

Chapter 2

Sustainable High-Rise Buildings in the Netherlands

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1 Introduction: High Rise and Sustainability

The concept of vertical living and working has been hailed as a solution to facilitate fast growth and urbanization of cities worldwide (Drew et al. 2014). At the beginning of 2015, the global population was around 7.2 billion people (USCB 2015). In 2050, the human population will be probably more than 9 billion and 10.9 billion by the turn of the next century (United Nations 2013), 75 % of whom will be living in cities (Hargrave 2013). Tall buildings can address many of the environmental issues facing cities by providing high-density, efficient buildings that link to public transportation systems and offer the type of amenities demanded by tenants (Wood 2013). As city living takes center stage, urban building of the future have to foster sustainable qualities, essentially functioning as a living organism and engaging with the users within. Cities throughout the world are growing rapidly, creating unprecedented pressure on material and energy resources. Cities with their financial and administrative centers are a key asset to the countries' national economy and to the cities itself. The local authorities want in order to assure the city's dynamism ideal conditions for business to operate (Plank et al. 2002). To do so, the local authorities need to assure that the demand for office space can be met within the center of economical activities. In this context, tall office buildings are becoming increasingly necessary as a result of the efficient use that they make of the limited land available. Besides the focus on offices, more and more focus is also on mixed use of the tall buildings, where the offices are combined hotels, shops, and apartments. Some of the new tall buildings become almost a city on their own. The buildings need to help to optimize city-wide production, storage, and consumption of everything from food and energy to water (Hargrave 2013). As in large cities, almost three quarters

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of their energy consumption is in buildings; this will be one of the main concerns (Plank et al. 2002). The most intensive use of energy of state-of-the-art high-rise buildings usually results from the cooling (40 %) or heating (30 %) of space, while lifts use about 5 % of a tall building's energy and lighting and electrical appliance can make up about 25 % (Plank et al. 2002). Careful building services design can minimize the need for heating and cooling throughout the year for example by applying seasonal thermal energy storage.

2 Historic Development and Specific Dutch Situation of High-Rise Buildings

High rise had become possible at the end of the nineteenth century due to several technical finds and improvements in building techniques. Steel and armed concrete simplified high rise and the introduction of the elevator safety braking system in 1853 made high rise practically useful (ASHRAE 2011). Due to the population and economic growth in cities, taller buildings became very popular. ASHRAE Technical Committee TC 9.12, Tall Buildings, defines a tall building as one whose height is greater than 91 m. The Council on Tall Buildings and Urban Habitat defines a tall building as one in which the height strongly influences planning, design, or use (ASHRAE 2011).

Although the Netherlands is a rather highly dense populated country, with around 16.5 million people on an area of around 200 by 350 km with 40 % water, it has not real big cities. The biggest cities are Amsterdam and Rotterdam with both less than a million, however especially in the western part of the country all cities are more or less connected to each other. There is no free unused space left. Especially in the big cities there is now a trend towards higher buildings although the Netherlands have no real tradition on this. Although, in 1897 the first skyscraper in Europe was built, the White House, 42 m high was built in Rotterdam, see Fig. 2.1. As most of the country is below sea level, protected by the dykes, the soil is often of clay and sand, not the most stable underground to build high-rise buildings on.

The high-rise record for a Dutch office building went next to the 64 m tall GEB building in 1931 in Rotterdam. Only in 1969 this was taken over by the medical faculty of the Erasmus MC which was 114 m. Then in 1982, established high-rise foundation and Rem Koolhaas praise of high rise in Delirious New York were a major stimulation of high-rise buildings in the Netherlands and especially in Rotterdam. From 1986 a large amount of high office buildings were realized in the city center. Since 1991 for quite a long period the record of tallest building in the Netherlands was held by the head office of the Nationale Nederlanden with its 151 m (Architecture in Rotterdam 2014). This was taken over by the Maas Tower (165 m) the highest building in the Netherlands, see Fig. 2.2.

Internationally seen the Rotterdam Skyscrapers are but small ones. Even in 1931 New York already had set the trend with its 381 m high Empire State Building. In the

Fig. 2.1 The White House—Rotterdam 1897 (Rijksmonumenten 2015)

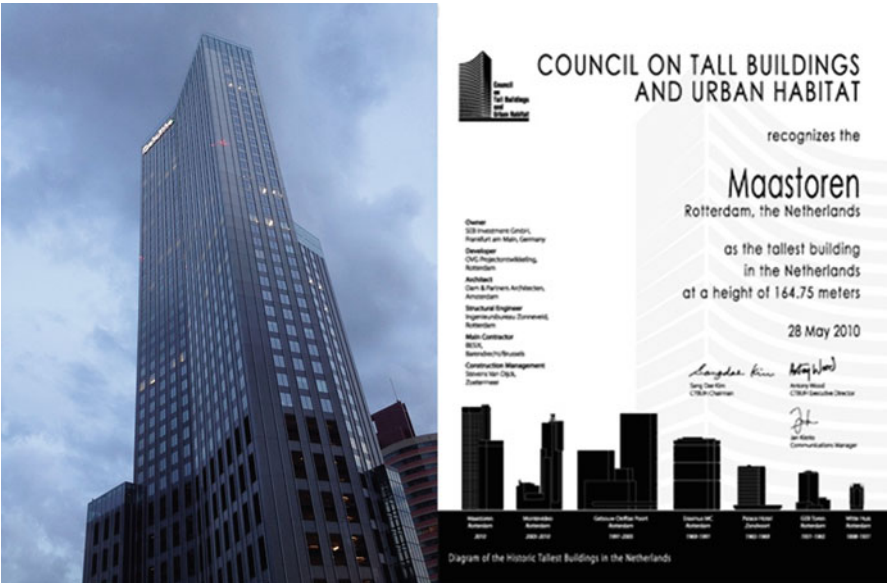


Fig. 2.2 Maas Tower Rotterdam, tallest building in the Netherlands

last decades, the sky seems to be the limit with Asia leading the way in extreme high rise with the Petronas Towers in Kuala Lumpur (450 m), the Taipei 101 (508 m) and the Burj Dubai (818 m) in the United Arab Emirates. The statistics of tall buildings are available at www.skyscraperpage.com.

