoregulation mechanisms than temperate and cool climates.

2.2 Climate-sensitive design

Before the age of fossil energy and building services man developed various passive building techniques to mitigate the negative effects of climate and utilise the positive effects. Examples of such climate-sensitive vernacular architecture can still be found around the world. In hot-humid climates, for example, a scattered layout of buildings with large open spaces between them allows for cooling breezes, while large roof overhangs provide shade. In hot-arid climates dense layouts provide mutual shading and large thermal masses attenuate the diurnal temperature curve. In cold climates thermal mass is also deployed in combination with insulation to minimise heat losses. A dense but irradiated layout guarantees optimal use of the sun's energy and blocking of cold winds. Temperate climates allow for a relatively high degree of freedom with respect to architecture and urban design, as thermal stresses are small. There are however some dichotomies: solar access to buildings and outdoor spaces is needed in winter while solar shading is desirable in summer. Furthermore, shelter from high winds is required with regard to the safety and comfort of pedestrians – in addition to the experience of wind chill, progress may be impeded or imbalance caused – but cooling breezes should be promoted during the warmer months. The challenge here is to find a 'zone of compatibility' (Oke, 1988) in building densities and the orientation and distribution of building masses.

2.3 Changes in climate and the urban environment

As a result of the development of technical indoor climate control systems the necessity of climate pre-conditioning by means of climate-sensitive urban design has decreased considerably. Moreover, globalisation has contributed to the distribution of western architecture - which has its origin in temperate climates - around the world. This leads to substantial solar gains and consequently excessive cooling loads in hot climates. Cooling systems in turn produce heat, which is exhausted to the street, so contributing to the heat outdoors. Furthermore, increasingly popular dense high-rise environments inhibit cooling breezes, causing the outdoor temperature and relative humidity to rise even more in already hot and humid climates. In contrast, the application of temperate climate architecture in cool and cold climates produces considerable heating demands, while chilling winds may have free play. So, not only does the globalisation of architecture and urban design lead to an increase in energy demand to provide comfort indoors, it can also cause uncomfortable, stressful or even unhealthy outdoor microclimates.

Closer to home problems also exist. The introduction of HVAC systems (heating, ventilation and air conditioning) has made thermal stresses indoors virtually obsolete – with a substantial rise in energy consumption as a result – but outdoors they remain. Moreover, due to the climate change predicted by the IPCC (2007) heat stresses will increase also in temperate climates as a result of a global temperature rise between 1.1 and 6.4 degrees Celsius, and an increase in hot extremes and heat waves. Combined with urban heat island effects, these conditions are likely to result in uncomfortable and unhealthy heat stresses, and more alarmingly a significant increase in heat-related mortality. Furthermore, higher temperatures stimulate the formation of ground-level ozone in urban areas, which can lead to or aggravate cardio-respiratory diseases such as lung inflammation and decreased lung function.

Air quality is an important aspect to take into account when referring to urban microclimates, since it affects physical wellbeing considerably. Urban areas do not only deal with ozone, but also with increasing concentrations of other pollutants resulting from human activities, such as particulate matter, nitrogen dioxide and sulphur dioxide, all hazardous to human health (World Health Organization, 2003). Whether air pollutants are either trapped in the urban fabric or dispersed away depends mainly on air movement, which in turn depends on the density of the city, height to width ratio of streets and open spaces, building height differences, and the orientation to the (prevailing) wind direction. Wide streets providing access to the wind are preferable for the ventilation of public spaces and dispersion of pollutants, however this may also lead to wind chill and wind discomfort or even danger – people blown aside – in case of strong winds. As climate change is also expected to bring changes in wind patterns, problems may be anticipated with regard to the urban wind climate and air quality.

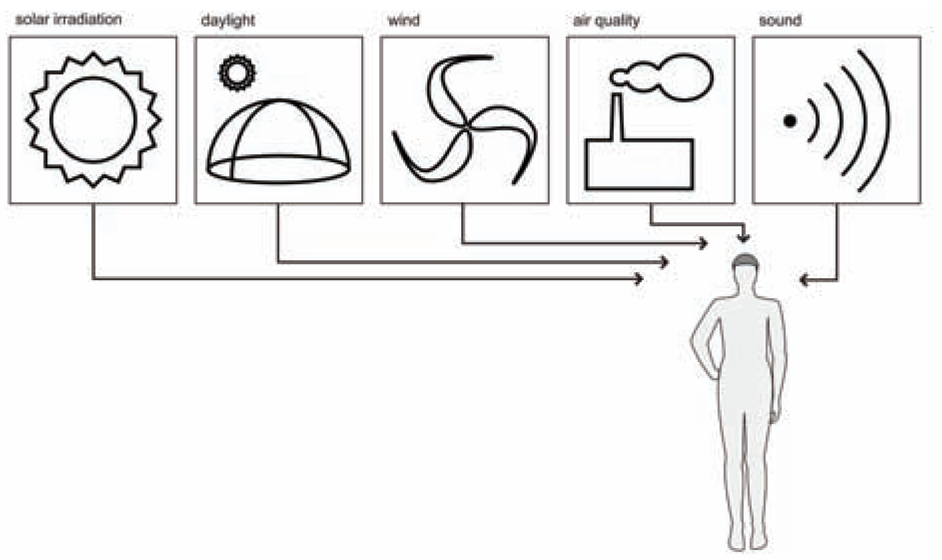

Figure 1 Elements of the urban microclimate acting upon the human body

Another aspect that is important for the environmental quality of the urban environment is sound. Traffic and other urban activities can produce high sound levels causing headache, distress, insomnia and noise-induced hearing loss (World Health Organization, 1999; Öhrström et al., 2006). The increasing amount of people living in cities is exposed to these adverse health effects. Urban densification is also likely to lead to more traffic and therefore more noise. By orienting building masses in the proper manner noise can be shielded, minimising sound levels behind these barriers.

One further important element of the urban microclimate is daylight. Daylight does not only allow us to see, it is also essential for the regulation of our circadian and neuroendocrine systems. Both are biological systems influencing various physical and psychological processes (Veitch et al., 2004). Artificial lighting does not have these beneficial biological effects (or certainly not to the same degree). Taking this into consideration, along with the need for a reduction in energy use, it is a desirable aim to let daylight provide the light levels required for various visual tasks as much as possible. This may be difficult since densification of urban environments causes a decrease in daylight access. Finding building configurations in dense layouts that allow for the best daylight access is therefore of interest.

2.4 Translation of knowledge

Translation of microclimate expert knowledge to design information is necessary with respect to four aspects. The first aspect is that of physics. The science of physics provides several theories that explain the behaviour of the various (micro)climate elements, such as thermodynamics, aerodynamics, optics and acoustics. A complete understanding of these theories by designers would of course overshoot the mark. To quote De Schiller and Evans (1996): "(...) there is a clear limitation in the degree of detail and complexity that the architect and planner can (and need to) assimilate as input to the design process." However, some simple and basic knowledge of these physics formulated in relation to built form might enhance designer intuition for climate-sensitive design.

The second aspect concerns the integration of expert knowledge of the different microclimate elements. Built form and its spatial parameters have a specific influence on each element. Spatial requirements for solar irradiation or shading, daylight access, wind shelter, air quality and noise attenuation may conflict or show promising combination possibilities. A certain building configuration might for example be favourable for daylight access, but not for noise attenuation.

The third aspect concerns the incongruity in use of spatial parameters used in microclimatological studies and urban design. Most studies on the influence of urban geometry on the urban microclimate investigate the influence of obstruction angles, the ratio of building height to street width (H/W) and relative street length (L/H). This is a logical choice since the behaviour of the various microclimate elements has a direct relation with these spatial parameters. For urban design or planning choices in the first stages of the design, however, those parameters are of less use: decisions concerning street design are made in later stages. For the urban design team to be able to make an estimation of the basic climatic conditions in the final built result, it is important to study and describe the influence of the basic layout of the plan area and its building density on the microclimate, because this is decided on in early urban design stages.

The last aspect is the suitability of information for design and (design) communication purposes as opposed to evaluation purposes. The majority of information and tools available on the subject of microclimates is often evaluative, presupposing a design that is to be assessed regarding its microclimatic performance. In order to be able to use information for design and communication purposes the presented information should be inspiring, explain basic principles and provide guidelines.

3. Transferring knowledge in a design process

Transferring information needs awareness of the context in which the information is needed and on the kind of information the receiver needs. Before presenting a framework for the transfer of information on microclimate in a design process, we outline a theoretical framework. The transdisciplinary model by Müller et al. (2005) is presented as a context for the design process and design communication. The perception of the receiver of information (the designer) is explained with the theory of Bakel (1995).

3.1 The transdisciplinary learning cycle in urban planning

Urban designers do not act alone, but function in a multi-actor environment. Depending on their role in the process and the nature of the process, the urban designer has to collaborate with principals, architects, residents, experts from various fields, institutions, municipalities and other authorities. All these participants contribute to the process with a certain activity, which can be categorised under three headings: design, science and deliberation. In order to strengthen the relationship between these activities and support the planning process Müller et al. (2005) propose a transdisciplinary model, which conceives design, science and deliberation as learning processes that follow the same sequence of creative, descriptive and normative steps, as depicted in figure 2. In the creative step, ideas or concepts that exist in the mind are translated into physical form. These physical products can be examined and described in the descriptive step. In the normative step, the information gained in the descriptive step is interpreted and translated into ideas and concepts, which in turn can be input for the (next) creative step.

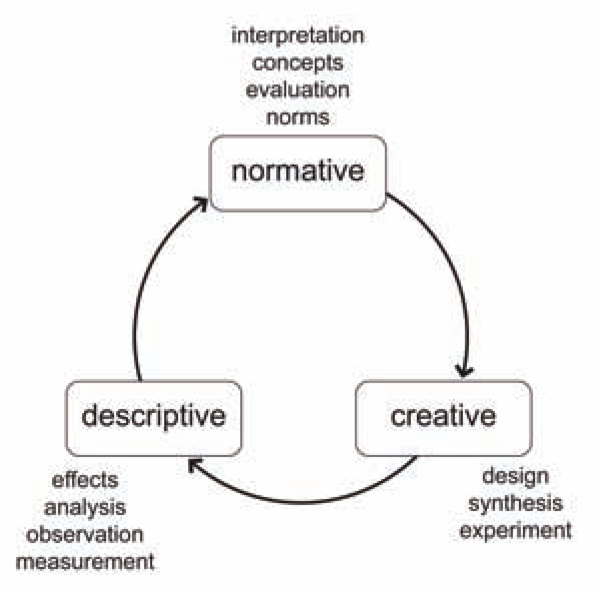

Figure 2 The generic learning cycle, after Müller et al. (2005)

This generic learning cycle applies to design processes, as well as scientific and deliberation processes. However, the processes differ in focus and aim. Design focuses on the creative step, aiming at developing design solutions to problems. Science focuses on the descriptive step, explaining certain effects, and deliberation focuses on the normative step. In coherence with their focus, each process also has a main form of expression. The design cycle uses mainly drawings and other visualisations, whereas in the science cycle numbers and statistics are more important, and in the deliberation cycle language is the primary form of expression.

Müller et al. suggest that the focuses of the different processes complement one another at the larger scale of the whole planning cycle (figure 3). Instead of being exclusive fields, design, science and deliberation can learn from and provide input for one another. In order to be as helpful an input as possible, the difference in form of expression between the fields should be taken into account. Using multiple forms of expression increases the chance of mutual understanding, which is not only beneficial for communication between participants but also for the whole planning process and its outcome.

