Use your potential!
Sustainability through local opportunities

Prof.dr.ir. Andy van den Dobbelsteen

Inaugural speech 5th of March 2010
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Intreerende prof.dr.ir. Andy van den Dobbelsteen

In verkorte vorm uitgesproken op 5 maart 2010 ter gelegenheid van de aanvaarding van het ambt van hoogleraar Climate Design & Sustainability aan de Faculteit Bouwkunde van den Technische Universiteit Delft.

Inaugural speech of prof. Andy van den Dobbelsteen, PhD MSc

Delivered in abbreviated form on the 5th of March 2010 at the occasion of his acceptance of the position of full professor of Climate Design & Sustainability at the Faculty of Architecture of the Delft University of Technology.
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Mijnheer de Rector Magnificus,
Leden van het College van Bestuur,
Collegae Hoogleraren en andere leden van de universitaire gemeenschap,
Zeer gewaardeerde toehoorders,
Dames en heren,

Sir Rector,
Members of the Executive Board,
Fellow Professors and other members of the university community,
Highly valued listeners,
Ladies and gentlemen,
Climate Design & Sustainability

Let me start by introducing the chair for which I was appointed as a professor. Climate Design & Sustainability is a new chair within the section of Climate Design, which is part of the Department of Building technology within the Faculty of Architecture, one of the eight faculties of the Delft University of Technology. You will understand the modesty regarding my position...

The double meaning of Climate Design

As a scientific area in within the context of architecture and urbanism, climate design is about designing the indoor and outdoor climate of the built environment. Its primary intention is to create comfortable indoor and outdoor environments or translated into physical aspects: light, heat and cold, humidity, air quality, acoustics and other forms of waves and radiation. With these starting conditions as the basis, the comfortable indoor and outdoor climate is pursued in a conscientious sustainable way, with a logical core focus on energy.

*Definitions*
- Climate design: the realisation of a comfortable indoor environment inside and outside the building
- Sustainable climate design: (negatively formulated) climate design by minimal consumption of energy and with minimal environmental damage or (positively formulated) climate design by an optimal use of energy and with maximum environmental benefit.

Because of the latter focus, in the previous 20 years, climate design has obtained a broader meaning, linking it to the global climate. Designing the global climate perhaps is too vain a goal, but in our field we have an influence and I consider it a major responsibility of my section to play a significant role in sustainable development. Sustainability is about holism (as will be discussed further on) and although our section should keep a core focus on comfort and energy, a vision on other aspects of sustainability – material, water and waste flows, human and economical factors – is essential.
The section of Climate Design consists of three chairs, which together form a rigid tripod structure of fundamentals, technology and application: Building Physics provides the fundamental knowledge for climate design, Building Services bring the dimension of technical utilities and smart technology, and Climate Design & Sustainability finally intends to bring these together in the sustainable design of a building or urban plan.

Linking education to recent findings from disciplinary or cutting-edge research is one of the main aims for Climate Design. Every academic lecture should contain new information and hence be different from the previous one. Learning is a continuous process of acquiring more knowledge, for students as well as staff. Every generation of students delivered should be smarter than the previous generation.

Organisational scheme of the Green Building Innovation research programme. Vertical are the basic competences of the chairs involved, horizontal the research themes.

The section does not stand alone in its sustainability ambitions: together with the chairs of Architectural Engineering, Product Development and Design of Constructions, Climate Design works on a joint research programme called Green Building Innovation. For the long term research of the chairs involved is founded on the basic individual competences, but for the short to middle term the Green Building Innovation programme has identified themes that are societally and scientifically urgent. These themes are: Closing Cycles, E-novation, Carbon Neutrality and Climate Adaptation. Each of the themes contain research projects executed by PhD candidates or experienced researchers.

Students of Architecture are educated on climate design from the very start in the Bachelor’s stage of the curriculum, commencing with basic insight and understanding, working towards more detailed knowledge of building physics and building services. In the master’s track students can specialise themselves as climate engineers or become architects and urban planners with a profound understanding of integral design, integrating climatic aspects into sustainable design. One of the key terms is smart and bioclimatic design, on which I will elaborate further on.
Having been educated in the Faculty of Civil Engineering, it is my special pleasure to work on a joint programme of the Department of Building Technology (Faculty of Architecture) and the Department of Building Engineering (Faculty of Civil Engineering & Geosciences). I intend to bring students of these two streams together in the School of Green Building Engineering, which focuses on competences and themes from the Green Building Innovation research programme. It will educate students to become sustainability engineers who have a profound technical background yet understand architectural design.

BK City, home to the Faculty of Architecture of TU Delft and topic of so-called E-novation, as discussed further on.
An ever more urgent necessity

Serious environmental problems
When the world was attempting to grasp the complexity of environmental assessment, Taeko de Jong [Jong et al. 1992] reduced the environmental issue to two main problems: loss of biodiversity and deterioration of the human health. If an intervention leads to one of these events, De Jong stated, it will be part of the environmental problem. He thereby directly referred to the UN Commission on the Environment and Development [Brundtland et al. 1987], whose definition of sustainable development does not coincide with any damage to the environment or human beings.

Definitions
- Sustainable development: a development that meets the needs of the present without compromising the ability of future generations to meet their needs [Brundtland et al. 1987]. This rather anthropocentric definition is mostly used, although in their report the Brundtland Commission emphasised the balance between economy and ecology, and equity among people, including an equally spread prosperity, thus opening the door to the triple bottom line concept (triple P: people, planet, profit) of Elkington [1997].
- Sustainability: this term can be seen as the ultimate goal, a situation of equilibrium between man and nature, and between human beings across the world. Since this implies as a static (fixed) and utopian (never achieved) goal sustainability itself is a wicked term, a theoretical goal, for which the road towards (sustainable development) is more important than its destiny. Nevertheless I will use the term of sustainability as to depict the scientific area of sustainable development.

Depletion too is a problem, as it restricts future generations to use these resources and manufacture specific products from them. Therefore, the three main environmental issues are: depletion, loss of biodiversity and deterioration of human health. Put positively we environmental engineers, designers and planners should focus on the avoidance of these by closing resource cycles, preserving biodiversity and improving the human health.

The real problem of resources: they do not run out but the original soil is depleted and material particles become dispersed in other places, impossible to be reused again.
Back in the 1990s I had discussions with Taeke de Jong about the problem of resource depletion, which I considered the third environmental problem. Within the environmental world De Jong had an academic yet controversial attitude, repeatedly asking the magnificent question "yes, but is this grave?" Matter does not really deplete but can fall down to their basic elements. It was only when I – before knowing the term – touched upon the exergetic consequence of winning high-quality resources while producing low-quality waste particles that cannot be converted to the initial material again, that depletion was put in perspective.

**Triple P**
The problems mentioned may already cover a vast and complex range of environmental sustainability issues, but in line with the triple bottom line [Elkington 1997], sustainability also has a social (people) and economical (profit) component. Although sometimes in our Faculty of Architecture one tends to forget, people are the starting-point of and sole reason for planning and design in the built environment. Economical issues we engineers also tend to ignore, although they in practice will define the success of our technical ideas. Nonetheless, we cannot keep a sharp focus on everything and so taking people as a starting-point, setting boundary conditions for comfort and health, I consider environmental sustainability as the core issue of sustainability in the area of Climate Design.

**The factor of 20**
It is also this environmental sustainability that can be best measured. After the provoking paper of Speth [1989], Ehrlich & Ehrlich [1990] presented a formula that added a quantification to the objectives of the Brundtland Commission.

<table>
<thead>
<tr>
<th>Year</th>
<th>Pres</th>
<th>Pop</th>
<th>Wel</th>
<th>Met</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2040</td>
<td>1/2</td>
<td>2</td>
<td>5</td>
<td>1/20</td>
</tr>
</tbody>
</table>

Pres = pressure on the environment; Pop = world population; Wel = welfare rate; Met = environmental metabolism

As the formula shows, taking 1990 as the year of reference and looking 50 years ahead, the population is expected to double, whereas the average rate of welfare should be increased immensely, since we do not want to give in and – as Brundtland et al. proposed – developing regions should be permitted to reach our standard of living. This leaves the environmental metabolism (or environmental impact) as the only parameters that we engineers, designers and planners can influence. It needs to be reduced by a factor of 20. This is not an absolute value, however a clear sign of the magnitude of our actions needed. This is illustrated by a deformed map of the world with the ecological footprint per country [Dorling et al. 2009]: the developed part of the world uses much more space than their actual surface allows, only because other parts are emptied. To grant these poorer parts the same prosperity would require four more earths.
In my doctoral research [Dobbelsteen 2004] I tried to explore the possibilities to achieve this factor 20 improvement for office accommodation. A survey ahead left no doubt as to the lagging performance, 10 years after 1990: office buildings on average performed no better than an improvement factor of 1.2-1.4. The best examples we had around 2000 scored 2.5, where 5 would have been on the straight line towards the factor of 20 in 2040.

\[ 	ext{year} \quad 1990 \quad 2000 \quad 2010 \quad 2020 \quad 2030 \quad 2040 \\
\text{factor} \quad 1 \quad 5 \quad 10 \quad 15 \quad 20 \]

The straight road to environmental improvement by a factor of 20, and where we were around 2000.