3 Tallest Dutch Building: The Maas Tower

Maas Tower is a 44-storey office skyscraper complex designed by Odile Decq Benoit Cornette in cooperation with Dam & Partners. Construction started in October 2006 and on 9th December 2009 it was finished. Next to being the tallest building in the Netherlands, the Maas Tower also has some interesting notable sustainable features. The water of the River Maas is used, together with aquifer thermal energy storage (ATES) underground wells in the soil, for the thermal energy storage. The basic principle of an ATES-system is the extraction and injection of ground water into two separate storage wells, located a sufficient distance apart from each other. During summertime, water is extracted from the coldest well and used to cool the building. This heats the water from approx. 8–16 °C. The heated water is injected at the warm well and stored until the winter season. During winter the extraction/injection flow is inversed and the heated water (with a temperature of approx. 14 °C) is pumped back to the building. Using a heat pump the heat is extracted from the water and the cold water (6 °C) will be injected in the cold well. This means that district heating is not required and CO₂ emissions for the building are virtually halved when compared to a conventional design. The ATES-system of the Maas tower in Rotterdam uses a monovalent heat pump system and combines aquifer thermal energy storage and use of water from the nearby river Maas. The water of the river is led past a heat exchanger which is connected to the building's climate control system. In this way, the building can "absorb" the warmth which is still present in the river in the autumn because due to industrial residual heat the average temperature of the river water is still above 20 °C. As the river water strongly cools down in winter a possibility was created to store the summer heat. At a depth of around 150 m two wells were drilled for a doublet aquifer. One well contains the water which is warmed up during summer, while the other contains water which is cooled down to about 6 °C (Beerda 2008). During winter time, when the river water is too cold to heat the office building, the system pumps up water from the warm well and after extracting the heat it is cooled down and stored in the cold well, see Fig. 2.3.

In the warm months, the exact opposite is done. During the first warm months of a year, river water is being used, which is still cold enough at that time to cool the building (Beerda 2008). If the river temperature rises too much, water of the cold well is extracted. Energy storage in underground is not a new concept, but combining it with the use of river water made it a novelty. It is especially interesting to Rotterdam and some other cities in the Netherlands as there are many rivers and in the past often cities were initiated nearby rivers. In this way cities making use of

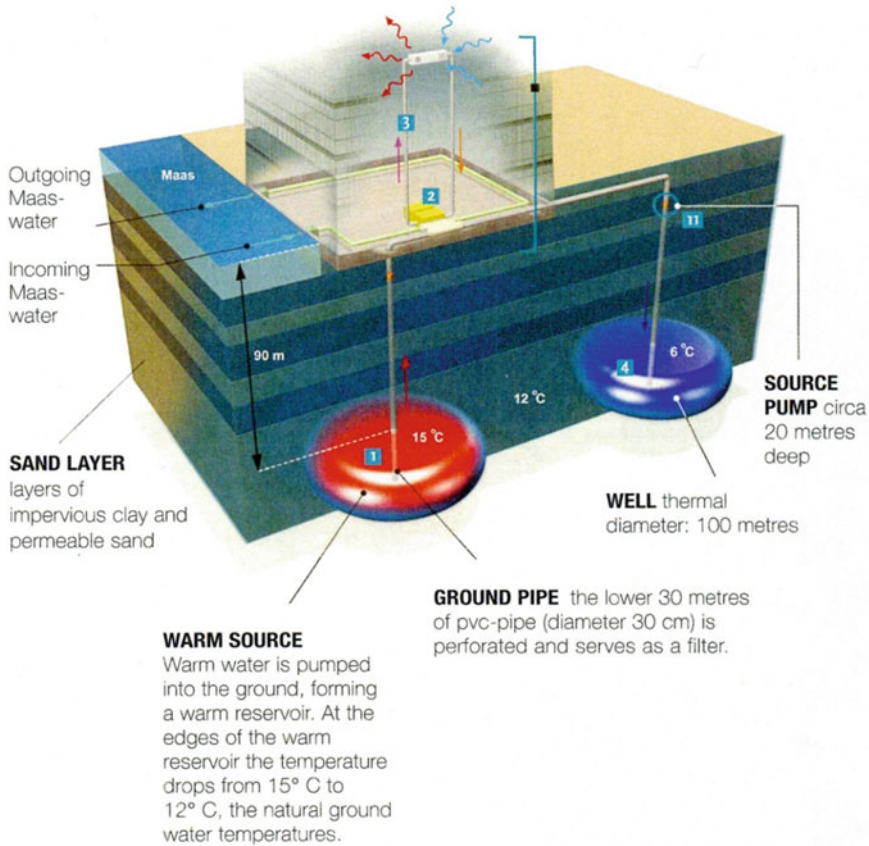


Fig. 2.3 Aquifer thermal energy storage system in combination with energy exchange with the water from the river Maas (Beerda 2008)

river water become energetic more economical, the ATES-system in these cases uses about 55 % less primary energy and their CO₂ emissions become half. The ATES-system of the Maas Tower was simulated and the results were validated by on-site measurements (Molenaar 2011). The results showed a seasonal performance factor (SPF) for supplying heat by the heat pump of approximately 3.8. This is slightly higher than the expected value of the SPF of 3.6 based on literature. Measurements showed that the heat pumps use approximately 78 % of the total electricity use of the complete ATES-system; the (transport and source) pumps use the other 22 % energy.