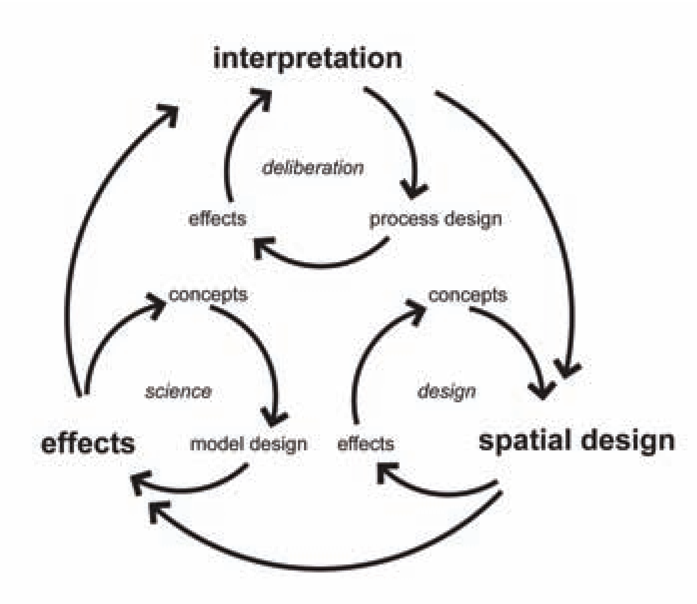

Figure 3 The transdisciplinary learning cycle, after Müller et al. (2005)

Before exploring the deployment of this theory for the translation of expert microclimate knowledge into design information, it is useful to first look into the design process.

3.2 Design styles

Design processes differ from project to project, not least because of the designer(s) involved. As Bakel (1995) so elegantly describes, designers can have different starting-points. Some prefer to start from the program, others start from a concept, and yet others prefer to begin from the site or existing situation. A program-oriented designer uses the design brief as a starting-point and as an evaluation instrument. The program-oriented designer is likely to start searching for the key problems to be solved. He may formulate a set of rules based on the design brief to facilitate decision-making. A concept-based designer starts forming a mental image of the design; this image can be formal, functional or other. He may also use a design analogy. Commonly used analogies are that of the city as a living and growing organism or the city as a machine, consisting of different parts. Whether these analogies are valid, is of course beyond the scope of this chapter. A site-oriented designer tends to be rather pragmatic, using what the site provides and what relations can be found inside and outside of the plan area. This design style is probably the most common in urban design and planning.

These different styles of designing could benefit from different kinds of information. The program-oriented designer might like to be informed about desirable climatic conditions, expressed in regulations or standards, and how to assess the microclimate. The designer that starts from a spatial concept would benefit from a description or depiction of the effects of certain spatial configurations on the microclimate, whereas the site-oriented designer might want to start by examining the existing climate.

The issue of expressing information in different ways was already raised with regard to interdisciplinary collaboration and communication in the previous section. In the next section various types of information are proposed, which complement each other and (partly) overlap each other. Sometimes a proposal is made to simply express the same information in different ways.

3.3 A framework for information transfer

In order to support different design styles, microclimatic information should present climatic requirements (for example maximum wind speeds for sedentary activities, for strolling and for walking fast) for the programmatic designer, climatic performances of different spatial layouts for the conceptual designer, and a simple climate assessment for the site-oriented designer. Since design is only one step in the planning cycle, the information should also facilitate communication with other participants involved in the planning process. Information exchange with researchers, managers or principals and others is of great importance and therefore the main form of expression of each participant should be taken into consideration. To meet al of the requirements listed above, the following set of information is proposed:

1. A set of quality classes of microclimatic conditions related to different activities or urban functions

These quality classes are preferably based on the norms stated under 2. This information can be used for the definition of design requirements at the beginning of the planning cycle, and facilitates communication between the urban designer(s) and the principal or governmental actors. Furthermore, the information can be used as an assessment tool, allowing for the comparison of design variants at later stages in the planning cycle. This kind of information is most likely to start off the program-oriented designer, since it states objectives that are to be met.

2. A summary of regulations, standards and recommendations concerning the microclimate

This is normative information, usually expressed in both numbers and words. It may serve as background information on the climatic qualities aimed for.

3. A description of the influence of spatial parameters on the various climate parameters and the total microclimate

The most important spatial parameters are: building density (intensity, expressed in a floor space index), compactness (expressed in a ground space index), average building height and orientation. This information could be expressed visually, showing basic principles, accompanied by a textual explanation, and some simple graphs and numbers, stating important units and quantities. The concept-based designer would probably benefit most of this kind of information, because it shows the impact of different spatial concepts. The information can be used for communication with experts or researchers, who may provide further explanations or supplementary knowledge when needed in later stages of the planning process.

4. A description of the behaviour of all microclimate aspects, separately, related to the various spatial parameters, and their main effects on physical wellbeing

This kind of information would probably best suit the site-oriented designer, since this allows them to make an estimation of the existing situation, and possible interventions they can make. Like under point 3, this information can be used for communication with experts or researchers. It might also be used by the conceptual designer for fine-tuning purposes.

5. An assessment method of possible promising combinations and conflicts

The various microclimate elements may have conflicting or matching spatial requirements. In case of conflict, an assessment should be made of the consequences of a compromise between contrasting spatial requirements, or a selection of one spatial type over the other. Information should be provided on spatial bandwidths or boundary conditions for favourable, neutral and undesirable microclimatic conditions. This information is probably useful in later design stages, when decisions are made concerning exact dimensions. It may facilitate decision-making for designers, but also for the whole planning team.

6. A simple graphic tool for analysis of the existing climate, showing the required basic climatic qualities and quantities

Nice examples of such tools are the bioclimatic charts by Olgyay (1963) and Givoni (1998). This kind of tool could be attractive for the site-oriented designer, since it enables them to assess the climatic strengths and needs of the site. It is also particularly useful for the principal; a quick climate assessment in combination with a list of possible quality classes (see point 1) can help them decide on what is desirable for the final design.

7. Examples of good practice

These can be found in abundance in vernacular design, but also some contemporary projects show climate-sensitive design. Bad examples can also be informative. Example projects can be inspiring to all designers, and are also a suitable tool for communication between all participants in the planning process. They can be referred to throughout the cycle.

4. Conclusion

In order to preserve physical wellbeing in a changing climate and a densifying urban environment, information on climate-sensitive design is of crucial importance. Passive building strategies that support physical wellbeing are preferable as they serve a sustainable development in the urban environment. Correspondence of the spatial requirements that the separate microclimate elements impose should be utilised, conflicts solved in accordance to other design requirements. This demands for a plain presentation of the complex relations of different qualities of the urban microclimate. The context in which this information is transferred is complex, because of the different perceptions of different actors at different steps in an urban planning process. We can conclude there is a need to present the same knowledge in multiple ways, depending on the stage the planning process is in and the actors involved. In the context of this complex planning process the urban designer plays an important role. Diversity in presentation of microclimate knowledge and a variation in emphasis do not only support communication in the planning process, but are also very likely to support the different design styles of urban designers.

Concluding from the above, there is a need for a design and planning instrument that has different layers of complexity in its information presentation, and that provides the possibility to approach the information from different directions. Common to both the design process and sustainable development is the need to emphasise the relation between different possible design decisions. The information framework proposed in this paper can help to bring these relations to light and support decision-making. A design instrument based on the proposed framework will enable designers and planners to estimate the influence of their spatial design choices on the microclimate and help them in creating conditions for urban microclimates that favour physical well-being.

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Can Public Policies Change the World?
The Potential of Public Policy to Stimulate Radical Change

Ellen van Bueren, MA[30]

1. Incremental vs. radical change

As many theories of society, public policy theories have evolved in the past decades. Between 1900 and 1950, theories on public policy and decision-making suggested that policy problems should be explored in a rational way. Policy analysis should start with a problem diagnosis, followed by the development of alternatives to solve the problem and an assessment of these alternatives and their consequences (DeLeon, 1988). From the 1950s onwards, scholars studying the policy process became aware of the constraints of this understanding of public policy-making, which was not merely a scientific exercise, but disturbed by irrationalities and practical limitations. For example, already in 1947 Herbert Simon pointed out that it was simply impossible to know all alternatives and their consequences, and rationality of decision-makers was therefore bounded. In 1959, Charles Lindblom published *The Science of Muddling Through*, in which he showed that policy-making concerns modifying existing policies more than creating new ones. In stable political settings, policy-making thus tends to be evolutionary instead of revolutionary. Allison (1971) added a behavioural dimension to this theory of incrementalism. In his analysis of the Cuban missile crisis he showed how internal organisational factors could influence the course and outcome of decision-making. Organisational routines, personal relationships and internal power struggles were examples of irrationality being part of processes that were assumed to be rational.

More recent literature on policy-making and decision-making builds upon the bounded rationality of decision-making. Literature on policy networks emphasises that relationships between actors are interdependent and reciprocal

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(Koppenjan & Klijn, 2004; Bruijn & Heuvelhof, 2008). ‘Government’ does not exist, but is made up of all sorts of organisations whose interests are not necessarily aligned and may even be competing or conflicting. Government organisations wanting to make a change cannot make this happen on their own. They need to mobilise the resources of other actors, public or private, for which they have to engage in a process of interaction and negotiation, with uncertain outcomes. Also private firms who want to make a change that exceeds their individual businesses need to mobilise support for their initiatives in the web of networked relationships of which they are part and in which they operate.

Such changes almost inevitably influence the relationships between actors and the rules by which they interact. These rules and relationships however often have been strongly institutionalised. They have been formalised in laws and regulations, or they are part of unwritten rules for interaction and communication. Institutions therefore are also referred to as ‘rules of the game’. By acting in accordance with institutions, knowingly or tacitly, they are confirmed and reconfirmed time and again and thus reinforced. They help actors to make sense of interactions and make interactions predictable. Throughout the years institutions have emerged rather than deliberately been designed. They are deeply rooted in actor behaviour. For policy makers, institutions are difficult to identify, address and change.

Initiatives for policy change will thus require support and resources from other actors and meet institutional resistance or inertia. Support is easier to mobilise when policies acknowledge vested interests and existing institutions. And even when building a coalition of actors that aims for an ambitious change, the direction and pace of change will be determined in a process of negotiation, in which actors exchange goals and formulate conditions and constraints for the process. As a result, policy proposals do not differ much from existing policies and policy changes tend to be incremental. However, since relationships and interdependencies include multiple issues and are long-lasting, there is also room to manoeuvre: losers can be winners in next rounds of a policy process, or can be compensated on other issues. For example, environmental organisations opposing the development of a new industrial area can be compensated by the creation of new ‘nature’ elsewhere. Policy-making is the result of interactions and negotiations between multiple interdependent stakeholders, a process in which stakeholders try to safeguard their interests and achieve their respective goals.

The interdependencies between actors imply that, despite hierarchical power of some actors, no actor is in a position to dictate and enforce policy goals. Policy goals have to be negotiated, and coalitions supporting policy goals have to be built. Drawing on Williamson's transaction cost theory (1975), scholars in public policy acknowledged that policies tend to be path dependent: it is cheaper and more reliable to build on existing relationships and policies than to develop new ones (Koppenjan & Klijn, 2004). For example, in contracting road construction it is easier for both principal and agent to adhere to already known contract forms, formats by which principals and agents know their roles and obligations. Transition costs, involving new kinds of contracts, can range from developing new contracts and new systems for monitoring and control to the loss of experience and good-will.

Radical policy change is unlikely to happen when socio-economic, political and physical conditions are stable. Only in times of crisis, when the existing balance in power is already under pressure and institutions are no longer taken for granted, revolutionary policy changes stand a chance. For example, the 2008 credit crunch may create a window of opportunity to make a change towards sustainability.

Figure 1 illustrates the relationship between interdependencies amongst actors and the opportunities to intervene in decision-making: when actors to achieve their goals become more dependent upon other actors, the opportunities to singlehandedly enforce policy change reduce.

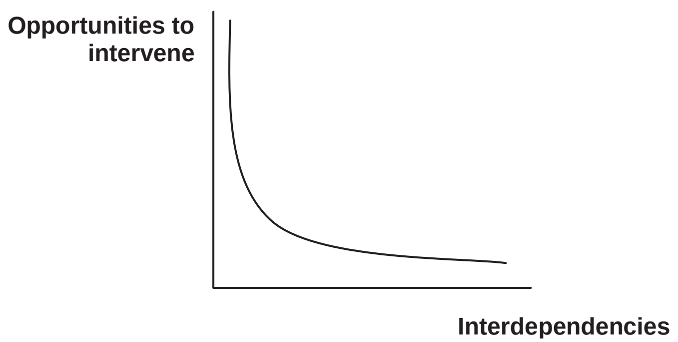

Figure 1 Relationship between interdependencies and opportunities to intervene in decision-making.

