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MorgenStadt
City of the Future

INNOVATION NETWORK

»MORGENSTADT: CITY INSIGHTS«

City Report

COPENHAGEN

2013

MORGENSTADT: CITY INSIGHTS (M:CI)

Climate change, energy and resource scarcity, a growing world population and aging societies are some of the large challenges of the future. In particular, these challenges must be solved within cities, which today are already home to more than 50% of the world's population. An ever growing number of cities are actively developing new and sustainable infrastructures and services, in order to safeguard and improve the quality of life of their citizens.

New technologies make sustainable development of municipal infrastructure and the availability of adapted services possible. Renewable energies, energy-efficient buildings, electric vehicles and new mobility concepts, flexible logistics and modern security systems are developing dynamically. New information and communications technologies are saturating and connecting all sectors and allow for the use of these technologies. The transformation of our existing cities and the development of new cities with the expectation of sustainability require a clear set of objectives, a long-term plan and the continual implementation of a plethora of projects addressing parts of the solution. Intelligent steering of the processes and active participation of the citizens in the conceptualization of solutions, that is to say, mature governance, are conditions for successful implementation.

Within the motto »Morgenstadt – City of the Future«, the Fraunhofer Organization focuses on the development of technological solutions for future-compatible, sustainable cities. Of the 60 Fraunhofer-Institutes which conduct applied research in different areas, 14 institutes compose a network for the development of sustainable cities. The institutes contribute high quality competencies in their individual fields, and work together in an inter-disciplinary manner.

From May 2012 until October 2013, 12 Fraunhofer-Institutes have conducted the project »Morgenstadt: City Insights« together with 30 industrial businesses and cities, with the goal of creating an inventory of good solutions for sustainable cities. Towards this end, a catalogue of inspiring cities world-wide was created and the following six cities were selected for in-depth study: Freiburg, Berlin, Copenhagen, New York, Singapore and Tokyo. A team of Fraunhofer researchers went to each of these cities, and through the use of interviews, discussions, and site visits they studied spear-heading projects and solution approaches. The goal was to find out how the example projects were initiated, conceptualized and implement, how successful they are, what success factors can be identified and what actors are involved. In addition, the goal was to determine under which conditions these solution approaches could be transferred to other cities.

Copenhagen has repeatedly been recognized as one of the cities with the best quality of life. Green growth and quality of life are the two main elements in Copenhagen's vision for the future. Copenhagen shall be a leading green lab for sustainable urban solutions. These facts formed the base for choosing Copenhagen as a city to be studied. This report describes the results of the on-site research which took place in Copenhagen in March 2013.

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City of the Future

INNOVATION NETWORK

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City Report - Copenhagen







City Team Leadership

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General Findings

When it comes to environmental achievements, Copenhagen has a clear vision and a mission to fulfil until 2025. Besides reducing climate impacts by aiming for a 100% renewable energy supply, the quality of urban living (»liveability«) is essential to the city's marketing strategy and is also implemented in many projects and appreciated by the citizens. Simultaneously, the city's prosperous industry has, over the past years, aligned itself to the changing international market and now focusses on services and trading instead of production. However, it is still dependent on growth. Therefore, the triangle between the following three items seems to be crucial for the city's orientation:

Business Innovation and Governance

A systematic urban planning approach: In Copenhagen, a huge variety of different visions, strategies, guidelines, and plans focus on sustainability from the three different perspectives (see triangle above). They can be legally binding, like the municipal masterplan, or be voluntarily introduced by the City of Copenhagen, such as a sustainability focused masterplan – the Climate Plan CPH 2025. It has been observed that Copenhagens' requirements for such plans are generally higher than the legal requirements, regardless of whether the documents are used on a strategic level or on an operational level. In some cases the goals are described in an abstract way (concerning strategic documents for long-term planning) while in others they may be very concrete (e.g. in the project implementation phase).

Therefore, the City of Copenhagen has developed a structured planning approach: the »Sustainability Tool« systematically accompanies the planning process and includes binding requirements and targets – the so-called 14 considerations – for new urban development projects that span more than 50,000 m².