The SPF of 47 for supplying cooling is high compared to the values from literature with an SPF between 12 and 50 (Molenaar 2011). The Annual Performance Factor (APF) of the ATES-system for the year 2010 is 5.0. However considering the large amount of additional stored cooling the real APF is approximately 6.0. The usage of

surface water (water of the river Maas) in combination with ground storage and heat pumps leads to advantages in four aspects (Molenaar 2011):

1. Maas water can be used as regenerator. Maas water can approximately be used during 3.270 h annually for the regeneration of heat and approximately 1.900 h annually for the regeneration of cold.
2. Maas water can be used to increase the temperature difference between the warm and cold well. By putting the Maas water system in sequence with the heat pump, the well water can be extra cooled in the winter and in the summer the well water can be extra heated. In theory this alignment leads to a reduction of the water displacement leading to a reduction of the electrical use of 3.5 %.
3. Maas water can be used as a direct energy source in midseason Maas water can approximately be used 5440 h annually as a heat source to the heat pump and it can approximately be used 3000 h annually for direct cooling supply. Using Maas water as a direct energy source hardly improves the energy efficiency; average of 1 % energy reduction.
4. Maas water can be used as backup for the wells of the aquifer Maas water and can also approximately be used 5440 h annually as backup by failure of and/or maintenance on the ground wells (as heat or cold source for the heat pump). Adding surface water to an ATES-system improves the efficiency (on average by 3.9%) because common problems of ATES, such as a low-temperature difference between the warm and cold source, exceeding the design water displacement and an disturbed energy imbalance in the underground can be reduced or even solved.

The Maas Tower consequently has unprecedentedly low CO₂ emissions for a high-rise building. It is an iconic Dutch project for “building with water” and an undoubtedly strong statement as it towers over the water (OVG 2014a). Techniplan Adviseurs, the consulting engineering company who did the HVAC design, won the Innovation award of the Dutch consulting engineers association for the system’s design. “The Maas Tower is a monument in the making and far ahead of its time” according to the jury of the prestigious FGH Real Estate Award when the building won this award. The building is much more than just tall. It is a perfect example of optimum integration into an urban environment.

4 The Biggest Building of the Netherlands: De Rotterdam

When your ambitions are greater than the available space you have two options: adapt either your ambitions, or the space. Architect Rem Koolhaas managed to add a third option: turn the city upside down. Or rather: stack it... (OVG 2014b). In order to accommodate all the cities of Rotterdam’s massive plans Koolhaas’ OMA Architecten designed an entire district with apartments, hotel, entertainment and leisure amenities, and offices. He then lifted the whole plan up and stacked it on top of each other: Literally a vertical city. Upon completion, De Rotterdam became the largest building

Fig. 2.4 Mixed-used towers of the vertical city concept of De Rotterdam



in the Netherlands at 162,000 m² of area and 149 m height. Its mass is broken down by three interconnected mixed-use towers, accommodating offices, apartments, a hotel, conference facilities, shops, restaurants, and cafes. De Rotterdam is an exercise in formal interpretation that is at once reminiscent of an imported mid-century American skyscraper, but epitomizes the off-center experimentalism of modern Dutch art of the foregoing century. Through De Rotterdam, which is the Netherlands' biggest construction project, OMA/Rem Koolhaas has developed the country's first vertical city, see Fig. 2.4.

It took 10 years to develop the building and is a good example of art out of creating space in high places in a country where ground-level square meters are seriously limited.

Koolhaas: "De Rotterdam is a persuasive design. Its fascination comes from the fact that, despite being an undoubtedly large building, it's actually formed of small parts that come together to form an exciting whole. This is in contrast to so many other buildings in Rotterdam that are just singular entities. De Rotterdam has an ambitious agenda: to be a residential building, a place of work, a recreation center and a hotel. For every component, we looked at how its circumstances, situation, and views could be best utilized. As a result, every part has a different character."

Everyday, 3000–4000 people will put De Rotterdam to full-time use: Through living in 240 apartments spread over 35,000 m²; through working in 60,000 m² of office space; through using a four-star hotel whose 285 rooms occupy 19,000 m²; through parking in a secure 25,000 m² garage with spaces for 684 cars; and through making use of 3500 m² of conference rooms, shops, restaurants, and cafés. In short, it's a building full of international appeal: in De Rotterdam sustainability is given the rightful attention while providing residents with comfort. In partnership with



Fig. 2.5 Under-floor heating/cooling of the apartments of De Rotterdam

Eneco, a sustainable energy supply concept was developed to equip the 44-floors apartments with under-floor heating and cooling by generating heat and cold from existing sources through heat pumps. The system allows high temperature cooling and low temperature heating because of the big active surface areas of exchanging energy within the rooms. The under-floor heating and cooling system makes use for cooling of cold water from the Maas, see Fig. 2.5.

The interior temperature of every room is controlled by its own thermostat and high performance. Heat-reflective double-glazing and windows to let fresh air inside reduce the cooling demand. The energy concept of De Rotterdam, see Fig. 2.6, is a high complex mixture of different elements combined with heat/power installation of the local City heating system, partly co-generation with biofuel, river Maas water cooling (Fig. 2.7), Aquifer thermal energy storage, and heat pumps.

5 Discussion Energy Performance of the High-Rise Buildings

In 2010 the European Commission launched the Energy Performance on Building Directive (EPBD) with the main targets to reduce CO₂ emissions with 90 % compared to 1990. It is specified that by 31st December 2020 all new buildings shall be nearly zero-energy buildings. Governmental buildings occupied and owned by public authorities, will have to be nZEB by 31st December 2018 according to the EPBD recast. The EPBD requires all newly build buildings to be nZEB in 2020 for different building functions. Existing buildings will also have to comply with this regulation towards 2050. Each European Member State (MS) has to work out a plan that includes an nZEB definition for different building functions, determining specific