With a reference lifespan of 75 years, almost 80% of the environmental load of offices is due to the consumption of operational energy, mainly heating/cooling, lighting and use of equipment (computers, coffee machines, elevators...). By the way, the latter of these three has since become the dominant source of energy use in offices. With a shorter lifespan and further energy reductions, the use of building materials becomes more important. In this respect, the supporting structure forms a predominant 60% of the environmental material investment in a building, of which preservation is significant to sustainability. Nevertheless it then needs to be apt for a long use.
Effectiveness
With a lagging performance my next assignment was to find effective measures leading to the factor of 20 improvement. Effectiveness is the extent to which an intervention leads to the desired result. This is so when the intervention either relates to a significant part of the problem, or when a great improvement can be made. Best of course is when both situations apply.

Effectiveness = Significance x Improvement

Much can be achieved through technology, but I found that we were trying to get a high-score in one direction only, while forgetting about two other factors: time and space.

Three dimensions of environmental sustainability: technology, space and time.

Improvement of the building service life and spatial efficiency both contribute to sustainability, and the product of these two together with the technical factor could much easier lead to the factor of 20. This was a potential unused so far and I studied several possibilities, all the way to changing the organisation of office work.

The most effective strategies to improve the environmental performance of office accommodation.

<table>
<thead>
<tr>
<th>Priority and solution</th>
<th>overall factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>The use of renewable energy</td>
<td>6.3</td>
</tr>
<tr>
<td>Sustainable organisation of work</td>
<td>2.1</td>
</tr>
<tr>
<td>Intensive and multiple use of space</td>
<td>1.6</td>
</tr>
<tr>
<td>Optimal building shapes</td>
<td>1.3</td>
</tr>
<tr>
<td>Optimal service life scenarios</td>
<td>1.1</td>
</tr>
<tr>
<td>Optimal supporting structures</td>
<td>1.1</td>
</tr>
<tr>
<td>Non-cellular office layouts</td>
<td>1.1</td>
</tr>
</tbody>
</table>

To cut a long story short: a factor of over 50 would be possible if we were to combine all effective measures in the dimensions of technology, space and time [Dobbelsteen 2004]. The message here was: use the potential that is already there. Most significant of all: a sustainable energy system.
03 Boundary conditions for a different future

It seems trivial, but when designing and planning for a long future, we should take into account the new future state of our world, and in the light of climate change and resource depletion boundary conditions and constraints may be totally different. Having experience both from the market and university it strikes me how little is thought about the sense of design decisions under altered conditions. One still designs under the safe conditions of today, which were actually formed in the past, forgetting about simple facts or at least probabilities of the near future. Just as physical properties of our built environment form the toolbox of a designer [Kristinsson 2002], comprehending future physical probabilities is fundamental. However, this is but a poor basis, since we can shape the future and have the ability to work towards a desired future state, and when still accepting the vision of the Brundtland commission, it should be a future our children and grandchildren would like to inherit. We just need to try to envision this future state and translate it back to measures we need to take now. This is generally known as ‘backcasting’ [Jansen & Vergragt 1992], which differs from the usual forecasting or ‘backtracking’, which takes a sustainable circumstance from the past and translates it to measures of now.

Three ways to approach the future: forecasting, backcasting and backtracking.

What are the physical probabilities of the future? Founded on scientific evidence (which is different from proof...) we may assume climate change, related water problems, urban warming and depletion of certain traditional resources, fossil fuels in particular. Since these three presumed conditions are the basis for most ongoing research in my field and since controversy about them repeatedly pops up, I will try to clarify this, so we can get on with doing something about them.

03.01 Climate change

A discussion renewed

When the Intergovernmental Panel of Climate Change and in its wake the rest of the world finally seemed to agree on climate change and the near to certain probability that man was having a strong influence on this [IPCC 2007] a series of events caused turmoil about the validity of the IPCC findings. E-mails and some details in the report were magnified in the media, in the Netherlands even causing a witch hunt on climate
scientists in general. This urged a hardly ignorable number of 55 Dutch climate scientists to send an open letter to the Dutch parliament [Turkenburg et al. 2010]. "That greenhouse gases in the atmosphere play a major role in the temperature on earth is elementary physics. As a result of the increase in greenhouse gases the equilibrium of thermal radiation on earth alters, most probably causing it to warm", Turkenburg et al. stated in their letter. This is the very essence of the climate change theory. Connotation: carbon dioxide is just one greenhouse gas; methane is 23 times more effective.

All planets in the solar system show a big difference between maximum and minimum temperatures, except for one small planet where the greenhouse effect keeps heat better spread over its surface and causes a positive deviation to the relationship temperature-distance to the sun: Earth [Astronomy Magazine]. We need the greenhouse effect, but should avoid planetary over-insulation.

It seems logical that human beings have caused a difference in the constitution of the atmosphere. I always show students one simple example to clarify this. It is the story of our highest quality of energy on the planet next to the sun:

A jungle, through binding of carbon
millions of years in bloom,
shifted to the north,
covered by a desert,
submerged under water,
sealed off by saline sediment,
incinerated and aerated under high pressure.
This is our natural gas.

Global paleogeographic reconstruction of the Earth in the early Devonian period, 400 million years ago [Blakey, 2008] – truly a world turned upside down.

This process started around three hundred million years ago, in the era that is aptly called the Carboniferous (359-299 mln years ago) during which vegetable matter was
stored in the underground and formed our coal of now, vegetable matter that had grown on the planet since the preceding period, the Devonian (416-359 mln years ago). We now unleash the sequestered content of carbon from the Devonian and Carboniferous periods relentlessly, within 200 years. If the fossil fuels we use are a substantial part of all organic matter from both periods, an effect could be we set ourselves back to the periods preceding the Carboniferous. And how was that? During the Silurian (444-416 mln years ago) and early Devonian the Earth was iceless, covered with water, hot – an estimated 30°C [Joachimsky et al. 2009] – and hence practically inhabitable.

In support of my layman’s deduction, Fedorov et al. [2006] concluded on the basis of their investigation of climate changes during the Pliocene period (5-3 million years ago, with similar external climate factors as nowadays but with substantially higher temperatures) that “a future melting of glaciers, changes in the hydrological cycle, and a deepening of the thermocline could restore the warm conditions of the early Pliocene.”

The climate is a complex system and we know little of it yet. I am not a climatologist but so are many who claim to know what is true or false. As a scientist I need to base my opinion on scientific evidence published through peer-reviewed papers. No academic work is flawless, and the IPCC have shown that neither are they. Nevertheless, the general – peer-reviewed, so I need to assume scientifically acknowledged – evidence from the IPCC still stands and so far I have seen little evidence that what is currently observed and measured has nothing to do with human activities, be it through CO₂ or otherwise.

Since the Industrial Revolution, temperatures on Earth have increased by 0.5°C. On the basis of what has not yet had an influence on this and the continuation of our current way of life, another 1.1 to 6.0°C increase is expected. This is a wide range of uncertainty, depending on the concentration of CO₂ and other greenhouse gases, but there is no value indicating global cooling.