The early integration of the relevant stakeholders within the planning and decision making process can be described as another most relevant success factor for the »Copenhagen Model«. Participation with more of the municipal administration departments, industry, knowledge institutions and citizens is needed, especially in order to ensure acceptance and also to finance projects that – once effectively carried out – are meant to make Copenhagen the worlds' first carbon neutral Capital.

Critical success factors for sustainability-driven initiatives are furthermore:

- strong political support with individual budgets for initiatives as well as a – relatively long-term – stable political system within the municipality
- acceptance by the citizens and companies, which can be achieved by a (pro-)active and integrative approach to communication.

Growth in Copenhagen: since the measures needed to reach the sustainability focused goals are very cost intensive, Copenhagen can only achieve these goals by increasing its number of inhabitants and companies.

Population growth: The entire sustainability concept in Copenhagen is based on long-term, and stable, population growth. In the past five years (as of 2013) the population of Copenhagen has constantly grown by 1,000 individuals per month, whereby this growth is a result of increasing birth rates, but also of immigration of young people and families to Copenhagen.

Green growth: Copenhagen realized that the only way to counter external influences and framework conditions, like the migration of producing industries to rural areas, is to re-focus on new kinds of business models.

- There is a growing need for new, integrated approaches and solutions – including different (service and industry) branches as well as different kinds of companies in size and structure. Such an innovative and integrated approach can only be realized through the joint utilization of potentials within the municipality, the producing industry and service providers.
- Furthermore, in order to attract new investors and innovative, companies (entrepreneurs, SME or big players), it is crucial for Copenhagen to create an open and innovative business environment. This must include a non-complex, cooperative financing concept like Public Private Partnerships (in order to minimize the risks for all parties) as well as the highest possible reduction of bureaucratic obstacles.

Oftentimes a business case is the foundation and the result of an investment project (exceeding a certain size) and the city is used as a test bed for new technologies and integrated solutions.

In order to generate these novel approaches, the City of Copenhagen actively supports networking between stakeholders through the maintenance of a business platform, the »Green Growth Network«, and the planning of events.

Key success factors are cultural preconditions, such as an open and friendly communication culture and regional location factors like the Öresund bridge connecting Denmark (Copenhagen) and Sweden (Malmö). Provided they are shown to be successful, the overall aim is to export and transfer the Copenhagen solutions to other cities.

Energy

Wind Energy: Generating energy on site is an important factor for a sustainable energy system within city limits. However, cities are large scale energy consumers and renewable energy sources are not easy to find and exploit on city grounds and it is often difficult to integrate them into existing structures.

Integrating large facilities such as wind turbines into the city landscape often provokes negative reactions from the citizens. In order to identify the most acceptable compromises for all parties involved, very well-structured communication and participation processes were used during the implementation of the Middelgrunden wind farm presented in this report. It was found that if citizens are involved in the financing and operations of such facilities, a higher level of acceptance can be achieved.

District Heating (DH) is a very mature and robust technology. The growth of DH systems in Copenhagen has been largely supported by legislation which defines limits and reasonable cost for the users as well as the structure of the companies. These comprehensive settings have been accepted by the citizens to such an extent that DH is now viewed as a mandatory public service, comparable to drinking water or sewage removal.

Access to the energy market, electricity and heating, has been liberalized during the past decade, according to European directives. In principal, everybody can provide renewable energies to the grids if the technical requirements are given. In reality, however, only very few private providers of renewable electricity are producing electrical energy in Copenhagen. Only few prototypes of solar thermal heat provision to the DH in Copenhagen are currently in a test phase. Cityscape legislation and the lack of availability of suitable areas for PV or thermal collectors handicap private and public initiatives. Less dense areas provide more possibilities for implementing renewable energies and this is being discussed further for the outskirts of the Greater Copenhagen area.

The **reduction of CO_2** emissions is largely driven by efficiency measures implemented by energy producers and grid optimisation as well as convincing end users to optimize systems and habits. Replacing all non-renewable fuels with renewable energies requires interaction with the surrounding areas and countries. This will be the challenge of the coming years, because it is unlikely that a change of the systems to a complete use of renewable energies will occur within the city limits of Copenhagen alone.