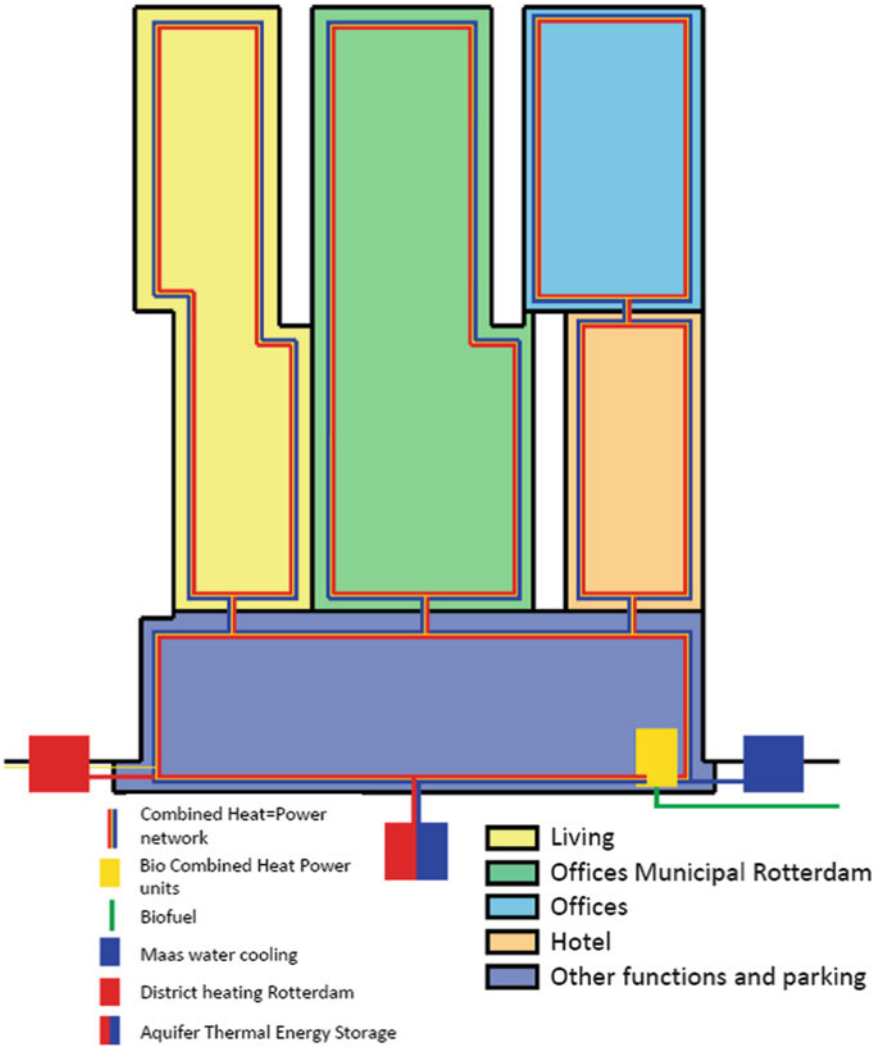


Fig. 2.6 Total energy system of De Rotterdam

building requirements. The definition of a nZEB is described within the EPBD recast in Article 9: “Technical and reasonably achievable national energy use of $>0 \text{ kWh}/(\text{m}^2\text{a})$ but no more than a national limit value of non-renewable primary energy, achieved with a combination of best practice energy efficiency measures and renewable energy technologies which may or may not be cost optimal.”

In the Netherlands performance is indicated by the Energy Performance Coefficient (EPC) which is described in the NEN 7120 norm. Currently, the EPC is 0.6 for residential buildings and will be lowered to 0.4 in 2015 according to a covenant of the new buildings sector, aimed at reducing the energy consumption of new

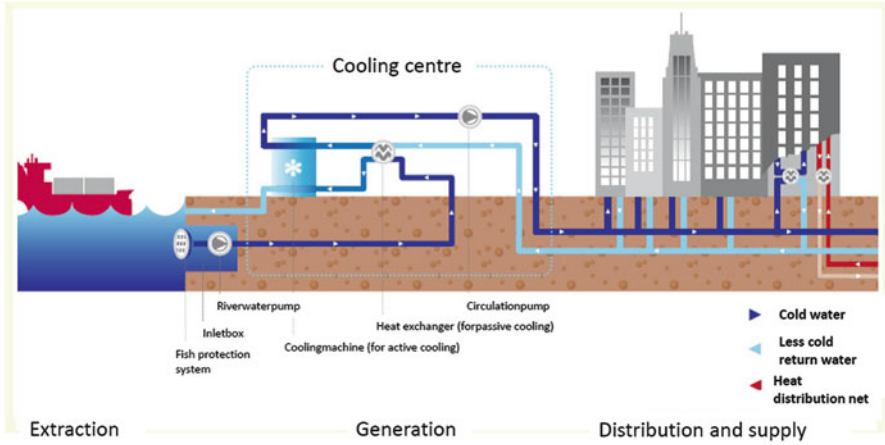


Fig. 2.7 Energy concept of the heating and cooling supply of De Rotterdam

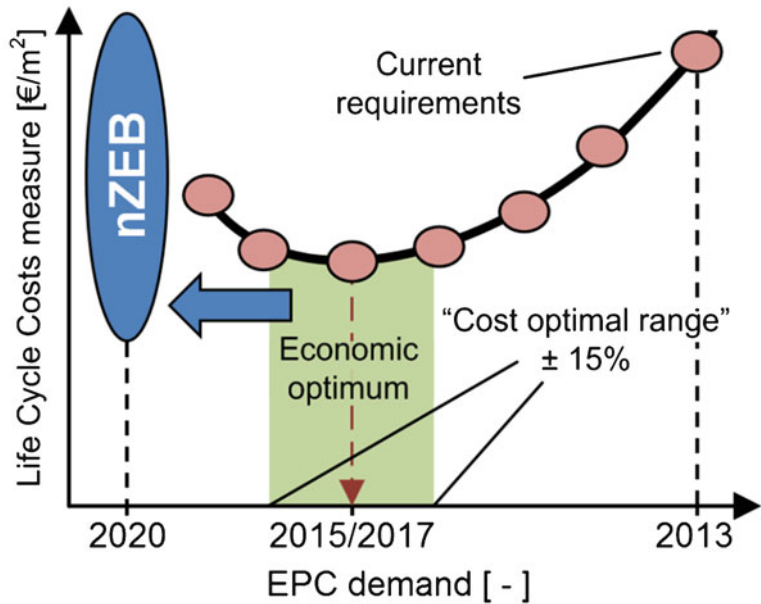


Fig. 2.8 Life cycle costs versus the EPC demand (Gvozdenović 2014)

buildings over time. In this signed agreement between the public and private sectors, a number of efforts have been agreed to reduce the energy use of new buildings by the year 2015 by at least 50 % compared to 2007 levels.