Yes, but is this temperature increase grave? Not for nature: it will survive with other species. But to mankind this will be disastrous. Two respectable authorities in the area, who propose different solutions for the problem but agree fully on the dangers, indicate at tipping points where changes will become

*During the Devonian period, the temperature dropped as a result of climate change (presumably through carbon sequestration in plants), causing the Late-Devonian extinction. During the Carboniferous period (also attributed to carbon sequestration) the temperature dropped further, paving the way for the Late Palaeozoic ice age. Under the influence of mankind, the Earth’s surface will now not automatically regenerate plant life that can eventually balance the temperature increase. And learning from natural history, it would take tens of millions of years to establish this.*

**What can we do?**

In my opinion there is a clear preference order of climate mitigation strategies against CO₂ emissions:

1. Avoid the unnecessary production of carbon emission by saving energy and using alternative sources.
2. Capture and use carbon emissions functionally in industrial and horticultural processes.
3. Compensate carbon emissions by new plantations.
4. Capture and sequester carbon dioxide in the underground, for instance in empty gas fields or coal mines (where the emissions originally came from).

Will these strategies help to reduce the human-incited climate change on a short term? No. The influence of our actions of the past will continue at least 40 years longer even if we stop emitting CO₂ today. Our action is needed for the longer run, for future generations, but for now we at least need to be ready for the changes expected, such as aggravated water problems and hotter cities. So, for the short to middle term perspective, climate adaptation is key.

**03.02 Dealing with climate change in the built environment**

**The water surge**

Since cuts on carbon emissions will not have a direct effect on the climate, we in particular need to adapt to droughts in some regions of the world, and excess of water in others. As one of the delta areas, the Netherlands should be prepared for the threefold water surge: a rising sea level, heavier rainfall and increased run-off from the mountains.

For a reason, most attention for climate adaptation has been paid to safety issues. The Delta Commission 2008 [Veerman et al. 2008] studied the risks of climate change on the Dutch mainland and presented 12 recommendations, all referring to protecting the land behind dunes and dikes.

How would this work for a simple urban plan?

**The 1.3 meter plan**

In the same period as the Delta Commission report, plans were developed for the lowest lying polder in the Netherlands, the Zuidplaspolder (ZPP) between Rotterdam, Zoetermeer and Gouda. Lowest spot: 6.76 m, near Nieuwerkerk aan de IJssel. In an
explorative study, civil engineers had modelled the case of a disastrous flood coming from the sea. One would simplistically expect a flood of at least 6.76 meter at the deepest point, but since the polder is compartmented and the Hollandse IJssel river has locks that can be shut in cases of emergency, flooding was expected up to 1.3 m. Now, in the lower parts of our country we are used to heightening the land by means of sand (either from land pits or from the sea bottom), and dredgers would be able to make a feasible plan for the ZPP based on integral suppletion, but when invited to contribute ideas to the project I decided to do it differently.

Nine selected dwelling types for the Zuidplaspolder 1.3 meter plan.

Together with colleagues Michiel Fremouw and Ann Karina Lassen I generated 18 different water-robust principles for dwellings [Dobbelsteen et al. 2008a]. From these we selected nine dwelling types that all are safe in case of a 1.3 m flood (1.6 m including waves, half a floor height, which is a practical measure for architects who love split-level houses). With regard to common houses, each one of the dwellings proposed would have an attractive extraordinary feature of living experience. Apart from the fun of doing this, it was a serious proposition to limit the deterioration of the historical polder landscape as much as possible. The water-robust dwellings leave a minimal footprint and even leave through-sight over the present pasture surface.

We spread the nine dwelling types on a patch of to be developed land next to the village of Moordrecht and noticed we could accommodate 300 houses, 50 more than with an average Vinex layout plan.
The additional costs for the future-proof 1.3 meter plan were estimated to be less than 25%. For developers this is almost an unacceptable extra amount of money, but what is the price of safety? And moreover, we can buy cheap clothes in every Primark, Zeeman or most second-hand shops, however few of you, readers, would proudly admit doing this. When financially possible we rather buy fashion or beautiful clothes of better quality. In contrast, for a lifetime investment in a house we prefer price over future quality.

The 1.3 meter urban plan. The yellow part is a traditionally supplemented reference part.

The Moordrecht 1.3 meter plan could be a show-case for climate-robust developments, which was enthusiastically received by the ministry, province and public. This was less the case with my proposal to flood the ZPP once every year ("stop the drainage pumps!"), in order to test the success of the solutions and generate a new touristic period when visitors could bring their boats to the polder and wave at people in their isolated but safe homes....

Urban warming
As stated a lot of attention regarding climate adaptation is paid to water, however, in addition to the water threat, the urban heat island effect will become a serious problem in case of global warming. Due to the large surfaces of stony material, limited amount of green and water and as a result of heat-emitting human activities (use of cars and equipment such as air-conditioners) in cities the climate is locally aggravated in terms of temperature. This will even be more so in the future. The Greater London Authority [Nickson 2007] calculated that within 40 years, summer temperatures inside the London metropolitan area may become 9 degrees higher than in the surrounding countryside.
There are statistics indicating the numbers of deaths at different outdoor temperatures. For human beings in our regions the optimal temperature apparently is 15-16.5 degrees, with a greater mortality with lower and hotter temperatures [Huynen et al. 2001]. This perhaps explains the emergence of first European human settlements (including caves, which internally have the mean temperature of a year) in Southern France. 9 degrees increase in temperature will inevitably lead to more illnesses and premature deaths. So reducing heat in cities and adapting to different circumstances in the future are important.

Temperature and total mortality [Huynen et al. 2001], the arrow depicting the optimal value.

This is why the interdisciplinary research programme on climate-robust cities, evolving from the Knowledge for Climate (Kennis voor Klimaat, 'KvK') FES programme, can have a significant effect on future cities. This programme will monitor the climate in several Dutch cities, estimate their sensitivity and vulnerability, propose strategies and measures to diminish the effects of climate change, calculate their effectiveness and come up with governance models to implement these strategies. I have the honour to coordinate the 'measures’ workpackage, which contains PhD projects on green, water, energy and planning/design.

Tax on waste heat
We all pay for the waste we produce: pollution taxes, which apply to waste material and waste water. This is financially needed for the collection and processing of domestic and industrial waste, for sewage infrastructure and waste water treatment. Waste energy has not been part of it yet, for understandable reasons. Waste energy never was an issue: energy depletion was no issue and neither was local warming through the release of waste heat. This attitude already caused severe problems to ecosystems when in summer power plants had to discharge their waste heat into the air and open water. Now the circumstances have changed even more, making the introduction of a waste heat tax desirable. The waste heat tax would make traditional power plants and air-conditioners more expensive, whilst sustainable energy plants, passive cooling measures and heat pump systems that use the waste heat from cooling would become more attractive.
There is an enormous potential to act smartly in regards to the urban heat island effect. Not just in terms of green and water (evaporative cooling), which may be considered a charming end-of-pipe solution, but also – and first – the avoidance of solar irradiation into the city through urban canopies, solar screens, reflective roofs and facades. However, since this implies partly passing on the heat to areas outside the city, the city could also swallow the consequences of its design and capture the excessive heat. In that respect it is interesting to know that the KvK research programme crosses and merges the divide between climate adaptation and climate mitigation: capturing excess heat can – when made useful – become an asset to the energy system of a city. I call this ‘climate pro-activation’.

So, the focus on reducing urban warming on the one hand should coincide with the potential to generate energy – either heat or electricity – on the other, directly or with intermediate storage. The KvK programme will contain research projects that combine these measures and I believe this will be promising.

We live in a climate with a mean temperature of 10°C, so theoretically we on average still have to heat our living environment to the optimal survival temperature of around 16°C, or the ideal mean temperature indoors of 21°C. Therefore, for us, climate change would bring us more to an energetic optimum. Thermally that is, for I will not expound on the effects on precipitation and storms.

Planning for climate adaptation

A complicated and full exposure of climate change problems will be experienced on the regional or provincial level. A region in a delta country as ours contains all functions and elements that play a role in future sustainable development. The question is either to remain robust against the greater threat of flooding, or to become resilient with regard to altering conditions, or to just adapt to changing circumstances, both in terms of water and heat. Rob Roggema is investigating this range of opportunities and how to implement these in a new way of spatial planning, for this is perhaps the hardest part of succeeding in change. In response to the current manner of ‘tame’ planning for well-defined problem areas, Rob proposes a new way to deal with the much less tangible problem of climate change: ‘swarm planning’. This by-pass principle of thoroughly deliberated local interventions – small but effective – sets off a series of desired following events (as with a swarm of birds following a movement shift initiated by one individual). Rob’s paper on swarm planning [Roggema & Dobbelsteen 2008] received the best paper prize at the World Sustainable Building conference in Melbourne and he continues to produce cutting-edge papers and books in the area of climate adaptation [e.g. Roggema 2009].