The history of theories of public policy and decision-making previously discussed shows that – in the absence of crises – attempts to radically change policies will meet a lot of resistance. Theories of decision-making emphasise the need for a process approach. Such an approach acknowledges that the definition of problems and solutions is not a neutral process, but the result of exchange of information, knowledge and points of view between interdependent stakeholders. In a joint learning process of interaction and negotiation, stakeholders can learn about the policy goals and how to achieve them, or at least they can agree to disagree (Bruijn & Heuvelhof, 2008). Public policy should aim to manage, support and facilitate this process of which the outcomes are unknown and uncertain, instead of trying to command specific outcomes.

In spite of this knowledge of the policy process, every now and then governments attempt to radically change policies. Especially in the case of urgent problems, such as climate change, the road of gradual change might be considered too slow.

2. Empirical research: intended radical changes were not achieved

This chapter discusses the results of four policies of the Netherlands' national government to enhance a sustainable built environment. Two of the policies aimed to enforce radical policy change by an approach that is characterised as 'command and control'; and two aimed to stimulate policy change gradually by engaging in interaction with stakeholders, and this approach is thus characterised as a 'process approach'. The objective is to answer the question whether incremental decision-making is all we have or that vigorous action is possible.

The period over which the policy processes have been studied include about fifteen years, from the early 1990s until 2008. Such a long period is required when studying processes of policy change (Sabatier & Jenkins-Smith 1993). They were studied in a qualitative way, including document analysis and semi-structured interviews with key stakeholders. The analysis and conclusions of these studies have been verified and discussed with some of the key stakeholders involved. Early findings of each of the case studies have been published in books and scientific journals (e.g. Bueren et al., 2003; Bueren & Heuvelhof, 2005); more recent findings have been discussed with stakeholders and will be included in a forthcoming thesis.

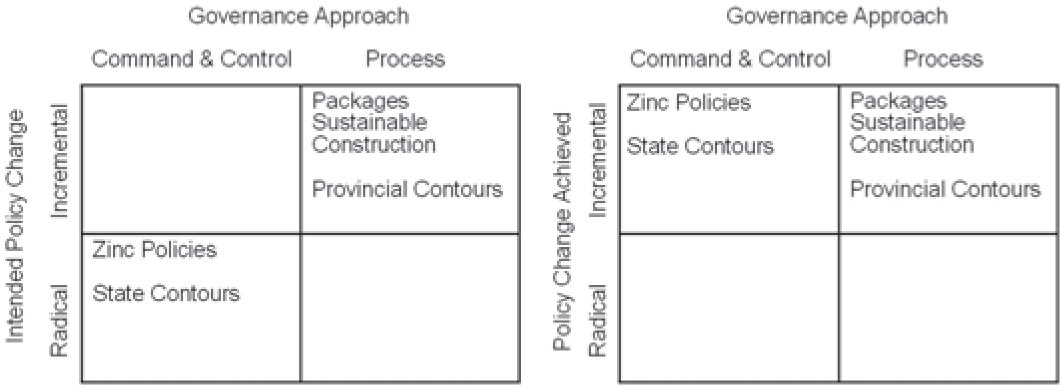

Figure 2   Intended and achieved policy changes

Figure 2 shows a classification of the policies studied. The classification is based on the policy approach adopted and the ambitions aimed for – the intended policy change – as well as the ambitions achieved. As the figure demonstrates, the policies aiming for radical change merely established policy changes of an evolutionary character: piecemeal, incremental changes, just as process-based policies did. The question presents itself: are policies aiming for radical changes worth a try, or is the road of piecemeal changes all we have?

The results of the governance approaches used in the cases will be compared and discussed, followed by a conclusion about the desirability of both governance approaches; but first, the cases will be shortly introduced.

3. The policy processes studied

The policies aiming to restrict urban sprawl can be split up in two cases, although they were not entirely independent from each other, as the description will show.

3.1 Reducing diffuse zinc emissions

Dutch water quality policies contain norms for zinc concentrations in inland surface water and aquatic sediments, but norm compliance has been a problem for decades. In the 1980s, zinc was therefore put on the list of prioritised substances in the Netherlands, which means that policy-makers should give priority to reduce the problems related to these substances. The Ministry of Water Management identified diffuse sources, large numbers of small sources emitting zinc, as the main cause for the continued exceeding of water quality norms for zinc. Zinc and galvanised building products were recognised as an important group of diffuse sources, and in the 1990s, several governmental and non-governmental actors in the areas of water management and sustainable building initiated communicative policies to prevent the outdoor use of these products in buildings and constructions, with a declining turnover of the zinc industry as a result. Additional to these voluntary-based policies the Dutch government successfully put the zinc problem on the European agenda, by pleading for European water quality norms for zinc.

However, the mere existence of norms for water quality did not directly lead to reduced zinc concentrations in surface water. Point sources had been successfully addressed in the 1980s, but there were many diffuse sources as well which were more difficult to identify and control. Diffuse sources consist of many small sources that are spread over a large geographical area. Enforcing compliance is therefore technically impossible. Furthermore, there are many uncertainties about the environmental effects of diffuse zinc emissions. For example, zinc is an element that is already present in the environment, and there are large variations in natural background concentrations. When norms are exceeded, it is difficult to identify the responsible sources. In addition, the relative contribution of buildings and construction to zinc concentrations in surface water and soil is uncertain. Sectors as transport and agriculture also are large emitters of zinc. These uncertainties make a legal demand for zero-emission construction products impossible. However, out of prevention, which is a principle for environmental policy-making in the European Union, the Ministry of the Environment considered reducing policies legitimate. In the absence of regulation, it stimulated the building and construction sector to innovate to reduce emissions, and it encouraged local authorities to reduce the use of zinc construction products on a voluntary basis. Meanwhile, the Ministry also explored legal opportunities to reduce zinc emissions from construction products.

By 2008, after twenty years of policy battle between government and industry on the question whether zinc emissions endanger ecosystems, the debate had not been settled yet. In many inland waters, zinc concentrations still exceeded the norms, as was the case mid-1980. Policy-makers at Dutch and European government level seemed to have won the battle over norms; all member states should have environmental quality norms for zinc concentrations in surface water and soil. However, in the Netherlands in 2007 the national association of water boards issued a guideline to the water boards stating that exceeding the zinc norms not necessarily required action. Many of the local governments lost interest in the issue and halted their zinc-discouraging policies until science and policy-makers would give a final verdict on the environmental performance of zinc construction products. The zinc industry meanwhile negotiated with the Ministry of Economic Affairs to safeguard its existence, which would have been imminent with a ban on zinc construction products. Also, the zinc industry searched for allies in the policy battle, which it considered unfair because of the relatively small contribution of the construction industry to zinc emissions and the uncertainty about the eco-toxicity of zinc in the environment.

3.2 Restricting urban sprawl with spatial contours

The 1993 National Spatial Strategy Document introduced spatial contours as an instrument to restrict and control urbanisation in the Netherlands. In designated parts, the so-called *state restricted areas* that were indicated on a map of this national white paper, local authorities were forced to encircle built-up cores with red lines on maps, like the medieval city walls. Figure 3 gives an example of such a state contour. All urban growth had to be accommodated within these lines. This would protect the countryside from urbanisation: ‘open areas’ would remain open, while land within the contours would be used more efficiently.

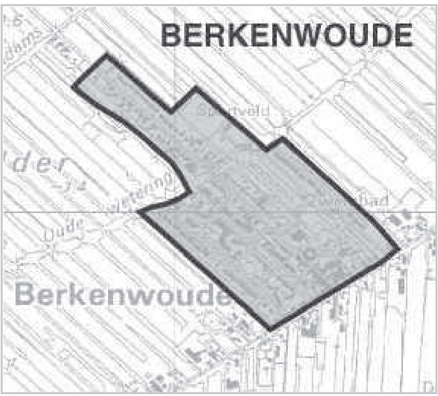

Figure 3 Example of a state contour as indicated on a map of a provincial spatial plan.

The spatial contours caused severe conflicts between local, provincial and national government. Especially the direct intervention of national government in local spatial planning policies was being contested, as well as the rigidity by which the instrument was implemented. In the Netherlands, spatial planning was an autonomous task of local government, as long as national spatial policies were respected. In 2005, a next National Spatial Strategy Document was approved of by the government. This document presented a fundamental change in urban compaction policies. Whilst the 1993 Document aimed to maximise central control on strategic planning decisions, the 2005 Document aimed to decentralise spatial planning decisions, including those decisions influencing urban sprawl. Thus planning would change from prescriptive planning to development planning, in which there was room for planning authorities to join in with emerging spatial developments. The contours were no longer part of national physical planning policies.

The 1993 Document also introduced *provincial contours*. Provinces could determine open areas they considered of regional importance. Within these areas, they should restrict urbanisation as much as possible. Developments should be concentrated within the existing urban cores which had been assigned a growth status in the provincial spatial plans. The provinces were given the liberty to implement this policy with the instrument of their choice. However, the instrument should meet the same conditions as the contours, i.e. its unambiguously enforcement and evaluation should be implemented and motivated. If not, the state could intervene and draw red contours. Many provinces implemented this policy by drawing green lines on the maps of provincial plans, and the provincial restriction policies were therefore also known as ‘green contours’. To determine the contours for the various municipalities within an area, local authorities cooperated. In processes of interaction and negotiation, they agreed on the values the contours sought to protect, and how this could be achieved best. The provincial contours were thus the result of a learning process on an inter-municipal level.

In 2008, although being abolished as an instrument of national policy, the red or state contours were still part of provincial spatial plans, which had a term of operation of ten years. In this period, the contours had had a limiting effect on urban sprawl. However, since the term of operation was not prolonged, it can be questioned whether the effect of the contours will endure. With a prospect of a less restrictive planning regime, it can be questioned whether the temporary contours really urged local authorities to more efficient land use, especially since supporting financial incentives were absent.

The provincial contours were less controversial. Municipalities in open areas , which had to develop the contours, started regional debates about the spatial qualities present in the area and how they could be best protected and supported. Provincial contours reducing sprawl and protecting nature were decided upon in deliberative processes. As a result, the contours were respected by all stakeholders, including environmental and agricultural organisations. Because of the success of these provincial contours, many provinces decided to make spatial contours an instrument of provincial spatial policy following the 2005 abolishment of the contours as an instrument of national policy-making. However, since the national red contour regime was no longer a threat, it can be questioned whether there is still an incentive for municipalities to determine contours on a regional level, which – in regards to spatial qualities - is an appropriate scale to decide on questions of urbanisation, as has been demonstrated by the provincial contours. Chances are that local authorities will optimise the contours on a local scale, leading to sub-optimised results for values as landscape, openness and biodiversity, values better served on a regional scale, which the contour instrument aimed to support from the start.

3.3 Stimulating sustainable construction with packages

The National Packages for Sustainable Construction were developed in the Netherlands from the mid to late 1990s. The Packages contained lists of measures for sustainable construction that could be applied in the design, construction and operation stage of buildings and other constructions. To attend to the specific traits of buildings and the built environment, separate Packages were developed for domestic buildings, for non-domestic or utility buildings (for example: commercial and industrial buildings, offices, and public service buildings such as schools, hospitals, etc.) and for civil infrastructures (roads, railways and waterways).

The main goal of the Packages was to harmonise and disseminate knowledge on sustainable construction amongst actors in the building and construction sector. The harmonisation of knowledge contributed to another goal as well: it brought uniformity in local sustainable building policies. The National Packages replaced the various lists for sustainable building by means of which local governments tried to stimulate and enforce sustainable building. Especially the Dutch building industry, that faced different requirements and constraints in each municipality, welcomed such uniformity.

The Packages were part of the Policy Program for Sustainable Building, which was formulated by the Ministry of Housing, Spatial Planning and the Environment in the 1990s. The program aimed to formulate sustainability goals and to develop instruments that would help the building sector to achieve these goals. The program aimed to closely involve the building sector in the development and implementation of the program. For the development of the Packages for Sustainable Construction, the building sector even took full responsibility and within a couple of years, the envisaged Packages were brought to market. To stimulate the use of the Packages, authorities at various government levels developed additional communicative and financial instruments. In 2000, following a change of government, the Ministry decided no longer to address sustainable building as a policy issue, but to concentrate on issues as energy use and the stimulation of consumer demand for sustainable buildings. Instruments supporting the Packages were abolished and the incentive for the building sector to keep up the Packages was reduced.