Buildings

Copenhagen distinguishes itself from most other Northern European cities through its growing population. This leads to a demand for new buildings to be used as both housing and office space. With two large development areas since 1992 (**Ørestad and Nordhavnen**) the city is meeting this demand and has simultaneously found an economical way of financing two new metro lines: the income from the sale of the building land is used to pay for the costs of the metro. In the new districts, a strong focus is on liveability and feedback from users and other experiences gained throughout the process are used to further improve the developments.

The city requires **new public buildings** and buildings built on public ground to meet tighter energy performance requirements than those generally applicable in Denmark. The Royal Danish Playhouse, which was opened in 2008, represents a landmark building in terms of energy efficiency.

Renovations of the **existing building stock** should have in general a focus on thermal improvement of the building envelope. However, a competing priority in Copenhagen is that the city's identity be preserved. This strongly limits, for example, the possibilities for reducing thermal losses through walls via external insulation or the mounting of photovoltaic panels on the roof. The major renovations conducted since the 1990's and onwards – in the quarters in and near the city center – have mainly included the exchange of windows and the insulation of roofs. A think tank involving all major actors in the field has been launched and is currently developing strategies to help accelerate the building renovation process.

Decentralized and renewable energy use through solar thermal collectors and photovoltaic systems is not a common approach, although one of the practice examples shows a district realising a large scale photovoltaic implementation plan (Valby). The main approach for reducing CO_2 emissions created by the building sector, of which 98% of the buildings are connected to the district heating net, is therefore the generation of electricity and district heating using renewables.
The general tendency that Copenhagen's **citizens expect the municipality to solve existing and upcoming challenges** also applies to the building sector. This is supported by the well-organized communication between citizens and administration.

Mobility

Bicycling: Without a question, Copenhagen is one of the top bicycling cities in the world. Besides possessing many unique features within the city that make the city bicycle friendly, Copenhagen has managed to export its expertise in the fields of bicycle friendly urban planning and bicycling infrastructure. On the one hand, this supports the city's reputation on a strategic and political level which also fosters the tourism sector; on the other hand, it promotes the regi-

onal economy: most markedly benefitting architectural and urban planning offices, construction companies and administrative and consulting entities.

Unique bicycle-related features in Copenhagen include:

- The Super Cycle Highway, which will connect suburbs to the inner city and reduce vehicular congestion.
- The dominant modal share attributable to bicycling and the vast infrastructure, including connected services and maintenance systems.
- The on-going urban planning process which takes bicycling into consideration (e.g. including synchronised traffic lights on 20 km/h to suite cyclists).

Even in Copenhagen, the success of bicycling is seen to be influenced by circumstances (flat landscape), an existing bicycling culture, good infrastructure and a clear political agenda in support of bicycling for both ecological and liveability reasons (at least for the past five to ten years). Last but not least, bicycling is seen as the most convenient form of mobility within Copenhagen.

Intermodality: Another important lesson that can be learned in Copenhagen is the growing concept of intermodality/multi-modal transport. Many of the city's metro stations are already multimodal stations (connecting bicycles and public transport). On the s-trains (regional trains) passengers are permitted to bring their bicycles on the train for free, which reportedly lead to a significant increase in the number of customers using the trains. Also, some of the reviewed electro mobility concepts currently focus on intermodality and therefore on the final urban leg of the mobility chain.

Electro mobility: Electro mobility is a rather young industry in Denmark. Most businesses in the field of electric vehicles (EVs) in Copenhagen focus on:

- conceptual solutions (intermodality, car sharing, urban parking and charging),
- supplying and maintaining charging infrastructure and renewable energy, and
- managing procurement.

It was often stated in interviews that there was a lack of supply of German cars, since Denmark would like to see itself as a high potential EV test field for German car manufactures (small, densely populated country with existing green charging infrastructure and financial advantages through tax savings until 2015). Some of the examples analysed are looking for strong partners for their concepts.