Cost-optimality Life Cycle Cost (LCC) calculations are essential for determining the Dutch nZEB definition, as they determine if the energy-efficient measures are

cost effective and can be implemented in the building law. In the near future, EPC requirements will be reduced to values that lay within the “Cost optimal range,” see Fig. 2.8 (grey area), determined by calculating the LCC over a period of 30 years. In 2020 buildings will have to be nZEBs (blue area in Fig. 2.8). Current calculations show that nZEBs will result in much higher LCC values than the economic optimum. Therefore, an LCC method which also takes additional gains (e.g., productivity, resale value) into account is proposed. Effectively including these gains leads to lower total life cycle costs and the economic optimum shifts towards nZEB requirements (blue arrow in Fig. 2.8). Focusing on gains and including these in the LCC calculation method is an important foundation for the Roadmap towards nZEBs.

The cost-optimality is a crucial aspect for the introduction of nZEBs in the Netherlands. The special power generation of the Maas Tower as well as the collective power generation system of de Rotterdam ensures a substantial improvement in all areas compared to the requirements of the current Building Regulations. As a result, the EPC of the Maas Tower is 0.98 or 35 % less than the current Building Regulations. The EPC of the mixed-used sections of the Rotterdam are:

- Apartments 0.55 (31 % less than Building Regulations)
- Hotel 0.93 (7 % less than Building Regulations)
- Offices Mid Tower 0.82 (18 % less than Building Regulations)
- Offices East Tower 0.77 (23 % less than Building Regulations)

Although we are still far from an EPC of zero, it shows that high-rise buildings can perform almost equal to normal tall office buildings. Drew et al. (Drew et al. 2014) performed a study towards the environmental performance of different housing typologies ranging from a 215-storey supertall building to single family residences, including several scales in between (123, 58, 34, 16, courtyard, 3-flat, urban house and suburban house). They concluded that taking into account the operational and potential carbon offsets through on-site energy generation, the communities that perform best overall are the high-rise buildings (58 and 34 storey) with the taller buildings performing best. This shows the possible benefits of vertical communities (Drew et al. 2014).

6 Possible Future Solutions

The Netherlands, as a densely populated country, combined with high standards of living had always to (and knows how to) mold the natural environment to suit its needs (MVDRV 2015). Time and time again more land was won from the sea. Perhaps in the near future extra space will be found not just by increasing the country’s width but by expanding vertically. Architectural office MVRDR raised questions of global significance when designing their plan for the 2000 Hannover World expo fair: Can increasing population densities coexist with an increase in the quality of life? What conditions should be satisfied before such increases in density take place? What role will nature, in the widest sense, play in such an increase in density?

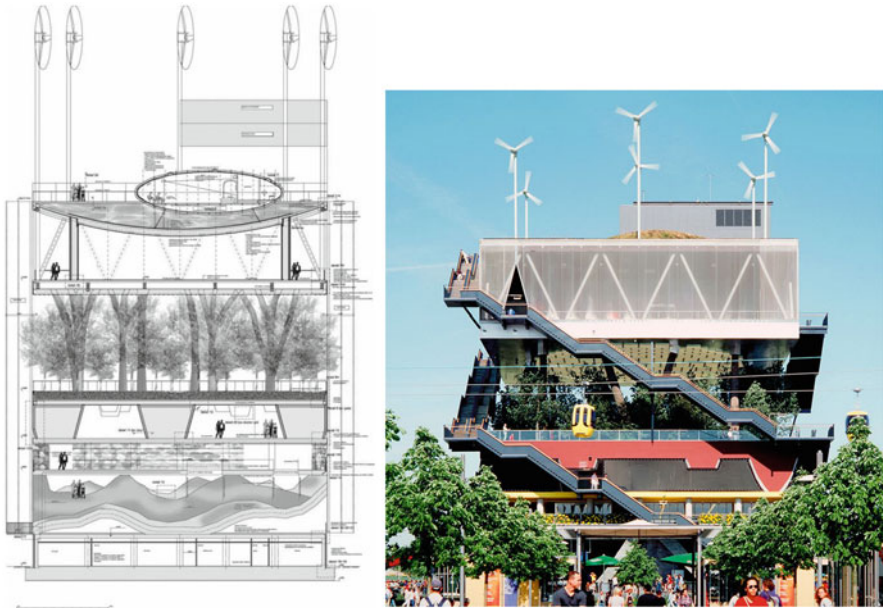


Fig. 2.9 Dutch pavilion World Expo Hannover

Is not the issue here “new nature,” literally and metaphorically? The Netherlands’ specific contribution to the ecological spectrum of the World Fair in Hannover 2000 showed was precisely a mix of technology and nature, emphasizing nature’s makeability and artificiality. Demonstrating that technology and nature need not be mutually exclusive, they can perfectly well reinforce one another. Nature arranged on many levels provided both an extension to existing nature and an outstanding symbol of its artificiality. It provides multilevel public space as an extension to existing public spaces (MVDRV 2015). It not only saves space, it also saves energy, time, water, and infrastructure. A mini-ecosystem was created as a kind of future survival kit. “Holland creates Space”: the theme for the Netherlands Pavilion at the 2000 World Expo in Hanover was to showcase a country making the most out of limited space. Six stacked Dutch landscapes form an independent ecosystem communicating cultural sustainability: progressive thinking and contemporary culture were combined with traditional values. The architecture suggests Dutch open-mindedness, while confirming the positive stereotypes of windmills and dykes. Of course, it also tests existing qualities: it attempts to find a solution for a lack of light and land. At the same time, the density and the diversity of functions builds new connections and new relationships. It can therefore serve as a symbol for the multifaceted nature of future sustainable high-rise buildings (MVDRV 2015). The Dutch pavilion at the Hanover World Expo 2000 (Fig. 2.9) demonstrated trends in sustainable high-rise building on land use by multilevel function, integration of renewable energy, preserving greenery, and reducing environmental impact within a natural setting (Rovers 2008).