During a number of years, the Packages were successful; especially those for domestic buildings were widely used. In 2007 the building sector decided that the Packages would no longer be updated. However, on a local level the influence of the Packages was still present. Local authorities had based their local sustainable building policies on these Packages, and although complying with these policies was voluntary, many developers and contractors decided to respect the wishes of the local authorities.

4. What did the policies achieve?

Although figure 2 merely presents an account of the intended and achieved policy results, it gives the impression that policies aiming for radical change failed and those aiming for incremental changes succeeded. To understand the classification of the cases in figure 2, the achievements of the policies are now briefly discussed.

In the *zinc case*, policy makers especially achieved results in the policy sphere, but failed (yet) to make a difference in the real world. Norms for zinc concentrations were consolidated and/or established on national and European level, but these norms could not make a difference in terms of lowered zinc concentrations. The norms did give rise to voluntary policy initiatives on a regional and local level, where governments discouraged architects, developers and contractors to use zinc in building and construction. Over the years, these voluntary initiatives became limited in number. In the absence of a univocal verdict by the central government and by science, about the harmfulness of zinc in construction, many authorities decided to halt reducing initiatives, also in cases of norm exceeding. However, those regional and local authorities that did decide to take voluntary action were rather successful: for example, developers decided to use alternative materials, such as PVC for roof gutters[31]. In the near future, the Ministry of the Environment expects to pressure the zinc industry also by a government-wide sustainable procurement policy, which would force producers to be open about the environmental performance of their products. To prepare for this next round in the policy process, the zinc industry has joined forces with steel producers and has approached the Ministry of Economic Affairs to mediate in the policy controversy.

The *national red spatial contours* failed to make a long-term difference as envisaged. The idea was that the contours would offer a lump sum of space to local authorities, forcing them to use land more efficiently: without the opportunity for sprawl they had to make better use of land within the already built-up environment. However, at the time of implementation, mid-1990s, legal planning procedures had already started for so many planned developments that authorities will not feel the intended scarcity of land before 2015. This is a very long time horizon for local politicians, who are used to look ahead no more than 4 years. In 2005, national elections again led to a change of government. Spatial planning policies were decentralised and the contours were abolished as an instrument of national spatial planning. Although the contours were part of provincial spatial plans valid until around 2015, there would be no legal restriction to urban expansion after this date. A recent study of urban sprawl in the Netherlands showed that the contours did have effect: 39% of new dwellings to be constructed in the near future will be built within the existing built-up areas, whereas 40% was planned (Buunk & Groot, 2008). In the long run, however the contours will be renegotiated when the provincial plans will be revised. In the absence of a national government enforcing a restriction of sprawl, sprawl is likely to increase, since green field developments are financially much more attractive to local politicians

[31] The environmental merit of this shift is disputed (eds.)

and real estate developers than inner-city restructuring. Without central back-up it is questionable whether the provincial authorities can resist municipal claims on land for expansion.

The *provincial green spatial contours* were rather successful: local governments and provincial authorities felt that they had positioned the contours in such a way that these supported the spatial quality of the open area to be protected, as well as the quality of the built-up cores of the municipalities involved. Local governments in open areas, which had to draw up the contours, engaged in processes of interaction and negotiation in which spatial developments of the region were discussed and decided upon. The regional level offered opportunities for the exchange of goals, functions and values, since not all spatial demands had to be accommodated within the territory of a single municipality. By 2008, provincial contours, like the red contours, were no longer demanded and controlled by the state. Time will tell what the disappearance of the threat of central government intervention has done to the provincial contours.

The *Packages for Sustainable Construction* achieved their goals, albeit for a limited period of time: knowledge about sustainable building was harmonised and disseminated amongst a large number of actors active in building and construction. The Packages had been used specially in the late 1990s. In 2000, the Minister of Housing decided that sustainable building could be taken care of by the market and reduced attention for sustainable building and thus for the Packages. In response, the building sector's attention for this harmonisation of knowledge diminished as well. A factor that contributed to the declining enthusiasm of industry is that in the development of sustainable building policies a next logical step would be from checklists to more informed choices about the environmental performance of products. This would involve the disclosure of product information. From a competitive point of view, the industry was not eager to publicise such information and showed no hurry to develop such initiatives itself, especially with the absence of a government incentive. In 2008, the Packages were still widely used as a basis for voluntary agreements between local authorities and actors in the housing and construction sector, and the Packages clearly responded to a demand for such lists.

The descriptions above already nuance the evaluative judgements of the performance of both governance approaches. There are positive and negative aspects to both cases, and the evaluative judgement depends on the criterion used. The following section will show how command and control approaches and process approaches evaluate these policy processes and their results.

5. Why do radical policies fail and incremental policies succeed?

Due to the dynamics of policy processes, policies can no longer be evaluated by simply asking the question: *did the policy achieve its goals?* The literature review in the first section of this chapter shows that in the past decades, we have discovered that there are many, legitimate reasons why policies would *not* achieve the original goals stated. The reasons are so strong and convincing, that policy-makers would almost be foolish not to change them. After all, not changing goals implies that policy-makers are isolated from new inputs, closed to external signals and information, not willing to learn and resistant to change. Already in 1985, Wittrock and DeLeon stated in their paper – with the meaningful title *Policy as a Moving Target* – that "…perhaps the one 'constant' in the policy process is change" (p. 20).

The recognition of policy dynamics has led to the development of a bunch of relative evaluation criteria that can be used to assess policy performance under changing circumstances. It is not just about formulating goals, but also about getting goals accepted by stakeholders who have the power to make or break policy by giving or withholding their support. As targets are constantly moving, the way of the policy process gains in importance over the achievement of predefined targets. In the absence of absolute, substantive criteria to assess the achievement of policy goals, proxies were developed for policy performance, for instance by asking questions as: Were stakeholders participating in or affected by the policy satisfied with the results of the process? Did actors involved in the process learn from it? Did they exchange and negotiate information and knowledge? Did they continue their interactions and thus create new chances for policy success? Approaches to governance evaluate policy performance based on this kind of questions.

Table 1 (on next page) summarises the evaluation of both governance approaches as adopted in the cases on several criteria which are commonly used to explain policy performance (Teisman, 1995, Koppenjan & Klijn 2004, Bruijn & Heuvelhof, 2008). This table confirms the view that policies aiming for radical changes are destined to fail. The one-sided formulation of goals seems to be the main weakness. By formulating goals singlehandedly, policies mobilise resistance: core values of actors with vested interests are trespassed; powers are ignored; knowledge becomes unquestionable and absolute; dynamics in the policy process – resulting from new participants and new information and knowledge – are ignored.

Table 1 Explaining policy performance of the cases

	Governance Approach	
Evaluation criteria	Command & Control (Zinc and Red contours)	Process (Packages and Green Contours)
Definition policy goal	One-sided, by single actor	In interaction with multiple actors
Acceptance policy goal	Goals were contested	Goals were accepted
Core values of stakeholders	Endangered	Respected
Blocking power of stakeholders	Ignored	Acknowledged
Dynamics of policy process	Ignored	Acknowledged
Role of knowledge	Unquestionable	Negotiated
Lessons learned	Yes	Yes
Ex-post satisfaction of stakeholders	No	Yes
Continued interaction	Yes	Yes

Also, in the light of continuous change, policies will by definition not be able to achieve the ideal situation as embodied in the policy goals: they reflect the ideal yearned for at a particular moment in time.

The dominant storyline in evaluations based on these process-based criteria is that by making ambitions tangible, from a single point of view, sustainability loses its magic as a policy concept. Exactly because of its ambiguity, it is able to reconcile competing values and bridge conflicting interests (Hajer ,1995). Ambiguity therefore is a functional requirement for formulating policy goals. It creates a shared territory which stakeholders can jointly discover. “It is precisely because they [actors] may not have quite the same thing in mind when they talk about ‘sustainability’ that the term provides a glue holding the actors and organisations together, framing spaces for innovation.” (Evans & Jones, 2008: 1430).

The flip side of these process evaluations – and this is pointed out by command-and-control proponents – is that the ambiguity of sustainability may invite actors to behave strategically. Concepts as sustainable development are broad and address a multitude of issues (Connolly, 1978). In the absence of a specific definition, actors can claim that their way is the sustainable one, and thus hi-jack the issue in support of their own goals. Once an issue has been claimed and framed by actors, it is difficult for other actors to reframe it and to make it part of other debates and policy processes. This strategy can be recognised in the case of the Packages, where the building sector was eager to develop such Packages by itself, on its own terms. The ambiguity can also lead to a masquerade, merely paying lip service to sustainability, no attempting to make the concept tangible. When made more tangible, priorities between the competing interests embodied in the sustainability concept are set and costs and benefits allocated. In this way, sustainability will keep everyone on board: nobody will oppose sustainability. This pitfall was potentially present in the case of the provincial contours, although it did not materialise in the sample studied.

From a process point of view, command-and-control policies fail to recognise the multi-value character of sustainability, requiring policy goals to be formulated in interaction with actors concerned. From a command-and-control point of view, process-based policies lack criteria to assess whether the ambiguity of sustainability is abused in support of particular goals. Nevertheless, process approaches have plenty of plausible and legitimate explanations for policy failure, and policies rather change than fail. Command-and-control approaches are more empty-handed when it comes to accounting for policy results. Even if successes are achieved, the ideal situation aimed for will always be far away.

6. Conclusions and recommendations

The dominant story line in contemporary policy evaluation is that policies aiming for radical changes fail and that incremental policies succeed. A central explanation is that the latter are better at making use of the ambiguity of the policy goals (c.f. Evans & Jones, 2008). They use it as a point of departure for negotiating policy goals. However, the cases and the discussion of the results and achievements show that it is too easy to draw this conclusion for the cases studied. In particular, three observations can be made.

The first is that the cases show that the success of process approaches is a combination of a tempting ‘carrot’ and the potential threat of a ‘stick’. The possibility of central government intervention when provinces or the building sector delivered a policy that did not satisfy central government urged these actors to take action. When this threat disappeared, in the case of the Packages the actors concerned put less effort in establishing policy goals, or, in the case of the provincial contours, they were expected to do so. Also process approaches thus benefit from strong central government intervention or the opportunity to make use of their hierarchical powers to intervene.

The second is that ‘hijacking’ an issue by formulating clear goals may be a sensible strategy for central government. This is what central government did in the cases of the contours and zinc. Formulating clear goals could determine the setting, the policy arena, in which the issues were addressed and the rules by which they were addressed. The other stakeholders had to play by their rules, on their grounds. This gave them a considerable advantage in the policy process.

A third observation is that in all cases, intentional or not, a multi-level game was played by authorities. Strict enforcement of policies on a central level created opportunities for negotiation and exchange of goals on a local or regional level, as happened in the cases of the spatial contours and zinc. In the case of the National Packages, central government gave the building sector the opportunity for self-regulation, which in turn was used by local authorities to more or less ‘enforce’ compliance to these self-established rules by making them part of local policies and covenants on sustainable building and housing.

Although it is easy to bash government for formulating policy goals which lack support and are doomed to fail from the start, the cases show that these policies can be functional as well. It offers policy-makers in other places, at other levels or at other times, more room to negotiate policy goals and achieve piecemeal changes by process approaches to governance.

While the cases are situated in the fairly democratic context of the Netherlands, a unitary state and member state of the European Union, the recommendation to enhance a sustainable built environment by a multi-level play may be applied in other contexts as well, such as federations and single-party states. However, in all contexts, even democracies, attention should be paid to democratic deficits in the policy process. The zinc case showed that it is very difficult for an industry to contest a policy that is based on prevention and voluntary action, also in a democracy as the Netherlands.

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Research by Design in the Debate on Wind Turbines in the Netherlands

Prof. Dirk Sijmons, MSc[32]

1. Introduction

The present debate on wind power and wind turbines in the Netherlands is focusing on the aspect of esthetics. Can one accept wind turbines in the Dutch landscape where the flat countryside seems to make our horizon extra vulnerable?