Will the research projects mentioned be redundant when, for whatever reason, climate change figures turn out to be different? No, because this type of research primarily explores the potential to make better use of the built environment and to seize all opportunities that lie there unused. This is necessary for another reason as well, for, as scholars in the area acknowledge, climate adaptation cannot be seen separate from the biggest problem of all: energy, which I will discuss subsequently.
03.03 The energy transition

Why we should become less dependent on fossil fuels
Most of us have no idea how much we are addicted to energy, fossil energy in particular. Energy is needed in every part of our life, especially our modern life with the energy consumption of its luxury appliances, but also in basic services as food, water, clothes and of course materials of the built environment itself.

Political reasons
Yes, but is this grave?
No, not unless the energy system falls out of balance, of which we have seen snippets during the repetitive Gulf wars and the Russian-Ukrainian dispute over the delivery of natural gas. With a growing pressure on the energy market and depleting fossil resources, the chance of a recurring event such as these becomes greater. What may seem a sure and safe contract now can become an uncertainty in the near future. This is a political reason to become more self-sufficient in energy and less dependent on fossil fuels in particular.

Economical reasons
Not only the cost of mobility and accommodation are strongly influenced by the price of energy; also the price of food and the predominant part of it of tap water is related to energy. Again we experienced a brief period of dismay when the oil price touched $145 per barrel, right before the credit crunch that saved us an energy crisis. The pain of the oil price is traditionally best felt in Arabic countries and the USA, where hardly any taxes are imposed on petrol and diesel. Experts such as Victor Sergeev expect that an oil price of around $200 a barrel will be reached within the coming years. This time, the whole world will notice. This is an economical reason for more self-sufficiency.

The oil price between 2005 and early 2010 [Digital Look].
Environmental reasons
There is also the environmental twist to prolonging the fossil age through import of coal (from South Africa and Australia!), mineral oil (from the Middle East) and natural gas (from Russia): possible climate change aggravation and ecological damage in case of calamities. Though impossibly the aim of the energy provision market, accidents happen and locally have a devastating effect.

Ethical reasons
And finally I want to raise the ethical issue: do we want to import a resource as coal, which we for various reasons choose not to excavate ourselves anymore, from other regions when on a global scale accidents happen almost weekly in coal mines?

Depletion of fossil fuel
Underlying if not accelerating all previous reasons to become less dependent on fossil energy sources is the depletion of mineral oil, natural gas and coal. Depletion nevertheless is a tricky term. Usually, prospected terms are determined by the volume of resources known, divided by the annual demand, possibly corrected for growth in this demand. In the 1970s the Club of Rome [Meadows et al. 1972] forecasted a maximum oil reserve of another 40 years. In the early 1990s Meadows et al. [1992] came with an update report, again providing a prospect of 40 years. And recently this figure was again mentioned.

Are oil reserves growing then? Of course not at a measurable rate. Fossil fuels are finite in the sense that the supplementation of new resources on the one hand are in no manner catching up with the consumption on the other hand. The trouble with depletion figures is that they are based upon the reserves that can be exploited in an economically feasible way at this moment. However, ‘at this moment’ is continuously altering. With energy prices lifting off, new fields of oil or gas and even the distillation of oil from tar sands become exploitable, thence prolonging the period of use.

A similar phenomenon can be seen with uranium, the source for nuclear energy. Of all uranium in the Earth crust only 0.7% is the usable U235; at the current low expense there is sufficient uranium for possibly 80 years (decreasing due to the worldwide increase of nuclear plants), but for a higher price this term may be prolonged to roughly 800 years [OECD-NEA, 2008], and with uranium from the oceans even thousands of years. Again, these figures are based on the current demand, even then there is no matter of real uranium depletion.

This process may linger for some while, but eventually every oil-producing company knows their core business is finite. It is the very reason that they wisely invest in alternative sources as well.

So worldwide we may perhaps profit from fossil fuels longer than expected, but again an ethical question could be: should we? In addition to the political, economical and environmental reasons not to, a remark can be made about the use of oil in synthetic products. If we want to preserve some of the primary resources for these high-quality appliances, we had better not burn it for lower-grade functions. This relates to the exergy principle which I will discuss further on.
The bean plant, a good metaphor for transition from condensed energy to solar panels.

There is one extra reason to be cautious about using fossil fuels to the full: we will need the energy source to make a transition to sustainable energy systems. The bean plant demonstrates how concentrated genetic material and stored energy directs growth to a point where its leaves (solar panels) are completed, thence providing the energy needed to grow further. Whether it be solar panels, wind turbines, geothermal drills or nuclear plants: we will need a considerable amount of fossil energy to build them. If we use this fossil energy for our current demands, there will be not enough for the transition.

All hell and doom so far, but I want to present solutions from now on – and thereby promising topics of research and education in the area of Climate Design & Sustainability. For, how are we going to become less dependent on fossil fuels and other imported energy?

All hell and doom so far, but I want to present solutions from now on – and thereby promising topics of research and education in the area of Climate Design & Sustainability. For, how are we going to become less dependent on fossil fuels and other imported energy?
04 Making better use of our own potentials

04.01 Energy potential mapping

If we want to plan and design better, taking into consideration locally available resources, mapping or charting these local opportunities will come in handy. The method of energy potential mapping (EPM) has been specifically designed for this.

Graphical outline of the method of energy potential mapping.

It was in the Grounds for Change project [Noorman et al. 2006] that a future sustainable energy system had to be found for the Northern Netherlands. This region has been the traditional energy supplier of the Netherlands ever since the exploitation of peat and subsequently oil and gas. The Dutch gas reserves are expected to run out within 25 years. This period is prolonged through summer import and storage of Russian gas, but all parties involved in the business know that alternatives need to be developed as well. The Grounds for Change design team [Roggema et al. 2006] came up with a cartoonesque way to illustrate the availability and quality of local potentials: sun, wind, water, biomass, underground, and the energy mix map, which showed an overlap of all potentials together.
The method of EPM had a follow-up and was enhanced in an energy study for the provincial environmental plan (POP) of Groningen, one of the three Northern provinces [Dobbelsteene et al. 2007]. The method obtained a structured approach of analysis of specific properties, characteristics and features that are converted into energy potentials for fuels heat and cold, electricity and CO₂ reduction. These potentials were then translated to possible interventions in the province, such as new housing developments, wind parks and planting of green.

On the basis of the proposed intervention we calculated that 50% of the current energy demand could be solved in a sustainable way, and 80% of carbon emissions reduced. This would be significant; however, if Groningen wanted to become fully energy-independent (see further on), a substantial improvement of the existing building stock (including industrial parks) would be required for the remaining 50% energy demand.

EPM was applied to a smaller scale when the municipality of Almere asked us to study the energy potentials for their proposed urban extensions, such as Almere East, Almere Pampus and the inner-city. We were involved at a late instant – the urban planner had already made four variants for Almere East – but our energy study uncovered some interesting features, which made us propose a totally different plan for the location [Dobbelsteene et al. 2008b].
I should say that our proposals were not received with great enthusiasm, but we still believe that the plan with a concentrated high-density development near the motorway and limited deterioration of the agricultural landscape (farms playing a role in the energy-neutrality of 30 court dwellings attached to them) would lead to a much better energy performance, also in terms of transport.

Another energy potential study concerned Schipholland [Dobbelsteen et al. 2009], where we for the first time presented the energy potentials in a stack of maps depicting the energy potentials at different heights and depths. A better example can however be given for De Groene Compagnie ('The Green Campaign'), south of the town of Hoogezand, by means of which we returned to the province of Groningen and studied energy potentials on the district level [Broersma et al. 2009], a smaller scale than in Almere (the approach of EPM can also be projected on the scale of buildings, which I will discuss further on under the header of smart & bioclimatic design). The district scale usually implies a negligible gradient of solar or wind power, but still some distinction in the underground and even more detail on the surface: farms, industry, timber vegetations etc. can be discerned more clearly on the scale of a few kilometres.