Water

For its **water supply,** Denmark relies on groundwater resources. Copenhagen, being the most densely populated area in Denmark and experiencing a strong increase in population, is faced with the greatest challenges when it comes to supplying its citizens with high quality drinking water. Since the late 1980's, the per capita consumption of water in Copenhagen has successfully been reduced from 170 to 104 liters per day. This was achieved through a combination of measures: awareness raising campaigns, increasing the price of water, metering of water consumption, water saving installations, and the reduction of net losses. A deterioration of water quality due to longer retention times in the network has not been reported, despite the fact that chlorine is not used in Copenhagen. Until 2025, Copenhagen's consumption objective is set for 90 liters per capita and day. As a secondary source, rainwater plays a minor role in the city. The collection of rainwater from roofs and its supply to the households for toilet flushing and washing machines is regulated on the city level.

Wastewater is discharged in a combined sewer system to two large, central wastewater treatment plants. Sewage sludge is used for the generation of energy. Innovative and decentralized concepts, such as the recycling of greywater, are currently being discussed for the planned development of the Nordhavnen district.

Adaptation to climate change is currently an important topic for Denmark`s national government. In the past few years, heavy cloudbursts have hit Copenhagen, resulting in unexpected flooding of the city's infrastructure and very high damages. A Climate Adaptation Plan was approved by the City Council in 2012, focusing on measures for stormwater management. The main objective is to make the city more resilient to heavy rain events and to protect the basic infrastructure. At the same time, the measures should increase the liveability of the city through the creation of areas where the rain can be stored or discharged on the surface. Even though there are many examples of successfully implemented stormwater management solutions for districts elsewhere, Copenhagen is one of the first cities to systematically address this issue on the scale of the entire city. Processes and technologies developed within the course of this process will be transferable to other cities with similar conditions.

If **stormwater falling on roads** is discharged into surface waters, it can have a negative effect on the quality of the water. Thus far, since stormwater is discharged temporarily, and with strong variations in quality and quantity, not many suitable processes for its treatment exist. In Copenhagen, a process called Dual Porosity Filtration for the treatment of road runoff in densely populated areas with very high runoff quality has been developed during the past decade.

Production & Logistics

Copenhagen has an ambitious goal: becoming carbon neutral by 2025. At the same time growth, employment and quality of life for the citizens are important goals for the City of Copenhagen. The City of Copenhagen successfully combines these objectives. Through the development into an environmentally friendly city, in which **new solutions for green technologies** are tested and used, **green growth** is triggered. Such green investment will not only help to reduce carbon emissions it will also create jobs. The City of Copenhagen is working together with different partners, such as private companies and organizations, research and education institutes, and public authorities to promote green growth. Today, Denmark and the City of Copenhagen have a strong cleantech and green enterprises industry.

Cluster organizations like the Copenhagen Cleantech Cluster are important for green growth. The Copenhagen Cleantech Cluster is a member-based public, non-profit association, which brings together the most significant actors from within the Danish cleantech industry. Cleantech industry is referring to enterprises related to green energy and environmental technologies. In the period 2004-2009 cleantech enterprises in the Greater Copenhagen area grew by 55%. In the same time the manufacturing industry grew only by 8%. Cleantech enterprises contribute significantly to the economy.

A very important lesson that can be learned in Copenhagen is the strong commitment of the city administration to actively use new green technologies in the city itself and thus, to serve as a **living lab**. In this way Copenhagen induces innovation, growth, and development in the cleantech industry which supplies products and consulting serves to reduce pollution and resource consumption. A potentially negative aspect of this development is an ongoing retreat of manufacturing industry out of the city, and possibly Denmark, with a simultaneous biased focus on the tertiary sector.