Fig. 2.10 Triple bottom line approach for rooftop farming, presented by Zoellner (Zoellner 2013)

By working with nature cities can become more resilient to the changing climate, while reducing greenhouse gases through natural carbon “sinks.” Embracing green roofs and facades helps to negate humans’ impact on the environment, and to achieve livable, sustainable built spaces (Yong 2014). Arup’s Cities Alive (Armour et al. 2014)—supported by the Landscape Institute and the Royal Botanic Gardens, Kew—describes the power of nature and the natural environment which could be used to offset a lot of effects. This to raise awareness of what the natural environment does, because it is often taken for granted (Yong 2014). Increasingly sophisticated technology will allow roofs, walls, and building façades to be “greened,” creating a filter for pollution, absorb carbon dioxide by acting as a carbon “sink,” as well as providing natural cooling and insulation to enhance air quality for city dwellers. Furthermore, green roofs retain a high amount of rainwater, so are perfect for harvesting, thus reducing the amount of water reaching urban sewage systems. Cities in the future will look vastly different to cities now (Arup 2015) with their green roofs, water roofs, vertical farming and even high-rise greening with trees like the Bosco-verticale by Stefan Boeri in Milan (Smith 2015). Brought about by concerns (over rapidly depleting natural resources, climate change and population growth, lack of physical space, transport networks with its intimate ties to oil prices and global food trade) food production systems, like vertical farming, could become integral elements in urban environments (Armour et al. 2014). Vertical farming techniques and urban agricultural systems, such as hydroponics, can potentially be utilized to help address the local food production as well as contribute to the environmental conditions within the cities. As a result of the economic, environmental, and social developments, Urban Agriculture will become part of the urban culture in the twenty-first century, see Fig. 2.10 (Zoellner 2013).

In Rotterdam, an architecture collective has reclaimed an old building in the center of the city and started using the roof to build an urban farm on top of it. As part of the 5th International Architecture Biennale Rotterdam, this first rooftop farm of the city on top of the Schieblock building was built as a Test Site. The garden houses vegetables and herbs (and some bees, too!), the urban rooftop farm,

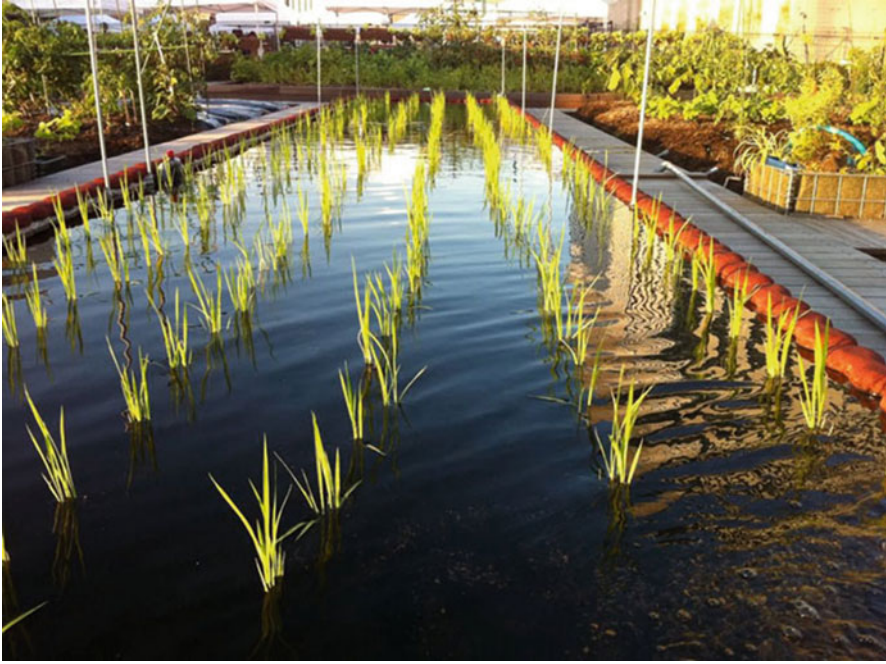


Fig. 2.11 Dakakker—Rotterdam (de Boer 2012)

called Dakakker, is an initiative of architecture firm ZUS and has sold its first veggies and herbs to local restaurants and shops. Also in Amsterdam, the Netherlands, the Zuidpark rooftop farm has opened its doors last year. Located along the city's ring road, Zuidpark focuses (more than other urban farms) on activities, workshops, and education, as well as on organizing special dinners with a view (Fig. 2.11) (de Boer 2012).

Europe's biggest commercial urban farm will soon be located in The Hague, Netherlands. A 1200 sqm greenhouse is to be placed on the roof of the De Schilde. Two of the building's top storeys, each measuring 1500 m², will be used for urban farming by city farming pioneer UrbanFarmers (UF) AG, a Swiss company. An indoor fish farm and boutique brewery are also included in the redevelopment plans (EuroFresh 2015).

7 Necessary Preconditions for Sustainable High-Rise Buildings Design

Until recently, tall buildings were mega-scale energy consumers with little regard for sustainable architecture. However, this is changing with a new generation of high-rise buildings that have been designed with energy conservation and

sustainability as their principal criteria (Ali and Armstrong 2006; Ali and Armstrong 2008). The sustainable design of high-rise buildings should be paid more attention because high-rise buildings consume a large amount of natural resources and energy (Xu et al. 2006). This started already in the early 1990s with passive design. Passive design is essentially low-energy design achieved by the building's particular "morphological organization" (Yeang 1999). The Menara Mesiniaga in Subang, Malaysia, designed by Hamzah and Yeang in 1992, presents an early model building for the physical translation of ecological principles into high-rise architecture. The fifteen-storey tower expresses its technological innovations on its exterior and uses as little energy as possible in the production and running of the building. Ecological design, for Yeang, involves "the holistic consideration, of the sustainable use of energy and materials over the life-cycle of a building 'system', from source of materials to their inevitable disposal and/or subsequent recycling" (Powell 1999).