At a workshop for De Groene Compagnie three radically different urban plans were presented, all based on the local energy potentials but brought down to individual self-sufficiency, network exchange or neighbourhood independency. The study concluded with a plan that combined all three extremes and that according to our calculations would become energy producing rather than consuming. It contained the idea of a local society of home owners where every member was shareholder of the neighbourhood energy company.
Energy Potential Pile - De Groene Compagnie (DGC)

Energy Potencies

<table>
<thead>
<tr>
<th>Source</th>
<th>DGC (700ha)</th>
<th>Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>9640 MWh(_p)/ha</td>
<td>6750 GWh(_p)</td>
</tr>
<tr>
<td>Wind, 100m</td>
<td>228 MWh(_p)/ha</td>
<td>160 GWh(_p)</td>
</tr>
<tr>
<td>Wind, 30m</td>
<td>56 MWh(_p)/ha</td>
<td>5 MWh(_p)/turb (39) GWh(_p)</td>
</tr>
<tr>
<td>Waste, households</td>
<td>1.7 MWh(_p)/ha</td>
<td>1.2 GWh(_p)</td>
</tr>
<tr>
<td>Residual heat</td>
<td>Kappa</td>
<td>2x 70 GWh(_p)</td>
</tr>
<tr>
<td>Biomass</td>
<td>4.7 MWh(_p)/ha</td>
<td>Maintenance DGC 2.4 GWh(_p)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eggfarm 1.1 GWh(_p)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maintenance surroundings 20 GWh(_p)</td>
</tr>
<tr>
<td>Underground upto -50m</td>
<td>ABF</td>
<td>140 GWh(_p)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jansen Wijhe 15 GWh(_p)</td>
</tr>
<tr>
<td>Aquifers</td>
<td>heat/cold storage</td>
<td>3.1 GWh(_p)</td>
</tr>
<tr>
<td></td>
<td>Maintenance DGC</td>
<td>Chickens manure gasification 1.7 GWh(_p)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maintenance surroundings (radius 10km) 20 GWh(_p)</td>
</tr>
<tr>
<td>Geothermal</td>
<td>-3000m 105°C</td>
<td>very suitable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>suitable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>unknown</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restriction area</td>
</tr>
</tbody>
</table>

The energy potential stack of De Groene Compagnie in Hoogezezand.
Energy-based urban plan for De Groene Compagnie.
Left (attached to jetties) autonomous individual dwellings: the orange patch next to that: apartments which draw energy from the nearby chicken farm; the big orange patch: the energy producing neighbourhood, with dwellers as the energy company shareholders.

A study we are currently conducting for Agency NL (formerly known as SenterNovem) concerns heat maps for the Netherlands. For the first time, EPM will be extended to the national level. We intend to present maps with ‘energy reliefs’, indicating the amount of energy available at various spots in the country, and then zoom into smaller detail. The main aim of the projects is to chart energy ‘hotspots’ and energy sinks, which for a sustainable development need to be better connected.

Relief heat map of the Netherlands, as proposed for an Agency NL study.
04.02 Heat cascading

The exergy of energy

This brings me to the academic issue of energy quality. The First Law of Thermodynamics states that energy can never be lost, ridiculing the idea of energy consumption, energy saving and energy efficiency. We nevertheless also have the Second Law of Thermodynamics, which introduces the concept of entropy, a part of energy that is generated throughout every process in nature and technology. To keep it simple, entropy can be regarded as the waste flow of energy, useless to perform work but still with a certain energetic content.

As the disturbing Sankey diagram by Jonathan Cullen and Julian Allwood [2010] below demonstrates, of all energy-input in the world, only 11.6% is eventually used to set things in motion or functional heat. All the rest of the energy is lost – or rather: has become useless – as entropy.

If energy remains constant and entropy is generated, something must be lost. This is exergy, which can be called the quality content of energy. As conceived by Carnot and later elaborated on by others such as Szargut et al. [1988], exergy can be defined as the maximum work potential of a material or a form of energy in relation to its environment. So exergy is relative to the environmental temperature, pressure and humidity. Any difference in exergetic quality has potential to alter something. Therefore, the exergetic value is an important measure of the quality and potential of energy.

The world’s energy flows in 2005 [Cullen & Allwood, 2010].
Total demand = 475 EJ = 475.10^19 J = 475,000,000,000,000,000,000,000 J, of which only 11.6% is made useful; all other energy is entropy, or energy wasted or lost.
There is one simple example to demonstrate that we need to switch from energy thinking to exergy thinking. We are very close to 100% energetic efficiency in hot boilers for buildings, meaning that the heat produced by these boilers in caloric value are almost equal to the original energy content of the gas that was incinerated for it. The gas flame has a temperature of 1200-1500°C and it is used to heat up our homes to 21°C. This may be done in an energy-efficient way, but in terms of exergetic potential lost, it has an efficiency of around 10%. With its combustion temperature, natural gas can serve much higher-grade functions than domestic heating. Think of metal or synthetics processing.

Exergetic thinking has already been part of petrochemical processes and industrial ecology. For the built environment it can be applied to the small-scale world of building services (heating, cooling, ventilation, air-conditioning, lighting etc.), but a greater potential lies in the big picture of spatial planning.

**The Value Deducted Tax**

We all know the Value Added Tax (VAT), Bruto Toegevoegde Waarde (BTW) in the Netherlands, that imposes a percentage of tax on goods or services that give added value to the economy. I have always wondered why we would want to punish value addition and through the understanding of exergy I think it should be reversed. We should actually pay for the quality decrease of products and energy when they reach their waste phase, the Value Deducted Tax (VDT), or Bruto Afgenomen Waarde (BAW) in Dutch. For products: if a product can only be incinerated or dumped, the final quality level is negligible, so there is total value annihilation. So the VDT imposition would be maximal. On the other hand, if all components of a product can be reused there will be hardly any decrease in value. Hence a minimal VDT. The principle is specifically applicable to energy or rather the energy quality decrease (exergy lost).

My proposition is that entropy is a relative term, related to the process it was calculated for originally, but considered in a broader sense, the entropy residing from one process may be exergy to the other. Or put differently: there is always an exergy content to energy, for in a different environment waste energy from the one process can be essential input to the other. Therefore, lower-grade functions such as domestic hot water and heating can be served by waste flows that are residue to a primary process in a higher-grade function.

*The current energy system (left) and a low-exergy, sustainable one (right).*
If we were to organise this in an effective way, the elements of our built environment would be energetically connected, not in the old sense of gas and power grids, but with an intelligent exchange of heat and cold at different temperatures. And since heat should not be transported over long distances, spatial planning should be based on blending instead of dividing functions. Thus reciprocal relationships can be established: one can serve the other, and reverse.

In practice, heat cascading encounters three fundamental problems: quality, time and distance. Firstly, the quality of waste heat flows needs to be sufficient to serve other purposes – else it needs to be upgraded by expense of auxiliary energy. Secondly, periods of the year when waste heat is produced are often not concurrent with the periods of need on the demand side. And thirdly, since at least half a century the spatial planning of our built environment has been founded on separation rather than mixing of spatial functions and this obstructs easy connections between heat sources and heat sinks.

It is exactly these restrictions that led to the interdisciplinary SREX project (Synergy of Regional Planning and Exergy), where spatial planners alongside with landscape architects, technologists and geographers work on a system approach to low-exergy regions. One of the promising papers from this project is by Sven Stremke [Stremke et al., submitted].

Energy = space
A profound understanding from EPM and SREX is the quintessence of space in a sustainable society. Especially in delta areas, which are densely populated and under threat of climate change extremities, space becomes an asset ever more precious. The battle for land is on for any of our basic needs: food, water, shelter, industrial production, recreation and not least: energy. It urges a well-deliberated spatial policy that gives way to sufficient production of food and products, storage of surge water and quality living and leisure, whilst the need for local provision of energy will put an enormous new claim on land. So far, due to the use of fossil energy – condensed solar power from vast surfaces during millions of years – we have abided our time in an age of relative spatial abundance. With fossil resources depleting we need to restrict ourselves to sources that require a lot of space on the surface.

Although not many people know this, the most effective energy source per hectare is the sun. With a potential of 1000 W/m² in our region and a photovoltaic efficiency of 15%, the sun is almost twice as productive as wind power and at least ten times better than the best-performing crop. A logical conclusion: biomass grown for energy is a silly decision; biomass should be deployed only for food and as a resource for industrial and building products!

The SREX project contains elements of urban planning, but a great leap in low-exergy urban planning was made with the REAP project, which I will discuss below.

04.03 Reaping the urban harvest

In natural environments energy potentials by the sun, wind and underground can be directive for new developments, but in dense man-made places anthropogenic technical processes are dominant, both in abundance and energy quantity. In cities the throughput of food, water, matter and energy is enormous but the predominant part can be internally
reused and recycled if we organise things differently. With the stark carbon ambitions of many cities in the world, this becomes a great opportunity. It also implies that the urban potentials need to be effectively seized. In Rotterdam we tried to kick-start this idea by the REAP method.