Security

Both strategically and operationally, Copenhagen is on a resolute and proactive path towards increasing the city's capacity to better withstand natural disasters. Its general exposure to and the most recent experience with numerous extreme weather events resulting in massive economic damage and infrastructural losses has lead city officials in Copenhagen to place long-term resilience planning at the heart of the ambitious Copenhagen Climate Adaptation Plan. Uniquely, the city has a clear strategy that includes technical, organizational as well as financial means and ends to better prepare the city for and enable its citizens and infrastructure to react to any adverse event. Especially when approaching large urban development projects – the Nordhavnen district is currently the most prominent example – the city will increasingly ensure the integration and implementation of resilience aspects into the full spectrum of both the design and planning processes. This includes:

- Comprehensive scenario development and planning, which is mandatory for all involved planners and architects and is to be reviewed and approved by the first responder community.
- The application of software-based vulnerability identification tools allowing the city to create comprehensive risk maps with which to inform citizens and the responder communities in order to improve the protection of those areas most affected.
- Emergency response planning that ensures the involvement of not only the respective responder communities and police forces, but also directly includes key officials on the administrative level, who jointly plan for and manage crisis situations together with the responder communities.

Aside from these long-term strategic measures, which will eventually translate into physical protection solutions for tackling the challenges posed by extreme weather events, the more operational efforts to address public safety and security challenges in Copenhagen focus on a broad span of activities, such as:

- Systematically identifying weak spots within the city regarding terrorist attack scenarios. Once completed, prioritized infrastructure and hot spots will be upgraded/reshaped.
- Strong engagement of the security community with citizens and socially organized groups in troubled areas in order to support crime prevention.
- Creating institutionalized bodies within city administration where the police, city officials and civic groups jointly monitor problematic areas and develop concepts to improve the security in troubled areas.

Undoubtedly, improving the protection of the city against natural disasters will be the top priority on the city's security and resilience agenda in the foreseeable future.

LIST OF ABBREVIATIONS

BEMS	Building Energy Management System
BIG	Bjarke Ingels Group
BIG	Business Innovation and Governance
B2B	Business to Business
B2P	Business to private
CBD	Center for Urban Design
CCMP	Cloudburst Management Plan
CHP	Combined Heat and Power
CPH	Copenhagen
CRM	Control, Regulation, and Monitoring
CTR	Metropolitan Copenhagen Heating Transmission Company
DANVA	Danish Water and Waste Water Association
DH	District Heating
DHW	Domestic Hot Water
DPF	Dual Porosity Filtration
DSB	Danish State Railway
DTU	Danish Technical University
EMO	Electro Mobility Operator
EP	energy performance
ESS	European Spallation Source
EV	Electric vehicle
HOFOR	Hovestadsområdets Forsyningsselskab – Greater Copenhagen Utilities
ICN	International Cleantech Network
ICT	Information and Communications Technology
KE	Københavens Energi
KL	Kommunernes Landsforening - Danish Local Government Association
MS	Market Share
PCT	Patent Cooperation Treaty
PJ	Peta Joule
PLUSnet	Concept for 2025 to ensure a high level of quality for chosen urban bicycle lanes, Super Cycle Highways, and restructured routes of hightly frequented, often congested bicycle lanes.
PV	Photovoltaics
RE	Renewable Energy
SBi	Danish Building Research Institute
SUDS	Sustainable Urban Drainage Systems
Super Cycle Highway	Bicycle Highway to connect the suburbs with the inner city
s-train	Regional train
TMU	Teknik-og Miljoidvalget
VEKS	Vestegnens Kraftvarmeselskab i/S

LIST OF FIGURES

1 GENERAL INFORMATION

1.1 »M:CI« – CITY RESEARCH IN COPENHAGEN

The six cities studied within »m:ci« were chosen after a rigorous selection process. Several international sustainable cities rankings were utilized and innovative projects and solution approaches were identified and analyzed. This was the basis for selecting, together with the companies and cities involved in »m:ci«, the six cities which provided innovative and inspiring solutions in different technological sectors, located on different parts of the planet and demonstrating different climatic and other framework conditions.

Copenhagen has repeatedly been recognized as one of the cities with the highest quality of life. Green growth and quality of life are the two main elements in Copenhagen's vision for the future. Copenhagen will be a leading green lab for sustainable urban solutions. These facts formed the basis for choosing Copenhagen as a city to be studied. The other cities analyzed are Freiburg, Berlin, New York, Singapore, and Tokyo.