The arguments posed may be emphasising aspects of beauty or unattractiveness, but the real debate should be on the arguments behind this point of view. There one can find a strong interaction between appreciation of these turbines in the Dutch landscape and the perception of this new form of energy. Are the newest generations of turbines just another type of windmill or are they perceived for what they are: true power stations with pillar heights up to 120 meter? Almost everybody in the debate hurries to pay lip service to clean energy but participants in the debate who are annoyed with the newcomers tend to play down the potential contribution wind energy can deliver to the production of electricity (arguments are heard as "these machines aren't even able to recharge our electrical toothbrushes") and tend to use the word horizon pollution[33] when describing the effect of proliferation of wind energy. On the other side, people who tend to like the turbines welcome them as a first step to CO_2-free production of energy and welcome them as the liberators from the carbon age (comparisons are made as "their calm rotation looks like tall sailing ships passing by").

The debate on wind, in other words, is fuelled by emotions as much as rational arguments. There is also a strong semantic layer of different denotations that every once in a while brings about a veritable Tower of Babel. These emotions should be

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[33] The term horizon pollution is a literal translation of the Dutch 'Horizonvervuiling' It was introduced in the 70ties in the Dutch *discours* by environmentalists to depict the effect of high rise buildings. It might be an endemic Dutch term. I'm not sure if there is a satisfactory translation in English, French and German

taken seriously to clarify the debate. A rational government explaining the facts to a population that is just backlogged in information cannot mitigate these emotions. We have to deal with the fact that some people seem threatened by the introduction of this new technology. This could have to do with the fact that we all too lightly took the current power sockets for granted. What always has been buried under the surface in the form of fossil fuels and has only been perceptible by the remote plumes of the power station suddenly becomes visible and very close, as wind-energy (and solar energy) are forms of decentralised production. One might also feel weary because every turbine feels like a tall totem to the end of the fossil era, and in some people they could even stir the uncomfortable feeling that they signify the end of the prosperous life we lived.

Figure 1 MVRDV proposes a far off-shore multilateral project on the 'Doggers Bank'.
Figure 2 An unexpected contribution to View on Deventer (co-production of Salomon van Ruysdael and NL Architects).

2. Energy Atlas

In my quality as National Advisor on Landscape, a function that I exercised from 2004-2008, I produced an advice on the spatial aspects of wind energy to the three involved ministers (Rijksadviseur Landschap, 2007). In the preliminary studies that underpinned the advice an extensive 'research by design' project was laid out to explore spatial strategies to accommodate the doubling of wind energy in the Netherlands. These studies were complemented by my production of a concise Energy Atlas (Sijmons & Hugtenburg) for the Minister of Spatial Planning to facilitate the debate after the presentation. Common ground is doing research on the perception of the so-called facts. The preliminary studies emphasises the different layers within the diversity of subjective perception. The Energy Atlas limited itself to the objective data. Both studies following the method of 'research by design', so every image is a hypothesis, a well-underpinned argument for enriching the debate.

To give direction to the preliminary studies we used four basic attitudes on domestication of new technologies in societies (Smits, 2002). Societies that feel the thread of new technologies seem to choose between the following four options. Banishing the monster is of course a reflex; embracing the monster: the flight forward; adaptation: transforming the monster; and finally pragmatic assimilation, that is changing the rules under which society calls something a 'monster'. As the National Advisor I acted as the casting director of these studies. We commissioned two architects (MVRDV and NL Architects), one urbanist (Matton Office), one landscape architect (Paul van Beek Landschappen) and an artist (Hans van Houwelingen) to do the job.

Figure 4 Ton Matton is championing a PR offensive for green power and connecting to local communities

Figure 3 Paul van Beek reminds us of our design tradition in place-making for windmills

MVRDV banishes all the mills to the North Sea and proposes a far offshore multilateral project on the ‘Doggers Bank’ between the neighbouring countries of Germany, Denmark, the UK and the Netherlands.

NL Architects embraces the turbines and conceived a complete new typology with chandelier mills, multiple use mills, industrial mills, flower-shaped mills, etc.

Paul van Beek reminds us of our design tradition in place-making for windmills. He makes a strong case for adaptation and redesigning the receiving landscape when planning for wind parks on land.

Ton Matton is championing a strong relationship between a PR offensive for green power and connecting to local communities. If the community could benefit from the new utilities, problems with NIMBY reflexes that result from top-down planning can be avoided by this assimilation strategy.

Hans van Houwelingen proclaims that primarily functional utilities as wind-turbines do not fit in our post-modern landscape and should be brought close to the places were electricity is most needed: the city. He shows an overwhelming amount of examples of how the urban program can be enriched by wind-turbines.

Martijntje Smits constituted a matrix of the attitudes distinguished to position the five research-by-design studies. The strong and weak characteristics of the analyses were used or avoided in the actual advice to the ministries.

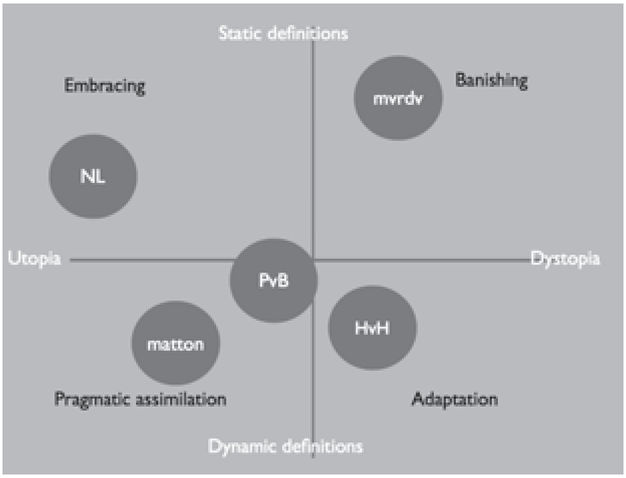

Figure 5   Matrix with the attitudes distinguished by Martijntje Smits'study

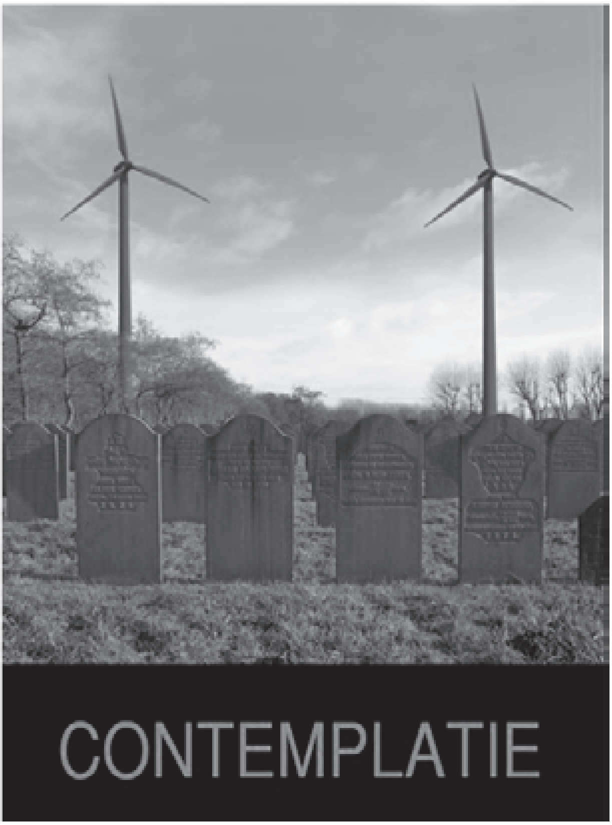

Figure 6   Hans van Houwelingen proclaims that wind turbines should be brought close to the city

The concise Energy Atlas is as a complement to the advice and aims to allow people to compare the spatial and environmental effects of ten ways of producing electricity. The unit of comparison chosen is the amount of electricity produced by all the Dutch wind turbines together in 2006: 3,387 GWh. If one is opposed to doubling the capacity of wind power the atlas informs (and confronts!) you to the effects of all alternatives to produce that same amount of electricity. Every modality shows its face in six ways: the size of the production unit, maps, a photo documentary of the generation of the energy source, the production and side-effects, info graphics on land use and a Life Cycle Analysis, a landscape with and without this specific modality and finally all are mounted onto our oldest Zuiderzee polder, the Wieringermeer. The following pages show this montage of the 3,387 GWh production of electricity in the old polder using coal, oil, hydropower, wind, solar, waste or biofuel.

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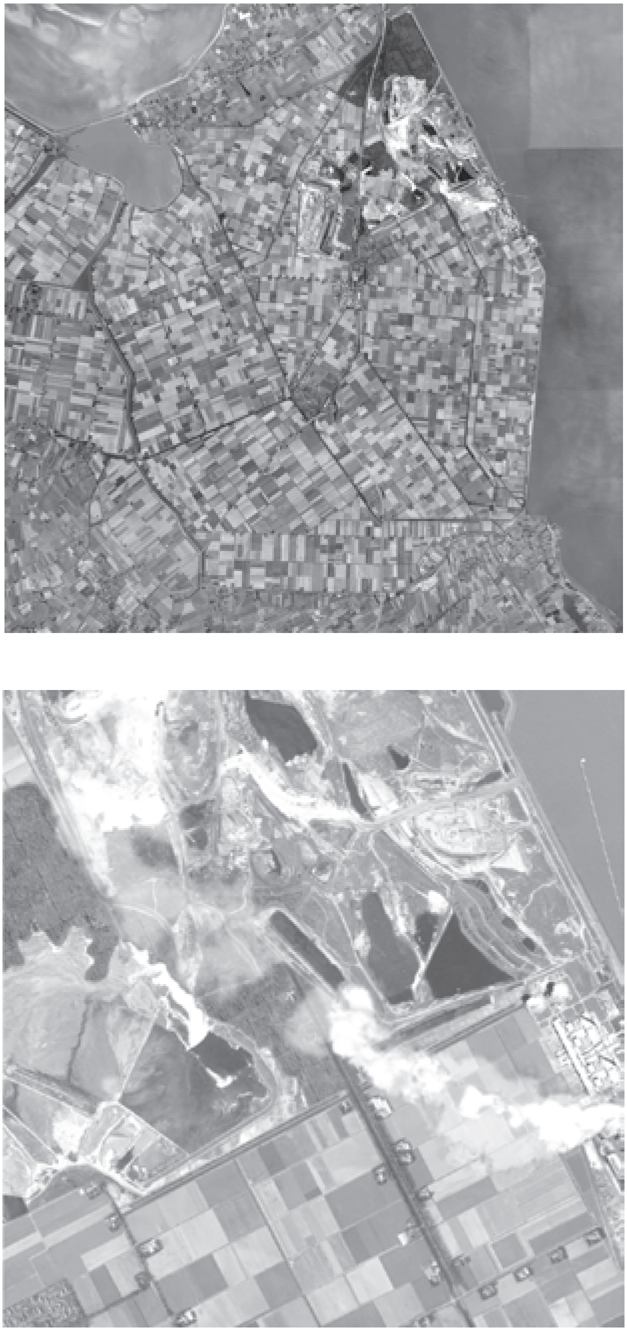