**The New Stepped Strategy**

Officially attributed to Lysen [1996] yet originally conceived under a different name in the late 1980s by Kees Duuyvestein, the Trias Ecologica (or Trias Energetica for energy), has long influenced the Dutch sustainability policy. This incremental approach has a logical outline:

1. Reduce the demand
2. Use renewable sources
3. Use finite sources clean and efficiently

After 20 years of Trias practice, I may state that the environmental awareness of planners and designers has definitely improved through the approach. However, from the assessments done for my doctoral research, I could conclude also that the environmental performance of the built environment had not reached the projected goals of the national environmental plans from the early 1990s [e.g. Ministerie van VROM, 1990]. More importantly, the penetration of sustainable energy into the Dutch market is very limited. In 2008 only 3.4% of all energy was produced by means of sustainable sources [CBS 2009]. With this accomplishment the Netherlands positions itself in the lowest range of the European list.

I believe that the Trias Energetica has not contributed substantially to a better outcome of this figure: when reducing the energy demand is limited to better thermal insulation and low-emittance glass, the remaining energy demand will still be so high that supplying it with sustainable sources is economically unfeasible. Moreover, in practice the third step was often mixed up with the first ("My hot water boiler has a high efficiency and thus reduces the demand for energy"), another explanation for the small dissemination of sustainable sources. A final reason for the slow retreat we should grant the old Trias for energy, is the depletion of fossil fuel, making the last step redundant and perhaps only useful in the transition period towards a sustainable economy.

Therefore I proposed the 'New Stepped Strategy':

1. Reduce the demand
2. Re-use waste flows
3. Use renewable sources and let waste be food to the environment

The second step is new, the third step has an addition inspired by the Cradle to Cradle principle [McDonough & Braungart 2002] and the old third step is abolished for a sustainable society. Although the first step of the initial Trias implicitly included the use of waste flows, in practice this was hardly ever clear and I deliberately explicated it because the moment a building or urban area starts functioning, waste is emerging: waste material, waste water yet also waste energy in the form of heat or cold. These potential resources are little used but should be widely arrested, and not only on the building scale, as the following example demonstrates.
The Rotterdam Energy Approach
The New Stepped Strategy (NSS) was picked up for a study on the conversion of Hart van Zuid (‘Heart of South’), an existing Rotterdam district, into a carbon-neutral one. With a team of urban planners, engineers, architects and myself to represent science [Tillie et al. 2009] we primarily focussed on the energy (input) side of the problem rather than the carbon emissions (output) side. I expanded the NSS by adding levels on a larger scale than the building: the cluster or neighbourhood, the district and the city. The idea behind this was that after reducing the energy demand and resolving the waste flows on the building level, rather than going to the next step of sustainable sources, in an urban context it would be much better to consider the opportunity to exchange energy with the building’s environs. We called this method the Rotterdam Energy Approach & Planning (REAP).

The REAP principle for urban redevelopment. In case of new urban developments, the demand-reducing steps should start at a higher level than the building.

In analogy with the energy potential mapping method, the present energy demand and supply of Hart van Zuid were studied and mapped, painting a clear picture of the myriad of energy pattern differences, close to one another and often appearing at the same time. Seeing this, one can only draw the conclusion that functions with these different patterns should be interconnected for an exchange of heat and cold.
Except for lighting and heating for a small office and entrance part, supermarkets put their energy only in cooling, thereby producing heat at the other end of the air-conditioner. This heat is emitted into the air, locally warming the urban climate, whereas it could be made functional for functions such as dwellings, shops or sporting facilities. An example in contrast is a swimming pool, which needs to be heated continuously, also in summer. This function could be combined with an ice skating rink that always demands cold. Climate engineers know that we have a simple utility that facilitates this: the heat pump, which – as in our fridge – cools one side while heating the other.

Energy demand by different urban functions ($W =$ heat, $K =$ cold, $E =$ electricity): different patterns occur at the mean time, causing unnecessary use of energy [image by DJA].

A thorough analysis of energy demand and supply in various seasons pinpoints the opportunities for exchange, the shortages and the needs for (inter-seasonal, weekly or diurnal) storage. Shortages can be resolved through additions to the existing buildings (e.g. greenhouses for addition of heat) or by means of so-called energy implants that balance the complete picture (e.g. a freeze house where the surroundings still demand heat).

From the intensive care towards a healthy urban organism
We tend to think that we are free and independent, but within the context of the built environment every building is like a hospital patient connected to various forms of drips: water, electricity, cable tv, sewage etc. This is not necessarily a bad thing, except that the waste of one function could serve another and that all of these commodities come from a central provision often far away, making the city vulnerable to calamities. Studies such as the one in Rotterdam emphasise that sustainable cities cannot function without an intelligent system for exchange of various streams, just as an organism from nature. In the urban context no building should function as an individual but seize the opportunities that are unique to the city and that the rural setting lacks.

The challenging road to energy-neutral, carbon-neutral cities is carried further by research such as by Nico Tillie, who studies the possibilities and liveability of carbon-neutral cities, thereby connecting the technical work to the people part of sustainability.

Technology may be the answer but policy is probably the problem
Technically, we can build entirely sustainable cities now. The main problem that keeps us from doing so on the one hand is the lacking guts to enforce it and on the other hand the current financial system that supports short-term solutions with minimal investment.
This is strongly supported by the governmental system of minimum-level legislation, which supports the market mechanism of striving for minimal quality.

The Dutch Woningwet (Housing Law) has dictated the construction industry ever since its well-intended introduction in 1903. Well-intended, because it was meant to abolish miserable conditions in social housing projects, it brought indoor climate requirements and minimum floor heights. This floor height of 2.40 meter was sustained until 2002, when in our country people on average had grown 18 cm, as presented by George Maat (nomen est omen) in his report "Hoe lang nog – De lichaamslengte van de Nederlander" [Maat 2006]. Instead of taking the directives of the Woningwet as minimum values, to developers they became the aim to save money. As Jón Kristinsson often stated in his 1990s lectures at my faculty: we are walking with our aura in the reinforcement steel of concrete.

The legislative system that rewards minimal performance can be compensated only by a principle that commences with optimal-level directives supported by progressive taxing or land-pricing on plans that fail to comply with the desired performance.

From the principle of minimal performance = reference to optimal performance = reference, with a progressive taxing or land-pricing on plans performing worse.
05  Smart & bioclimatic design

05.01 A methodological approach to design

So far, the solutions I presented apply for a large scale, from region to the neighbourhood. In this chapter I will return to the core focus of our Section of Climate Design – buildings – and show how the methods and approaches presented until now are also functional for the design process of buildings.

Definitions
- Smart: intelligent, related to natural intelligence (natural generic cognitive ability to reason processes) or artificial intelligence (perfect imitation of behaviour by a computer) [Timmeren 2001]
- Smart architecture: sustainable design intelligently interacting with the environment [Hinte et al. 2003]
- Bioclimatic design: the passive low-energy design approach that makes use of the ambient energies of the climate of locality (incl. the latitude and the ecosystem) to create conditions for comfort for the users of the building [Yeang 1999]
- Smart & bioclimatic design: a design approach that deploys local characteristics intelligently into the sustainable design of buildings and urban plans [my own definition]

A key term in the academic material of Climate Design & Sustainability, with the basis formed by Building Physics and the innovative technology of Building Services, is ‘smart & bioclimatic design’. This is a design approach taught to students of the Faculty of Architecture, which combines the common sense of bioclimatic design with the smart use of technology in architecture.

Vegitecture, Ken Yeang’s plan for an urban structure based on vegetation [Llewelyn Davies Yeang].