All selected cities demonstrate interesting and trail-blazing projects and solution approaches for improving sustainability. Each of the cities, however, has a different strong-point in relation to the sectors studied in »m:ci«. These sectors are: governance and business innovation (BIG), energy, buildings, mobility, water, production and logistics, security, information and communications technologies (ICT).

The six cities selected belong to the world-wide most inspiring cities with interesting and trail-blazing projects and solution approaches in the area of sustainability. However, this selection is not meant to suggest any judgment regarding the value of many other cities which also belong in this classification, but which were not studied.

1.2 OBJECTIVES

It is quite difficult to compare cities in terms of their sustainability and their projects designed to increase sustainability, since there is no uniform catalogue of criteria and because the framework conditions in each city are different. This brings up the question of whether it is even possible to learn from the experiences of individual cities.

»m:ci« works with the assumption that although a city with sustainability-oriented projects and approaches is reacting to specific problems – using resources locally available – and is implementing its project under local framework conditions, the main challenges addressed are, nevertheless, comparable in many cities world-wide and the projects are planned and implemented according to similar patterns. The objectives of »m:ci« are, therefore, to understand the activities within the individual cities, to identify the specific framework conditions present, and to recognize the patterns within the activities.

Thus, the »m:ci« research visits have the following objectives:

- Analyze the selected practice examples in relation to motivation, conception, planning, implementation success and the measurement of success.
- Identify key drivers and framework conditions which have affected the projects and solution approaches either positively or negatively.
- Analyze the network of actors and their roles within the studied projects and solution approaches.
- Discuss the transferability of projects and solution approaches to other cities.

1.3 SECTORS STUDIED

The criterion of sustainability permeates all dimensions and aspects of a city and can therefore never be wholly captured. A research project on sustainability must, therefore, always concentrate on a specific area. Seven sectors which are strongly characterized by technological solutions were identified within the »m:ci« project, and the business innovation and governance sector was included additionally, as it is also considered important for the successful conception, planning, and implementation of projects designed to increase sustainability.

The following eight sectors are thus analyzed in this study and include the following aspects:

Energy
Import, creation, distribution and use of electricity, heating/cooling, gas und fuel.

Buildings
Energy-efficiency, comfort, holistic balance of all building styles within a city, buildings and public space, resource efficiency and recyclability of materials used.

Mobility
Range of available mobility options, modal-split, energy use, area requirements, emissions, use of public space.

Water
Water supply and disposal, water quality, reliability of supply, rainwater drainage, energy use.

Production & Logistics
Production in the city, distribution of goods to stores and to consumers, induced traffic volume and emissions.

Security
Security of public spaces and in buildings against vandalism, crime rate, terrorist attacks, security in relation to natural disasters.

ICT – Information and Communications Technology
City administration data, electronic availability of city services, information options in public spaces, ICT-infrastructure, ICT applied for intelligent steering and user-friendly options in the areas of energy, mobility etc.

BIG – Business Innovation and Governance
Policy and administration structures as well as methods and concepts applied to determine objectives, conception, decision-making, planning and implementation of solution approaches and projects aimed at increasing sustainability in relation to the initiation, organization, steering and evaluation of processes and projects, active participation of citizens and all relevant city actors, city development and planning as regards its linkage with politics and administration.

In Copenhagen, the sectors energy, buildings, mobility, water, production & logistics, security, and BIG were studied.

1.4 RESEARCH APPROACH

The two-week research stay between March 18 and 29, 2013 was conceptualized as follows:

City support
In advance, the lord mayor was informed about the research stay.

Indicators
15-65 indicators were identified for each sector, and the data associated with these indicators was studied in advance of the research stay.

Practice examples
The researchers identified interesting practice examples in their individual sectors, in advance, which were then studied during the visit. Data and information on the examples was collected and analyzed.

Interviews
Relevant actors within each practice example were identified, and interview appointments were made for within the research stay period. The interviews, typically 1.5h in duration, were conducted on the basis of a standardized guideline, which was adapted to each interview. The interviews were recorded, when permitted, and later analyzed.