Sustainable design aims to meet the requirements of the present without compromising the needs of future generations by encouraging the use of renewable resources, alternative strategies for energy production and conservation, environmentally friendly design, and intelligent building technology. Intelligent building refers to a building that has certain intelligent-like capabilities responding to preprogrammed stimuli to optimize its mechanical, electrical, and enclosure systems to serve the users and managers of the building (Yeang 1996). The sustainability of a design for a high-rise building can be evaluated in the framework of international certification systems which have various sustainability criteria classifications aimed to minimization of environmental impacts of buildings (Gultekin and Yavaşbatmaz 2013). LEED (Leadership in Energy and Environmental Design) is one of the leading internationally recognized certification systems developed by the U.S. Green Building Council (Heller 2014). It guides designers to apply methods for meeting the criteria for sustainable sites, water efficiency, energy and atmosphere, materials and resources in terms of ecological sustainable design; the criteria for efficient use of resources and low operating cost in terms of economical sustainable design; and the criteria of indoor environmental quality and innovation and design process in terms of sociocultural sustainable design. Gultekin and Yavaşbatmaz (Gultekin and Yavaşbatmaz 2013) examined 13 LEED certificated high-rise buildings that are now in use: Bank of America Tower—New York 2009, The Visionaire Building—New York 2008 and Taipei 101 Financial Center—Taipei 2004 have LEED Platinum certificate; Conde Nast Building—New York 1999, The Helena Building—New York 2005, Eleven Times Square Building—New York 2007, 7 World Trade Center—New York 2007, 555 Mission Street Building—San Francisco 2009, Comcast Tower—Philadelphia 2008, Hearst Tower—New York 2006, and Solaire Building—New York 2003 have LEED Gold certificates; One South Dearborn Building—Chicago 2005 has LEED Silver certificate; and 30 Hudson Street Building—New Jersey 2004 has LEED certificate. According to results of the evaluation (Gultekin and Yavaşbatmaz 2013), ecological, economical, and sociocultural sustainable design criteria are largely met in the examined LEED certificated tall buildings. The compliance with sustainable design criteria for the examined LEED Platinum certificated tall buildings is 99 %; for LEED Gold certificated tall

buildings 97 %; for LEED Silver certificated tall buildings 92 %; and for LEED certificated tall buildings 76 %. These examples show the possibilities of sustainable design for tall building design. While the concept of sustainability is becoming accepted, there is little worldwide consensus on what specific actions should be taken: an ecologically sensitive perspective, an energy-efficient approach, a bioclimatic approach, or a technology-conscious perspective (Utkutug 2004). Even up to now many different approaches are suggested (Mendis 2013; Jin et al. 2013; Navaei 2015; Milana et al. 2014; So et al. 2014; Raji et al. 2014).

8 Integral Design as a Solution for Sustainable High Rise

Sustainability is a crucial issue for our future and architecture has an important role to direct sustainable development (Taleghani et al. 2010). Although this path is not completely clear (Voss et al. 2012), the ultimate goal is clear: to design and build buildings that give more than they take (Gylling et al. 2011; Active 2013). In the Dutch Building Industry gaps of knowledge between the worlds of design and engineering were recognized by researchers as well as practitioners (van Aken 2005; Savanović 2009; Quanjel 2013). New approaches are needed to bridge the gap between architects and consulting engineers (structural, building physics and building services). The traditional building design process was a fragmented process where engineers and other experts were introduced after some of the most influential design decisions have already been made (Xu et al. 2006; Heiselberg 2007). This led in many cases to non-optimized buildings by nonintegrated addition of sustainable options like renewable energy systems or energy efficiency measures (Poel 2005; Brunsgaard et al. 2014). No longer conceptual building design should be done by architects alone, a whole design team with members from different disciplines is required to cope with the complexity of the current necessary sustainable development right from the beginning. During the conceptual building design process, synergy between different disciplines is essential to reach optimal sustainable building designs. King (King 2012) stated that in order to do anything meaningful in terms of moving to low carbon society, we need a consistent framework and design method, within which we can apply knowledge embodied in a design team.

Knowledge development in daily practice starts with effective collaboration between the participating disciplines in a design team (Emmit and Gorse 2007), making designing the most central activity in new product development. Concept designs can be seen as the basis of knowledge development within the design-team related to specific design solutions (van Aken 2005; Hatchuel and Weil 2003). For that reason concept generation is an essential part of the early design phase. During this phase, the most important decisions for the product/product-life cycle need to be made, even though relevant information and knowledge is lacking and domain experts might not be available and communication between them is very difficult.

Since the early 1960s, there has been a period of expansion of design methods through the 1990s right up to the present day (Cross 2007; Chai and Xiao 2012; Le Masson et al. 2012). However, there is still no clear picture of the essence of the

design process (Horváth 2004; Bayazit 2004; Almfelt 2005a, b) and many models of designing exist (Wynn and Clarkson 2005; Pahl et al. 2006; Tomiyama et al. 2009; Ranjan et al. 2012; Gericke and Blessing 2012).

In the Netherlands, Methodical Design is a quite familiar design method in the domain of mechanical engineering and being taught at different educational institutes. The Methodical Design process (Kroonenberg and van den Siers 1992; Blessing 1994) is a problem-oriented method derived from the General System theory (von Bertalanffy 1976) and distinguishes based on functional hierarchy complexity levels during different design phase activities. This design method that was further extended into Integral Design through the intensified use of Morphological Charts (MC) was developed by Zwicky (Zwicky 1948) to support design activities in the design process (Savanović 2009). General Morphological analysis was developed by Fritz Zwicky (Zwicky 1948) as a method for investigating the totality of relationships contained in multidimensional, usually nonquantifiable problem complexes (Zwicky and Wilson 1966; Ritchey 1998; Ritchey 2004). Morphology provides an arrangement for supporting overview of the considered functionalities and aspects and their solution alternatives. Transformation of the program of demands by a design team, into aspects and functionalities listed in the first column of a matrix, and formulation of the different solutions and relations related to these aspects and functionalities listed in the related rows to them, forms a MC. The traditional main aim of using MC is to widen the search area for possible new solutions (Jones 1970). The MC is a key element that can improve the effectiveness of the concept generation phase of the design process as it is an excellent way to record information about the solutions for the relevant functions and aspects. The MC aids in the cognitive process of generating the system-level design solutions (Wynn and Clarkson 2005) and also has definite advantages for communication within group work (Ritchey 2010). The MCs to visualize sub-solution alternatives play a central role in the Integral Design approach for design teams as all the individual MCs are combined into one Morphological Overview (MO). The MO of an integral design team process is generated by combining in two steps the different MCs made by each discipline. First, functions and aspects are discussed and then the team decides which functions and aspects will be placed in the MO. Then, after this first step, all participants of the design team can contribute their solutions for these functions and aspects by filling in the rows within the MO. Putting the MCs together enables “the individual perspectives from each discipline to be put on the table,” which in turn highlights the implications of design choices for each discipline. This approach supports and stimulates the discussion on and the selection of functions and aspects of importance for the specific design task, see Fig. 2.12.