Figure 7 Coal: Wieringermeer powered by coal

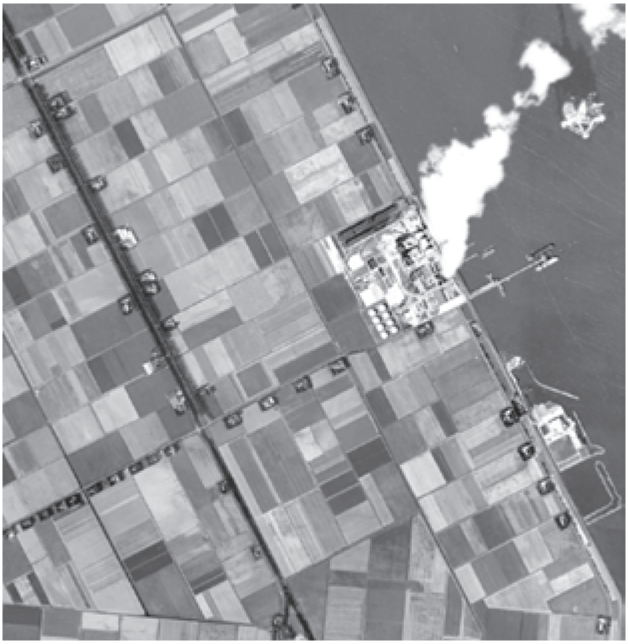

Figure 8   Oil: Wieringermeer powered by oil

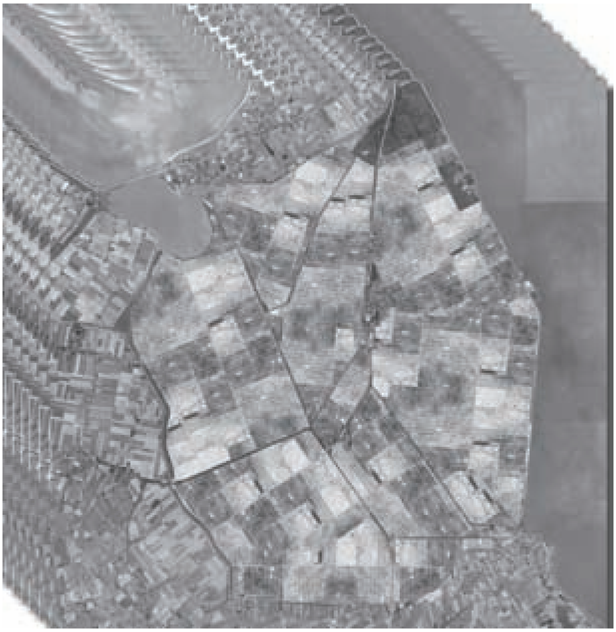

Figure 9   Waste: Wieringermeer powered by waste

Figure 10   Biomass: Wieringermeer powered by biomass

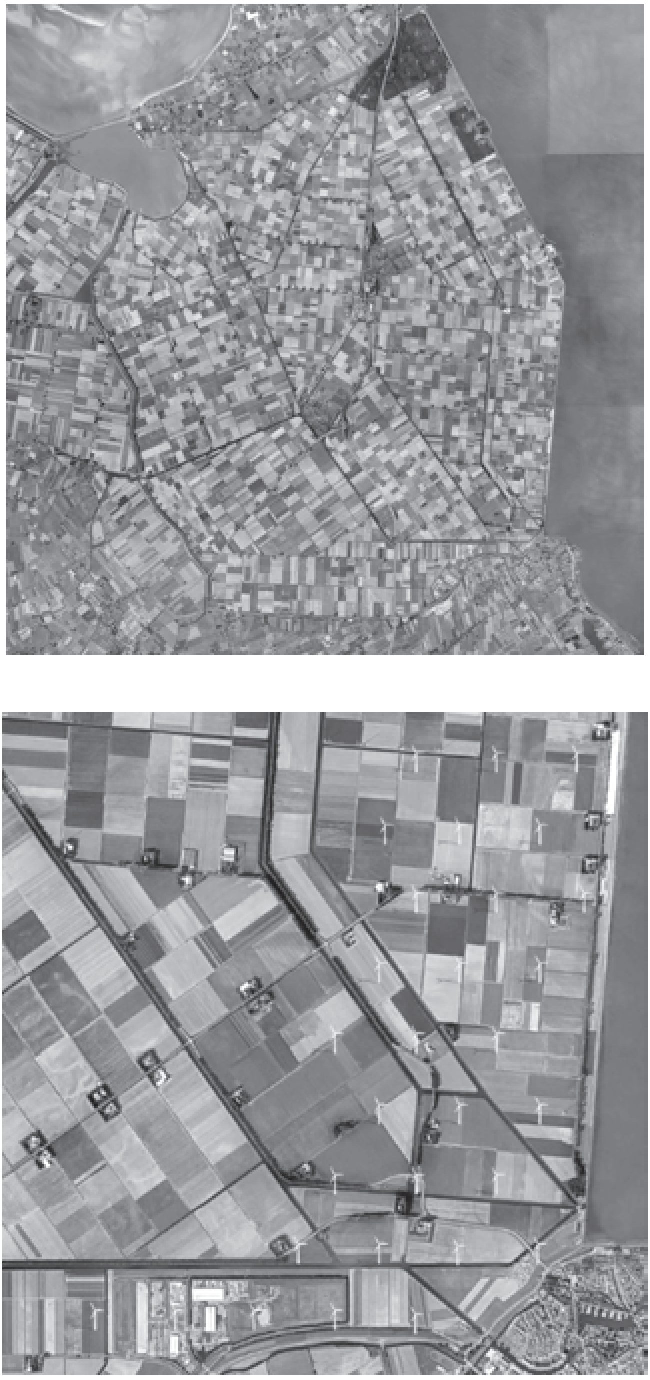

Figure 11 Wind: Wieringermeer powered by wind

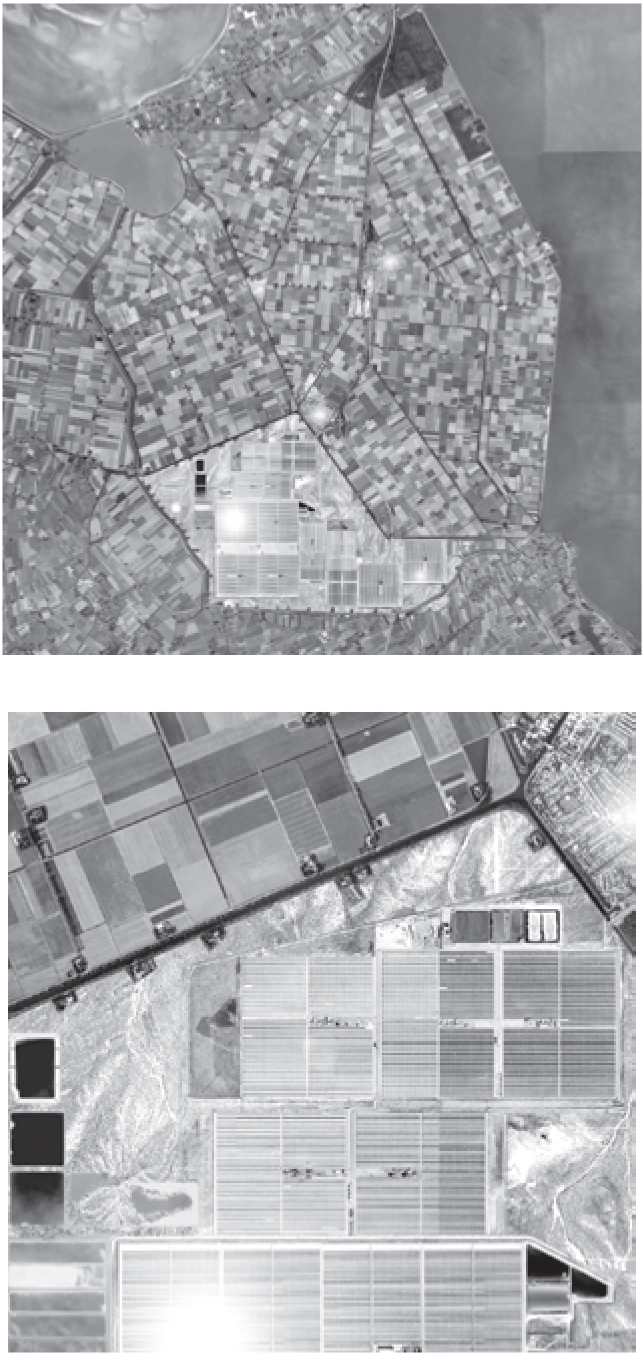

Figure 12   Sun: Wieringermeer powered by the sun

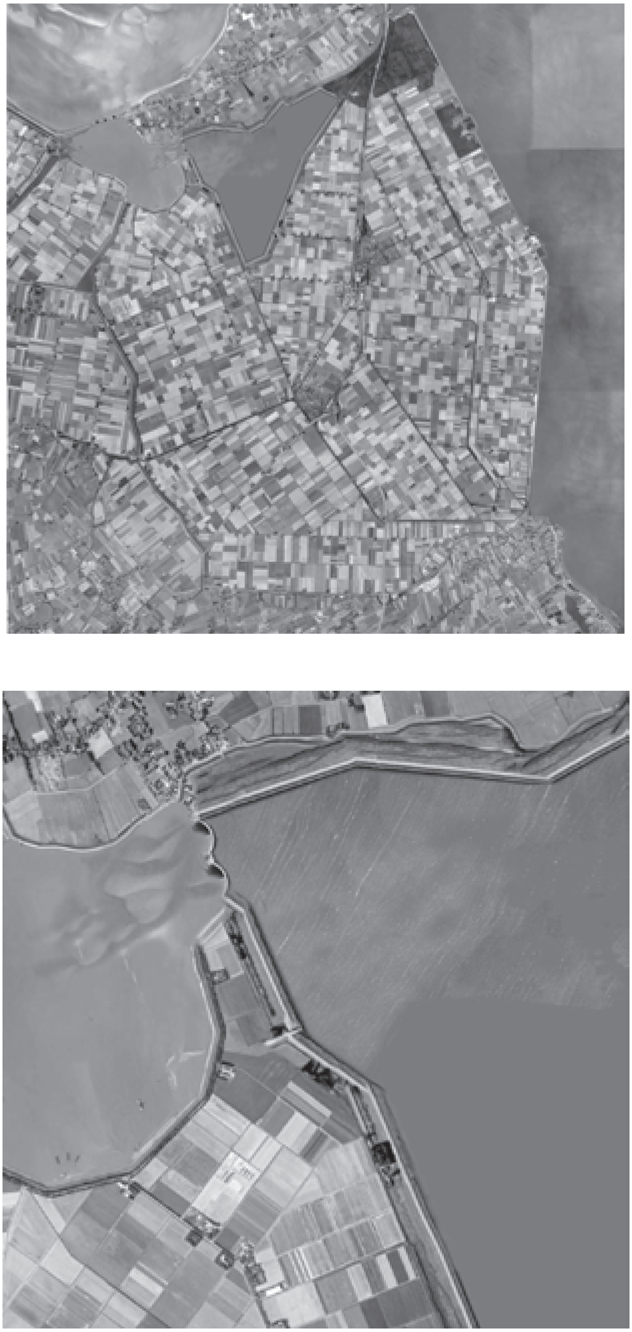

Figure 13 Hydro: Wieringermeer powered by water

Epilogue

Prof. Andy van den Dobbelsteen, PhD MSc[34], Dr. Machiel van Dorst, MSc[35], Dr. Arjan van Timmeren, MSc[36]

This book puts the largest things humans create – the built environment of cities, towns and villages – squarely within the context of the triple crisis of peak oil, species extinction and climate change. Doing research on sustainable development in the built environment means being a 'generic expert'. Only within our area of science one would read a book as this one, touching on a vast variation of specialisations. Diversity within the domain of sustainability is essential from two perspectives. First of all, sustainable development is a package deal: optimising by doing vigorous research on a well-limited topic only has effect if one is aware of potential trade-off effects within other disciplines. And the second incentive of being diverse has to do with the designer's and engineer's perspective - being on the lookout for enriching combinations. If one applies mind mapping to the field of sustainable development in the built environment two basic disciplines would be found: environmental science and sustainable building. Environmental science has a history dating from 'Silent Spring' (Carson, 1962) directly to our present insights in climate change. More than before, knowledge related to this discipline that has been spread has a significant influence on socially and technically oriented science and design. The limits to growth are becoming the problems of today, as credit crunch and climate change are present. Sustainable building on the other hand may have a history in vernacular architecture; it started as a discipline in the beginning of the seventies emerging into a variety of solutions and interpretations. This diversity underpins our observation that this discipline is coming to age and at

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the same time emphasises the unknown future. Within this frame the various chapters of this book will serve as a context for your research (are we on the right track?) and may bring new enriching combinations with your own work to join the road towards an interdisciplinary approach.