Bioclimatics is a traditional architectural stream from an era when people experienced the limits to materials, water and energy and acted accordingly, making full use of the available opportunities on site. Every region in the world used to design according to bioclimatics, for another approach would mean complete squandering of resources. Ken Yeang has personally reintroduced and popularised bioclimatic architecture, and he is still unsurpassed in his bioclimatic and ecological approach to skyscrapers in particular [e.g. Yeang 2006].
Backyard management or global stewardship
Trade and globalism have detached human beings from any sense of constraints, which may have been acceptable in the past two hundred years of abundance. However, with the disappearance of rainforests, the depletion of fossil fuel and certain metals, as well as the uncontrolled production and shift of hazardous waste to developing countries or the environment, it is time to take control again. This could be done in two ways.
- First way: solve as much as possible in our own backyard. Not that I oppose global trade, on the contrary, but thrown back to our own possibilities and limitations, we will learn better to become sustainable. Moreover, if we manage to resolve our own problems at home, we can help others who have little means to do so.
- Second way: take shared responsibility for all countries in the world where we draw resources from. This would come down to global stewardship. If we translated most of the ethics and social, economical and environmental quality regulations at home to these countries of resource origins, it would be a much better world already. That this is possible is demonstrated by the successful Fair Trade and Max Havelaar brands for food and Forest Stewardship Council for timber. Quintessential however is the uncompromised choice for these products only.

Smart & Bioclimatic Design as we teach it – not only me but also my valued colleague Arjan van Timmeren, for instance – follows a clear line of reasoning:
1. Starting-points
2. Local characteristics
3. Boundary conditions
4. Smart design
I will explain the steps below.

Adaptive thermal comfort: people accept higher temperatures in summer [Linden et al. 2006]
Adaptive thermal comfort: people accept higher temperatures indoors (Tbin) when outdoor temperatures are high (Te). The purple line follows the most energy-efficient climate settings [Linden et al. 2006].
Formulating starting-points
Smart & bioclimatic design commences with desired conditions, quality requirements or (energy) performance scores. This comes down to the 'people' element of sustainability – essential needs of humans and added quality to their lives: safety, human health, comfort, convenience, happiness, beauty and fun. Specifically for the area of climate design it relates to comfort (light, heat, humidity, acoustics and air quality) and the acknowledgement of individual control on it. An example of this is the model of adaptive thermal comfort by Linden et al. [2006], which gives the acceptance margins of a comfortable indoor climate in relationship with the outdoor temperature. This model is very suited for energy-saving when we design our climate systems close to the lower boundaries in winter and higher boundaries in summer, instead of holding the middle, as a result of which still a lot of users feel too cold in summer and too warm in winter.

Studying the local characteristics
This step you have already encountered in the previous chapters, for instance as part of the method of energy potential mapping. In our field, local characteristics relate to features that can influence the climate design or energy use of a building: the local climate, seasonal and diurnal differences, weather conditions, the underground and surroundings, either natural or anthropogenic interventions: no building stands alone.

Defining boundary conditions
This step needs to lead to an underlayment plan or a set of boundaries for the design. These are based on the local characteristics studied in the previous step. They may be translated to rules of thumb for the orientation, rough shape of the building, roof type or façade detailing, to give a few examples.

Smart design
This is the creative and fun part of smart & bioclimatic design, using the preparative work as the toolbox and playing field for the real stuff: architectural design and architectural engineering.

Good ideas: earn them
Not proven by empirical or neurological research, from my own experience I believe that creativity flourishes best with a clear image of the final aim and profound understanding of all conditions that influence this endeavour. I think it is as with sports or music: talent is an important asset but every famous sportsman or musician will tell you that more than 80% of success comes from hard work, determination and good preparation. Likewise, you would need to earn good ideas.

05.02 Case study of the Dutch chancellery
To demonstrate the approach of smart & bioclimatic design I will show some outcomes of a preparative study we did for the new Dutch chancellery in Canberra some years ago, about which we published an international paper [Dobbelsteen et al. 2008c]. This was an interesting case for us, because it concerned a different climate zone and the findings would be used by the architect who was to be selected to make the design. I will discuss a few issues.
A first issue we raised with the Ministry of Foreign Affairs was about the starting-points of the building design, not just the brief yet also wishes related to the use of energy, water and material. It was here that we could discuss the adaptive thermal comfort idea to reduce the energy demand in summer and winter even before we started.

Without the need to travel we proceeded with the analysis of local circumstances. For Australia Canberra has a relatively mild climate, almost continental and on average only 2 degrees warmer than the Netherlands, but with big differences between day and night as well as between summer and winter. So moderating the indoor temperature through deployment of building mass or the underground would be desirable. Located at a southern latitude relatively close to the Equator, in summer the sun reaches a height of approximately 82° (to the north!), so almost vertical. Therefore we studied all possible façade elevations and proposed rudimentary obstructive element positions to avoid irradiation, as well as a suspended tropical roof to keep the solar heat at bay and reflect most of it.

Different solutions for different façade elevations.

Another interesting typical feature was the predominant wind from the north-west, bringing in hot air from the desert during daytime and freezing cold at night. This wind therefore had to be obstructed. The building site had no tree coverage in that direction, but the old chancellery building from the 1950s was exactly positioned against this wind direction. So we proposed to preserve the old building and use it as a windscreen and its cellar as rainwater storage. For, as you probably know, lack of water is Australia's climate menace.

All findings from the analysis we translated into a crude underlayment plan, with sketches presenting alternative solutions to solve specific climate and energy problems.

Urban underlayment plan for the Dutch chancellery in Canberra.
From here on the architect, Rudy Uytenhaak, would have to finish the assignment, which he did, making a proper architectural expression – a smart design – of the local boundary condition sketches. His design of the new Dutch chancellery was round and therefore lacked the strictly different facades we had sketched, proposing a beautiful gradient in the solar obstructive elements. Uytenhaak also did something we had strongly discouraged: design an atrium. He however provided it with a rotating sloped roof, which could keep out all undesired sunshine, generate power and which gave the building a stark architectural expression.

Three types of roofs that should be compulsory from now on
Dutch roofs are stupid: if they are sloped they do not produce energy nor function as a rainwater collector; if they are flat they do neither and have black tar foil which heats up to 80°C in summer. As far as I am concerned, only three types of roofs are allowed from now on:
- The Green Roof: rainwater buffer, temperature moderator, micro-climate improver, passive cooler and moisturiser, park landscape for people
- The Energy Roof: power and/or heat generator, rainwater collector, solar reflector, active cooler
- The Greenhouse Roof: power generator and heat collector, rainwater collector, passive cooler, CO₂ sequester, urban agricultivator, winter garden and home restaurant
I'll discuss the Greenhouse Roof further on.

05.03 We do not stand alone

Rudy Uytenhaak is not the only Dutch architect who successfully integrates sustainability into his designs. I am glad to notice that the market is filling up with architects who dare to take the step to design sustainably, without the obsolete perception that this accent would only diminish the architectural quality but rather seeing it as a necessity and extra challenge and potential for a new type of architecture. So, many follow this track now. I cannot mention all of these architects I regard, but I want to highlight a few of them who have always had sustainability on their banner.
Last year SeARCH was elected Dutch architect of the year, and an important reason was the original vision of its main architect, Bjarne Mastenbroek, on sustainability and the passionate way he uses it in excellent architecture. In that sense he has much in common with Hiltrud Pötz and Pierre Bleuzé of opMAAT.

Two different architects with a ceaseless drive to design energy-neutral or even -delivering buildings are Thomas Rau and Paul de Ruiter. Paul de Ruiter's architecture is far from what grumpy architects refer to as ecological buildings and he succeeds in combining a modern architectural expression with a top performance in sustainability.
Among the older and wiser yet not less energetic architects is for me the godfather of sustainable architecture, Jón Kristinsson. Retired already nine years ago he is unstoppable in conceiving innovative techniques to be applied in holistic sustainable buildings. Jón’s design for the Villa Flora in Venlo would be – I dare say – the greenest modern building in the world, as it closes every cycle of energy, water and materials. Except for two things: Dutch law does not allow drinking water decentrally made from precipitation, and the waste water treatment produces somewhat too much nitrogen. I suggest to him he add a nettle farm to his building and this too will be solved...

05.04 The fun of exploring new directions for design

The exemplary architects mentioned above hopefully convey the fun of working on sustainable building design, while taking into account fundamental or even enhanced quality levels and using local circumstances optimally. At present I see several new areas for further development of urbanism and architecture into the direction of becoming fully sustainable. In the very first chapter, I already presented the four themes of our research programme of Green Building Innovation. I hope that the need for three of these is obvious after having read the booklet up till here: closing cycles, carbon neutrality and climate adaptation. Here I will explain the fourth one, E-novation, as well as other challenging topics for the area of Climate Design.