In case of building design, MCs can be used to explicate discipline-based object-design-knowledge. Merging MCs of all involved disciplines results in an MO of the available object-design-knowledge within a design team. However, MO are not to be regarded as the end result of the team design process, rather as the initial phase based on which integral design can be done.

The description of the MO may read as minor implementation difference of the old MCs. However, it is a subtle but essential difference: the MCs represent the individual interpretation of reality, leading to active perception, stimulation of

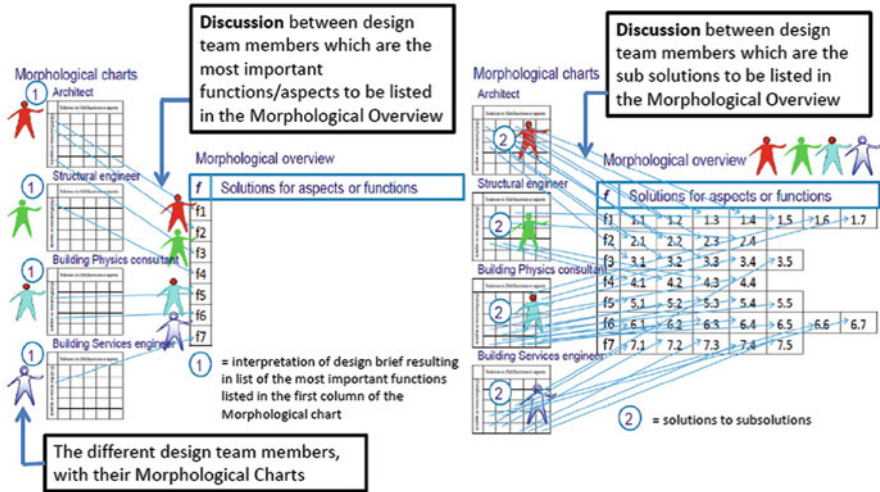


Fig. 2.12 Building the morphological overview; Step 1, the MO contains the chosen functions and aspects (1) from the different MCs. Step 2, the MO with the accepted sub-solutions (2) from the separate MCs

memory, activation of knowledge, and defining of needs. Within the MO, this individual result is combined with those of the whole design team. The MO is the representation of the design team's interpretation/perception and activated memory/knowledge: the design team's mental model (Badke-Schaub et al. 2007).

As the Integral Design start from the program of requirements, the method especially emphasizes the sustainable development necessary to achieve nZEB. Due to reflection within the design team during the process, sustainable thinking is developed, and thus it becomes more than just merely the creation of mapping disparate skill sets within the team. The multidisciplinary dialogues lead to knowledge sharing (the MCs), knowledge integration (the MO), and knowledge generation (new solutions which were not included in the morphological charts, but are inspired by them). During this process, the information from the morphological charts are discussed and explained to each other. Any barriers to communication are overcome by the team members by solving the misunderstandings and the development of a shared insight, which forms the basis for the MO.

9 Discussion and Conclusions

Many city planners see high-rise buildings as a way to address the fast-increasing need for a more sustainable concentration of infrastructure, energy and carbon offered by denser cities in answer to the growing population and urbanization (Wood 2013). High-rise buildings are viewed as a way to change the functional dynamic of a city towards a more sustainable direction. However, high-rise buildings alone are

not the answer. Far too often the sustainability and impact of a single building is evaluated without considering the larger context. Skyscrapers only become truly sustainable when they are integrated into the urban social and economic fabric. This requires different approaches and a rethinking of the design process (Wood 2013). Sustainable tall buildings especially, an Integral Design process is necessary because of their scale and the fact that sustainable design of high-rise buildings affects so many different elements of a building, such as daylighting, which in turn concerns siting, orientation, building form, facade design, floor-to-floor heights, interior finishes, electric lighting controls, and cooling loads, among other things. Integral design is different than conventional design in its focus on active conceptual design collaboration within a multidisciplinary team.

Design processes can be improved through improving three types of process communication (Senescu et al. 2013; Senescu and Haymaker 2013): understanding, sharing and collaboration. Through visualizing the individual contributions within a design team, morphological overviews based on the individual Morphological Charts stimulate the emergence of solution concepts within design teams. By structuring design (activities) and communication between design team members Integral Design's Morphological Overview forms the basis for reflection on the design results. Through this it helps the design teams come forward with new design propositions. The Morphological Overview supports the communication within the design team and leads to better understanding, sharing and collaboration (Savanović 2009). Although, the proposed model of Integral Design has an implicit proposition which tends to portray it as mere problem solving across various professional domains, it has to be emphasized that the reflection by means of the Morphological Overview enables the introduction of creativity beyond the mere functional, decompositional approach.

As stated by Janet Beckett, director at Carbon Saver a consultant company specialized in Low Carbon Building design and building engineering physics, there could not be a better time than now in time of global change to implement a paradigm shift—we cannot continue in the same vein (Beckett 2012). Earlier dialogue and true cooperation in the project design means it is easier to build on sustainability, and add innovation and engineer-integrated solutions (Beckett 2012).

Designing nZEB requires that architect and engineers overlap their knowledge and skills and share the character of a designer (Brunsgaard et al. 2014). A new kind of architect is needed, who can accept the principles of engineering alongside the building aesthetics, to balance form and function for an optimal sustainable design. A new generation of architects to be inspired by engineering and science, willing not only to listen to concepts and ideas of engineers, but to really truly design together with engineers solutions that can be beautiful, useful as well as sustainable. Also a new kind of engineer is needed, one who is better able to communicate about possible alternative proposals as well as the realities of how engineering services impact on the building and not just solving problems or making calculations.

The challenge is getting synergy between all members of a design team on board with the design process in a sustainable high rise. By exploring the underlying aspirations for building, the team may come to see that the real goal is not the building per se, but the services and benefits it can offer to the client and the community at large.

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