Building, skin and technology

The so-called fundamental goals of the ‘generic expertise’ mentioned before can be found within the chapters of ‘Building, Skin and Technology’. Here the presented disciplines overstep the problems and aim for solutions on the level of materials, building components or buildings. Within this context the usability is essential. As for usability the case of the hempcrete projects (Woolley) is a fine example for other research projects presented at the Delft SASBE2009 conference. The role of our international community of generic experts is to put this type of research results into our own context so they become universal. In the exemplary case of hempcrete the quality of being a lightweight material while at the same time maximising the characteristics of a heavier material, which both insulates and stores heat, is the universal part. The conditions under which hemp may grow is of course a local issue. This also goes for innovations on indoor climate control as they can be considered the backbone of our expertise.

Sustainable building being at the very centre of our studies may present itself as being technical and close to perfection. We are on our way to energy-producing ‘cradle-to-cradle’ buildings. Meanwhile, as technicians find the most excellent solutions the attention is shifting towards a broader perspective within this aim for sustainable building: creating conditions for sustainable living. Within the system of (indoor) climate control the user gets a place as ‘an essential component’: people being part of the solution instead of the problem. In his introduction ‘One Planet Architecture’ Thomas Rau opens up an even broader perspective. A sustainable building is not only healthy and people-oriented, but will enhance awareness of our planet. So back to the generic expert that is smart enough to see sustainable building as a condition for sustainable living. A culture pessimist would blame technology for neglecting the human perspective in the past. We would like to emphasise the positive approach; the use of technology is coming to age and has the quality to serve the users in most advantageous way.

Regional and urban design

Scaling up to the urban and regional level, sustainable design becomes less concrete. The practical reason is the growing influence of the social and cultural environment. The context of the design task becomes more complex and the time spans becoming longer. Du Plessis emphasises this quality by calling the planning problems inherently wicked (difficult to define and unpredictable). By combining planning with the concept of sustainable development (which also can be labelled as a wicked problem), things would even become more complex. Overall, the clarity we found within Building, Skin and Technology, has not been reached yet in urban design or spatial planning. This has historical reasons. Sustainable techniques start out at the level of materials and products and eventually worked their way up to the scale of a building and finally even result in the development of sustainable bulding clusters or neighbourhoods. On the scale of a city or a region a sustainable development is more focussed on specific sub flows or aspects, like water, green, traffic. A focus on one aspect of sustainability gives you a starting point to grasp within this complex reality. It also gives the possibility to come to a multi-scale solution.

The most prominent example is using water as a starting-point for a sustainable development within the urban fabric. Agudelo et al. present a more efficient and sustainable urban water system as the final goal. The results show a system analysis that leads to the description of the potentials for multi-sourcing, re-using and cascading of water. This approach has a quality in its own because it may even result in a full closure of water cycles. At the same time it has potential quality for the urban context as different flows may be interconnected. Agudelo et al.: “A further step is to analyse how to address the relation among the different flows within the urban tissue. For this purpose the same functional unit and principles will be used, also to address competition regarding the spatial claims by the different flows.” On a local scale Wisse is using water for heating and cooling of buildings. The effects on the design will be on the building level and urban level, but also on water quality and emerging problems such as the urban heat island. So, taking a single flow as a starting-point may get you back to the complexity of the city.

From a technical sciences viewpoint the urban scale was - and still is - too complex. We are still not capable of applying a life cycle analysis for an entire city. From the starting-point of a spatial planner the interpretation is the opposite: sustainable science gives us handles and levers to understand the complexity of a city (or a region) in a dynamic way (so including processes of adaption and resilience). A similar approach is introduced within the chapter of Roggema. Approaching the city as an ecosystem (including variables as the rise of sea level) results in a comprehensive problem. This underpins the argumentation of Du Plessis emphasising the power of sustainable science by focussing on understating the dynamic interactions of ecological systems (of which the city forms a part). The difference lies in Du Plessis defining the city as a *social*-ecological system. This gives us a parallel with the actual development within architectural sciences aiming for sustainability as described before.

Du Plessis and Roggema give us insight in how transformation should be handled or understood, as it is a natural characteristic of a sustainable development. The optimistic approach is incorporated in the system approach, in contrast to Van Bueren's contribution, where the policy perspective was taken as a starting-point.

Management and transformation

A technical and/or a designers approach in general incorporates an optimistic approach towards sustainable development. Practical solutions and methods for creating conditions are common ground. Although 'Management and Transformation' related research mostly drags us back to everyday reality, the constructive approach is also present.

The challenge in the developed world can be found within the transformation of the existing housing stock. Although the process of transformation in itself is part of the discussion, the practical topics still concern the main focus. Transformation of the existing building stock is shifting towards the debate on adaptable buildings. As Van Hal says: "An industrial, flexible and demountable (IFD) approach seems promising." The tension is within the approach on adaptability: are we going to adapt the existing building stock or are we going to create a new adaptable built environment? As in the conclusions of Manewa et al.: "The main difficulty faced by practical changes/conversions arose because early design was not focused on future flexibility. This emphasised the importance of incorporating higher level strategies of adaptability in future new buildings which provide economically sustainable solutions for the whole country." When moving away from the practical solutions we are getting closer to limitations every day in our exertion towards a sustainable built environment. Again the limitation can be found in the context. First of all, our planning tradition is to blame. Remøy and De Jonge are emphasising the influence of the location on a feasible adaptability. So there may be a lack of knowledge on building transformation, uncertainty about financial feasibility, and little knowledge about the chances and risks of transformation processes. Problems then probably can be solved easier. However, at the end of the day buildings within monofunctional office areas are not considered to be suitable for housing. The second setback is the limited opportunity for radical change. Van Bueren explains to us the reasons why policies aiming for radical changes are destined to fail.

Building smartly in a changing climate

Being an expert in science or technology provides a focus. The generic expert also needs this focus to guide him or her within the complexity of the field of sustainable development in the built environment. In-depth research leads to new theoretical insights. At the same time a broad perspective leads to the necessary enriching combinations, to possible ‘synergy’. Today’s innovations often are based on this kind of combination. Building smartly means integrating solutions: combining solutions of the different flows, or environmental issues with social issues, or environmental insights with policy and management. From a scientific point of view, special attention should be paid to combining empirical methods with technical or design-based strategies. This book addresses all these aspects, and all should be judged within their own context. However, it is up to the generic expert to overstep the differences in approach and blend them into one integrated approach to the built environment. From this perspective the contribution of Sijmons gives us a clear set of arguments and hypothesis. It also makes clear that these can only be found by practice-based ‘research by design’.

A generic view is not meant to define our common objective. We need diversity in ways to approach the effects of a changing climate; as through the ages (bio)diversity has always been the backup for survival. Within this notion we hope to help you, being a generic expert, starting up interdisciplinary approaches as well. And in doing so within the context of sustainable development, get into debate on what smart and sustainable architecture and built environment should imply. We the editors of this book are keen to facilitate this.

Acknowledgements

This book is constituted from selected papers from the 3rd CIB International Conference on Smart and Sustainable Built Environments (SASBE2009), held in Delft, the Netherlands from June 15th to 19th 2009.

SASBE2009 was organised by people from the Delft University of Technology, under the auspices of CIB. SASBE2009 was sponsored by the Rotterdam Climate Initiative, Dutch Green Building Council, the Municipality of Delft and BuildDesk.

Apart from us, the Organising Committee consisted of Elma Durmisevic, Tadeo Baldiri Salcedo Rahola and Siebe Broersma, Marcello Soeleman and Koen Kegel from Stylos, Tim Vermeend for external support, Rudger Smits for graphical design, the incredible Corry van der Drift and Els Bakker from Aula Conference Centre, and our inexhaustible student assistants Martine Verhoeven, Ronald Velner and especially Michiel Fremouw. Martine and Siebe were a great help with the book.

Wise advice we received from the following members of the SASBE2009 Steering Committee: Jay Yang, Wim Bakens, Wytze Patijn, Jon Kristinsson, and Anke van Hal.

We got empathetic support from our SASBE2009 Partners: PLEA (Koen Steemers), iiSBE (Nils Larsson), CABA (Ron Zimmer), UrbanOrganism (Jos Hendriks and John Rade), Arko Publishers. (Arend Jan Kornet) and of course in particular Techne Press (Heleen Gierveld), who made the enterprise of this book possible.

Specifically for this book we would like to thank the authors of chapters and special contributions: Ken Yeang, John Worthington, Chrisna du Plessis, Rob Roggema, Claudia Agudelo, Adriaan Mels, Ronald Rovers, Kees Wisse, Thomas Rau, Agnese Ghini, Tom Woolley, Roel Gijsbers, Marc Cox, Tim De Haas, Peter Kok, Harm Hulsbergen, Anke van Hal, Hilde Remøy, Hans de Jonge, Anupa Manewa, Christine Pasquire, Alistaire Gibb, Robert Schmidt, Marjolein van Esch, Ellen van Bueren, and Dirk Sijmons.

We also like to thank our fellow SASBE2009 Scientific Board members, who with us were responsible for the reviewing process of scientific papers: Elma Durmisevic, Frank Schultmann, Jeremy Gibberd, Vanessa Gomes Silva, and Jean-Luc Salagnac.

And last but certainly not least we want to express special gratitude to the SASBE2009 Technical Committee, engaged in the blind reviewing process of initially 250 abstracts and eventually 150 papers: Ilker Adiguzel, Elisa Boelman, Jos Brouwers, Ellen van Bueren, Jean-Luc Chevalier, Abdol Chini, Derek Clements-Croome, Ype Cuperus, Jaap Dawson, Peter Erkelens, Ana Maria Fernandez Maldonado, Alex Fraaij, Rob Geraedts, Mark Gorgolewski, Johannes Halman, Gilli Hobbs, Frank van der Hoeven, Per Jostein Hovde, Edward Hulsbergen, Laure Itard, Tom Jefferies, Lutz Katzschner, Gregory Keeffe, Charles J. Kibert, Tillman Klein, Ulrich Knaack, Hedzer van der Kooi, Gijsbert Korevaar, Katarzyna Kujawa, Stanley Kurvers, Jos Lichtenberg, Peter Luscuere, Ardeshir Mahdavi, Craig Martin, Peter Mensinga, Karel Mulder, Bjarne Olesen, Chrisna du Plessis, Jouke Post, Susan Roaf, Roberto Rocco de Campos Pereira, Ronald Rovers, Silvia de Schiller, Thorsten Schuetze, Sacha Silvester, John Storey, Rudi Stouffs, Peter Teeuw, Wim Timmermans, Bige Tuncer, Stefan Uhlenbrook, Jan Vambersky, Karel Vollers, Theo van der Voordt, Hans Vos, Martin de Wit, Tom Woolley, and Grietje Zeeman.

Thank you all!

Andy van den Dobbelsteen, Machiel van Dorst and Arjan van Timmeren

Index

Abstracts

1. Urban Sustainability Science as a New Paradigm for Planning

Planning problems have been described as inherently wicked, i.e. difficult to define, unpredictable, and defying standard principles of science and rational decision making. Sustainability science is a new area of science that focuses specifically on understanding the dynamic interactions of social-ecological systems, of which the city is a particularly significant example. Building on the literature of planning and sustainability science, this paper presents an argument in favour of sustainability science as a theoretical basis for a planning paradigm that can effectively engage with the wicked problems presented by cities and their sustainability. The paper acknowledges that this argument is in the early stages of development and presents it as a stimulus for broader discussion and further development by a larger community.

2. Regional Planning for a Changing Climate in Groningen Province

Unpredictable changes in climate will cause turbulent environments for the next century. In spatial planning it is difficult to deal with uncertainties and long term perspectives. In order to deal with an uncertain future, these shortcomings in planning need to be taken away. This can be done by starting to look at climate change and regional planning as a wicked problem instead of as a tame problem, like we usually do. In the planning process an environment needs to be created, in which the characteristics of wicked problems can be tackled: a wicked bypass. This has been done in the Groningen case, in which environment the backtracking method was used. This method shows an area specific point in history when Groningen was in a sustainable equilibrium state. The key elements of this equilibrium state inspired future thinking and formed the basis of a new planning approach, which is able to deal with a complex and uncertain future. Instead of a blueprint plan for the upcoming century, strategic interventions are defined, which start spatial developments and enhance resilience in the surroundings of the intervention. The strategic interventions enable people in the area to be better prepared for unexpected circumstances and thus less vulnerable for the effects of climate change.