The greenhouse as an asset

In Kristinsson’s Villa Flora the greenhouse is an essential asset. In an earlier study he had found that one hectare of modern, smart greenhouse (using fine-wire heat exchangers and heat and cold storage in the underground) is a solar collector that could provide heating for 7 to 8 ha of new ultra-low-temperature-heated houses. This area is based on average Dutch urban plans, the Vinex density. If we were to combine greenhouses with apartment blocks, I calculated that every 3 to 4 stories of apartments could be served by one layer of modern greenhouse (presumably on top).
Sketch for a building solving four problems at once: water storage, housing development, food production and energy-neutrality (idea for the Dutch 'Westland').

This simple ratio based on heat supply and demand has additional advantages: the greenhouse could be used for locally grown food (urban agriculture) and these plants could absorb the CO₂-filled exhaust from the apartments. Furthermore, the greenhouse roof would simplify rainwater collection for use by the plants or in the apartments. As you know, buffering rainwater becomes more urgent in cities.

**Fossil-free developments**

The importance of greenhouses became perfectly clear when I had to work on a region free of fossil fuel, together with planners, architects and technologists. Groningen was again one example to be elaborated, and we found that, with assumed energy savings of 50%, we had to create 250 km² of photovoltaics (PV) and wind turbines together. The only spot where we could find sufficient land for this was the ecologically and economically depleted area of the Veenkoloniën ('peat colonies'). Planning 250 km² of modern horticulture that uses excessive carbon dioxide and has a closed heat balance, with PV on the south side of the shed roof and wind turbines between the greenhouses, we could solve the biggest part of the assignment. In addition, the facility would produce high-quality food and organic material, making it very productive and viable.

**Energy and comfort in buildings: theory, plan and reality**

Many plans are well-intended but turn out to perform worse than anticipated. Things go wrong during the design, construction and operation stage, which we need to understand in order to avoid:

- How correct are energy calculations?
- What goes wrong in practice (the design, construction or operation stage)?
- What can we do about this?
- Do people behave differently than anticipated?
- What are the behavioural mechanisms behind this?
- How can we design sustainable buildings that forgive mistakes or that fit user behaviour?
Groningen Fossil Free: the province as it provides its own energy by non-fossil sources. The yellow-green patches to the south-east consists of modern greenhouses providing most of the energy, in addition to food and material, whereas it also serves as a carbon sink [image by Kasper Klap].

Technologies unlimited
As part of the Delft University of Technology of course I want to contribute to the development of new technology for the built environment. The SREX and REAP cases urge for new techniques of heat and cold exchange without excessive use of infrastructure. Also on the building level in the area of energy and climate, new technical improvements can still be made for the building envelope or building services. In that respect I think the tendency toward adaptive and responsive techniques is promising and should be enhanced towards intelligent interaction of building and surroundings, for which the gentle art of biomimetic architecture as taught by Leeds professor Greg Keeffe [e.g. Keeffe 2010] provides a thorough basis.
Forgive me for mentioning him again, but Jón Kristinsson is one of the very few architect-inventors who come up with new ideas and techniques every year. Among the latest are the Smart Skin and the Air Mover, an inventive passive ventilator he developed with his equally smart brother. The Breathing Window, which he invented in the late 1990s, is finally going to be launched on the market. The principle is simple: fresh air is let in through a fine-wire heat exchanger where exhaust air exchanges its waste heat by an efficiency of 90%, thus providing ventilation and basic heating simultaneously. It is a perfect solution for buildings with limited floor heights, where suspended ceilings are undesired and for renovation projects, which brings me to the term of E-novation.

**E-novation, the assignment of the coming decades**

Education at the Faculty of Architecture may predominantly concern new buildings and new urban developments but after the coming 15-20 years – a decisive period for sustainable development – 90% of the built environment will consist of exactly the same elements as we have now. So we may design brilliant sustainable buildings, which we can, but the real challenge lies in the improvement of the existing stock, where – as discussed – at least 50% of energy savings need to be accomplished.

*During my doctoral research I developed a model to compare decisions regarding renovation of an existing building versus demolition and reconstruction, taking into account the age of a building and its expected service life after intervention. For students I used the old faculty building of Architecture as a case. I had better not done that, because it turned out that the building should either be completely stripped and sustainably renovated, or demolished and replaced by a sustainable new one. Surprisingly for students, this case showed that preserving old poor-quality buildings not always is the best solution. As you probably know this very building burned down in 2008, the year of comparison reference in class...*
I use the term of E-novation to describe energy renovation innovation. It is an assignment much more complicated than designing a new building, as not all measures are possible, requiring ingenuity to significantly improve the energy performance. Close as close can be, we will work on the sustainable renovation of the present building of the Faculty of Architecture, BK City. It is a perfect example of the complexity of an old majestic building where unlimited intervention is not possible or allowed. Within the coming years the BK City Slim project will have to make BK City the paragon of E-novation, probably presenting a collection of strategies instead of just one solution:

- Standard solutions (post-insulation, replacing windows, upgrading building services)
- Technical approach (LTH/HTC floors and walls, heat recovery, heat pumps, heat and cold storage)
- Local approach (cabins in large spaces, local heating/cooling, wrap up internally)
- Innovations (Breathing Windows, heat-radiating furniture, greenhouse over the building)
- No savings – sustainable generation (PV and wind turbines here or elsewhere, green power, geothermal heat)

**Relevant research for E-novation**

E-novation will bring a myriad of issues to be studied for optimal results:
- Comparing different types of renovation for different buildings
- Developing new solutions for roofs, facades and floors
- Developing new technology for climatisation
- Studying physical aspects of building renovation
- Measuring comfort before and after intervention
- Assessing energy performance before and after intervention
- Determining the sustainability performance achieved
- Surveying user behaviour and experience

**New tools**

Another challenge in the area of sustainability is the development of tools that support, stimulate and assess sustainability on various scales. The Life Cycle Analysis (LCA) methodology has been the scientific basis for the assessment of products and buildings (for instance with Dutch tools as GreenCalc+), whereas the market often demands for simpler yet more integral models. BREEAM-NL (the Dutch variant of the British BREEAM tool) is an illustration of the market forcing a generally accepted model that is internationally convertible.

A greater challenge still is the assessment of development areas or entire cities, requiring the inclusion of less quantitative elements of social and economic sustainability. The Dutch Green Building Council has initiated the development of such an area development tool, in which I participate to develop a module on the urban climate. On an even larger scale Winy Maas’ Why Factory’s enterprise on the Green City Calculator is both complicated and necessary to regard cities as a system, which as stated should function as an intelligent organism.
Conclusion

A start rather than a conclusion
To draw conclusions at this stage frankly would be rather rash, since I have only started recently with this academic assignment and mission to construct a solid team that I want to become excellent within the international context. My starting-point is modest, since the Climate Design staff size is relatively small still and under pressure of the present financial limitations imposed on us. Nevertheless, I think we are doing quite well already, acquiring external funding to attract new, promising or high-potential staff and PhD candidates, and serving many students of this generation who naturally understand the necessity. I consider myself at the start of a challenging enterprise with my colleagues, students and clients, and I want to ask you to keep us sharp and focused, for it is not just a scientific burden we have upon us.

Gratitude
I want to thank the people who consciously or inadvertently guided me up to this point – my teachers, colleagues, friends and family... - however, my words can never suffice here and rather than forgetting names and thereby causing life-long discord I thanked them personally after the delivery of my inaugural speech.
Four exceptions here: my student assistants Martine Verhoeven and Michiel Fremouw, thank you for supporting me with this booklet. Ann Karina Lassen, thanks for the native English check. And not least: thank you Sandra, for every reason – and you have suffered most from my idealism, ambition and workaholism.

A final message
Through his keynote speech at the SASBE2009 conference in Delft, June 2009, Sir David King made me understand that, in regards to tipping the climate balance, the years 2010-2025 will be decisive for the success of our interventions. I believe this is even truer for energy. The 'Decisive Period' of 15 years implies that not everyone can have an influence. So the sustainability challenge is a matter of the right generation.

Our sustainability pioneers are retired – not inactive but less influential in the political arena. The baby boomers generation had great ideals – I understood – but so far have failed to do the sustainability thing right while they are in power. Born in the 1960s I am part of the slightly younger generation. We, troubled lot, are in the waiting room but will soon take over. In the 'Decisive Period' children currently younger than 10 years old will hardly have any influence.

Therefore, this I know. My daughters Noé and Isha, they are too young to intervene on time. So I need to take responsibility for them. Everyone who can read this booklet needs to take responsibility. I hope you will join me in this.

I have spoken.

Ik heb gezegd.
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