3. Urban Water Tissue: Analysing The Urban Water Harvest Potential

Accelerating urbanization, increasing scarcity of resources and climate change force us to re-think and redesign urban systems towards closing of cycles, minimization of impacts and strategic management of resources. Cities are complex systems with multiple functions, large demands for resources, intense competition for space and high dependence on external resources (urban and rural). To deal with this complexity the “Urban Average Tissue - UrbAT” concept has been developed as an approach towards visualizing the existing demand and supply of a given resource in a specific area. The UrbAT also explores potentials for closing cycles, by means of multi-sourcing, re-using and recycling activities. The UrbAT offers a simplified and standardized representation of a city and its different functions in an “Average hectare”. Water-UrbAT is an attribute to UrbAT dealing with water. It measures the maximum potential for harvesting water within an urban system. The Urban Water Average Tissue matches the available resources with the existing demand, in terms of quantity and quality requirements, making visible the potentials for multi-sourcing, re-using and cascading water within the system, ultimately aiming for a full-closure of water cycles, thus avoiding the need for external resources. This paper presents the Dutch urban water tissue (Water-UrbAT-NL). The results provide approaches for a better and more efficient way of meeting our water needs, by making optimal use of cascading and reuse principles.

4. Urban Surface Water Application for Climate-Robust Cooling of Buildings with Aquifer Energy Storage

Urban surface water challenges architects to integrate the building and its environment. Urban surface water application also gives an interesting perspective for heating and cooling of buildings. In an integral design approach, these two challenges meet each other. This paper presents the potential of urban ponds for cooling of office buildings together with aquifer systems in the Netherlands. Using aquifers, the captured energy can be stored until the moment that the energy can be applied effectively. It is shown how urban surface water can be integrated in innovative sustainable cooling concepts with aquifer storage. The annual temperature cycle of a typical pond is presented using both measured and simulated results. The key parameters for an effective energy capture from the pond are presented, followed by the requirements of a typical office building in the Netherlands.

It is obvious that the required energy from the pond is strongly influenced by the outdoor climate, amongst other key factors. On the one hand, the outdoor climate determines the energy consumption for heating and cooling of the building. On the other hand, the energy capture potential of the urban surface water is strongly influenced by the characteristics of the outdoor climate. For a climate-robust design, the effect of climate change has to be incorporated.

Scenarios for the climate change as developed by the KNMI are applied in order to develop future design reference years. Subsequently, the cooling demand of a typical office building is evaluated as well as the required energy from the surface water. Cooling demands are presented for concepts with and without heat pumps. Finally, the required area of urban surface water will be derived. The results provide guidelines for architecture and urban planning.

5. The Well-Tempered Envelope: A Prototype as a Sustainable Residential Building

The paper presents an ongoing research at the Department of Civil, Environmental and Land Engineering, and Architecture of the University of Parma, on the topic of sustainable healthy indoor environments in residential buildings. In this case, indoor comfort is strictly linked to low energy winter heating and summer cooling, the use of eco-compatible materials and components and, lastly, to the application of sustainable building technologies.

This applied research makes use of an architectural prototype built with dry technology – mostly using wooden components and easy disassemblable, renewable, recyclable materials – on which thermal, hygrometric and acoustic performances of the envelope and the entire building, in winter and summer seasons, are verified. A special analysis will be dedicated to the evaluation of the sun screens contributions and the adaptive capacity of the envelope in relation to the sun direction. The verification system is hybrid, as both theoretical and experimental methods for the calculation of the physical parameters are being used.

Two are the fundamental aims of this research. The first one is the identification of an appropriate dry technology for a sustainable envelope - characterized by easy disassembly and maintenance, and formed by ecological and bio-compatible materials – , which would be capable of maintaining internal comfort with a very low energy consumption. The second one is the development of a theoretical and experimental verification protocol to check thermal, hygrometric and acoustic indoor performances, during both the design and the usage phase of the building.

The paper presents the architecture and the technology of the prototype, now under construction, and a first draft of the verification protocol on the behaviour of the envelope in relation to a sustainable healthy indoor environment and its energy consumption.

6. Zero Carbon Building Methods: The Case of Hempcrete Projects

Despite aims to create zero energy and zero carbon buildings, most methods of construction remain a compromise in which energy savings are obtained at the expense of resource and energy consumption. While some still argue that embodied energy is not as important as energy saved in use, if we are to reduce impact in the short term we need to find ways of building buildings that are not dependent on materials that use high levels of petrochemicals and carbon emitting manufacturing processes.

Increasingly natural building materials are becoming available using renewable resources and with low emissions in manufacturing. Renewable materials based on wood, hemp, straw, flax, sheep's wool and so on actually lock up carbon into buildings and have many other advantages. We are starting to see the beginning of a new approach to building physics, investigating the way in which natural materials perform. This new building physics considers the dynamic performance of materials that can store heat, reduce thermal shock, manage water vapour and humidity and lead to better indoor air quality when compared with conventional and synthetic materials.

At the moment conventional methods of measuring thermal performance disadvantage natural materials but empirical evidence is now emerging that natural materials can out perform or match synthetic materials. This is best illustrated in the case of hemp and lime composites that are being increasingly used in the UK. A number of case study examples of hemp lime buildings will be presented at the conference. These range from houses to a brewery warehouse, office and University buildings.

7. Development of a Membrane Roofing System with Integrated Climate Control for Community Shelters

In case of calamities and emergencies, shelters offer great relief to large groups of survivors. For community supporting functions the current sheltering solutions are not satisfactory. A humane and feasible solution should be developed to fill this niche. The research group product development has developed a flexible and low cost semi-permanent building system for dairy cattle. The roofing of the arched building consists of multiple layers of membranes. The system proved to be technically and financially feasible, therefore it was chosen to be translated to a Community Shelter for emergency situations. Consequently, the membrane roofing system has to be further developed into a system for active climate control. The building climate has to be controlled without the input of energy, due to the possible lack thereof on location

A similar case is the development of an Arched Stable for the breeding of pigs in the Netherlands. The internal climate conditions for both cases are, oddly enough, nearly alike. Both applications demand a stable indoor temperature of 20-25°C and a high level of indoor lighting. The ventilation rate for livestock is substantially larger because of air pollution, although both are extremely high compared to normal dwellings. To achieve a reliable indoor climate in all situations, the large ventilation rate proved to be the most critical and challenging boundary condition. The solution is sought in combining multiple layers of semi-transparent membranes. Layers filled with standing air provide insulation capacity. In between the insulation layers heat recovery by large laminar counter flows will provide zero energy pre-heating of indoor air. Calculations prove that the principle works efficiently. The concept will be tested on a small scale before scaling it up to real-time applications. If proven reliable, the community shelter with integrated climate control will set new standards to the quality of relief in emergency situations.

8. Transformation of Monofunctional Office Areas

Building transformation and programmatic transformation into housing is a way of activating and reusing structurally vacant office buildings. The term structurally vacant indicates vacancy of the same space for three consecutive years and without perspective of future tenancy. Former research has shown possibilities for transformation through theory and practise, and has delivered instruments for determining the possibility for transformation of vacant office buildings. Still, building transformation is not taking place on a large scale. There are several reasons to be found; lack of knowledge about building transformation, uncertainty about financial feasibility, and little knowledge about the chances and risks of transformation processes. However, one aspect that is not mentioned that often is the location of structurally vacant office buildings.

In the Netherlands, more than 70% of the structurally vacant office buildings are located on office parks or industrial sites on the perimeter of the city centres or along the ring roads of the major cities. The location characteristics of these sites in most cases render the office buildings situated there unsuitable for housing, because of lack of public transportation, facilities and services, and also because of the unsafe and not very attractive public space. Is transformation of these buildings and areas still an option? Can urban renewal be initiated through the transformation of structurally vacant office buildings into housing? And, vice versa, what is the impact of urban redevelopment on the transformation potential of office buildings? In this contribution we will discuss the obstacles and opportunities of transformation of structurally vacant office buildings on monofunctional locations, both theoretically and based on empirical data.

9. Towards Economic Sustainability through Adaptable Buildings

The existing building stock in most countries does not meet the parameters of economic, social and environmental sustainability. Physical, functional, technological, economical, social and legal obsolescence are the principal factors driving the decommissioning, refurbishment, alteration and/or adaptation of a building. In the UK the Government promotes optimum use of the existing building stock through mixed use in urban centers and encourages conversion of redundant office and retail space into leisure, service and/or residential uses rather than demolition and renewal. There is therefore a growing need to design new buildings that are adaptable and flexible over their life span whilst at the same time improving user satisfaction. A constraint to the implementation of a policy of life span adaptability is the difficulty of understanding the economic considerations over long time scales. This paper investigates the issues surrounding the economics of the life span of adaptable buildings, and establishes a conceptual framework for their economic sustainability.

The investigation is based on a case study of how the uses and function of the built environment and its supporting infrastructure have changed over a period of 100 years undertaken within a semi-rural Borough in England, UK. This case study includes a trend analysis identifying the life spans (of buildings), the evolving planning policies and associated social and cultural issues. A conceptual framework is developed and the economic impacts of the changes are evaluated through Whole Life Analysis. The validity and reliability of proposed framework is yet to be tested.

10. Transferring Knowledge on Urban Microclimates in the Urban Planning and Design Process

The last decades building densities have increased rapidly, and they can be expected to increase more if approaches to stimulate intensive land use are to be followed. For the liveability of these dense urban environments its microclimates are of great importance, since microclimates can significantly affect the physical well-being of urban dwellers. An urban microclimate can be defined as the distinctive climate in a small-scale urban area, and is constituted by the influence of the built environment on the larger scale climatic conditions. In other words: the spatial layout of a neighbourhood sets the conditions for its microclimates. There is a significant body of scientific knowledge on the influence of the built environment on microclimates, but it is difficult to directly apply this knowledge to urban designs and plans. This paper proposes a framework for the structuring and translating of scientific climatic knowledge into information that is useful in the different phases of the design process. This tool will enable designers and planners to estimate the influence of their spatial design choices on the (future) microclimate and also has the capacity to play a role as a communication tool in a multi-actor environment. This will help creating conditions for urban microclimates that favour physical well-being.

11. Can Public Policies Change the World? The Potential of Public Policy to Stimulate Radical Change

The Al Gore movie has given the world a renewed and visualized understanding of the need for rapid, fundamental change. However, processes of change tend to be slow and depend upon the sensed urgency for change. As long as key stakeholders are not convinced of the need for rapid change, they tend to slow down such processes to protect their vested interests. Complicating factor in many policy fields is that decision-making power is scattered over a multitude of actors. Change can only be established when many of these actors collaborate in support of a common goal, but a common goal is difficult to define and rewards for collaboration are uncertain and in the future; they do not outweigh the certainty of short term costs and benefits of continuing ‘business as usual’. Processes of change therefore tend to evolve slowly and incrementally, also in the built environment.

Government is considered to protect common or public interests for which it can formulate and implement public policies. Theories of governance and public policy, especially in a democratic context, emphasize that government is not omnipotent and can merely support and guide processes of gradual change. Policies tend to acknowledge these constraints. As expected, sustainable development makes slow progress, while climate change contributes to a growing sense of urgency for action. In response, a growing number of scientists, interest groups, politicians and private firms call for strong government intervention. Government should ‘command’ the sustainability goals to be achieved and ‘control’ or enforce compliance with these goals.

Is this a viable call? Is government intervention restricted to the support and guidance of processes of gradual change, or can public policies also enforce radical change? This question is addressed in this paper, by comparing the effects of public policies aiming to support a sustainable built environment in the Netherlands. The cases show that attempts to enforce change, indeed, do not achieve the goals aimed for. However, these policies do create a sense of urgency for stakeholders to collaborate in other, related policy processes. Indirectly, these policies therefore speed up the process of gradual change. Public policy makers could make use of this effect and should try to find and sustain a balance between their role as a ‘commander’ of radical change and as a ‘facilitator’ of gradual change.