Viewings
The practice examples were, whenever possible, viewed or visited, in order to gain a personal impression of the project.

Round Table
On the first day of the research-stay, a round table event was held. City Architect Tina Saaby Madsen presented an overview of highlights regarding sustainability in Copenhagen, and the research team presented itself in front of various members of the city administration and other important stakeholders in Copenhagen.

Morgenstadt Lab
During the 'lab' on the first Friday of the research stay, the researchers and city representatives discussed – following a defined method – several hypotheses relating to the practice examples in Copenhagen. The hypotheses had been developed by the researchers and were based on the interviews conducted within the first week. The discussions served to recognize the patterns inherent in the implementation of projects and solution approaches in Copenhagen.

1.5 CITY TEAM COPENHAGEN

The research was conducted by the following Fraunhofer researchers during the research stay:

Sector	Researcher
BIG	Andrea Rößner, IAO
Energy	Arnulf Dinkel, ISE
Buildings	Heike Erhorn-Kluttig, IBP Hans Erhorn, IBP
Mobility	Dominik Noeren, ISE
Water	Marius Mohr, IGB (City Team Leader)
Production & Logistics	Sylvia Wahren, IPA
Security	Daniel Hiller, EMI

The following Fraunhofer institutes were involved:

IAO	Fraunhofer Institute for Industrial Engineering, Stuttgart
IBP	Fraunhofer Institute for Building Physics, Stuttgart
IGB	Fraunhofer Institute for Interfacial Engineering and Biotechnology, Stuttgart
IPA	Fraunhofer Institute for Manufacturing Engineering and Automation, Stuttgart
ISE	Fraunhofer Institute for Solar Energy Systems, Freiburg
EMI	Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, Freiburg

2

2 COPENHAGEN – AN OVERVIEW

2.1 COPENHAGEN AND ITS HISTORICAL DEVELOPMENT

Declared as the Danish capital in the mid-fifteenth century, Copenhagen has long had an important political and economic position in Denmark (Copenhagen Visitor Centre 2013). The shape of present suburban Copenhagen (Copenhagen metropolitan area) was strongly influenced by a city traffic development plan dating back to 1947. This so called Fingerplanen (five finger plan) shaped the Copenhagen metropolitan area into the form of a hand (palm is Copenhagen city) since the metropolitan area was designed to be developed along five 'fingers', when it comes to new buildings and infrastructure such as the s-train lines (see chapter 2.5) (Cahasan; Clark 2006). In the spaces between the fingers, green wedges were created to provide recreational and agricultural areas.

Sustainability in Copenhagen is not a recent trend, but rather a process dating back to the 1970's. In those days, Copenhagen was faced with decreasing groundwater levels, which led to new measures in water efficiency implemented in the 1980's. The oil crisis of 1973 and 1974 led to a strong shift away from fossil fuel solutions. In 1975, a nuclear power plant in Barsebäck, a Swedish town located 20 km in the north-east of Copenhagen, was completed. With the introduction of an energy tax in 1977, Copenhagen undertook a change towards energy efficient solutions. The DH systems were enhanced in 1979, following a change in the legal regulations governing heat supply. Since Denmark has few natural resources and labour costs are high, the harbour industry experienced difficulties competing internationally, and declined drastically in the 1980's. This created large, unused urban spaces (City of Copenhagen und Danish Ministry of the Environment 2008). Also during the 1980's, areas previously used by the military became available, allowing Copenhagen to acquire new development areas. Simultaneously, the »Copenhagen heating plan« was integrated into the municipality's public infrastructure.

Mayor Jens Kramer Mikelsen, who took office in 1989, had a strong influence on the city by leading Copenhagen out of its economic crisis. In the 1990's, Copenhagen's DH and power supply were made more efficient and a higher ratio of RE was integrated. Past investments and consistent regulations in DH systems are now bearing fruits: 98% of Copenhagen's buildings were using DH as a heat supply in 2013 (City of Copenhagen 2009). The development of a new district named »Ørestad« was approved in 1992. In 1996, Copenhagen was nominated the European cultural capital, evoking a building boom in the city.

The City of Copenhagen reacted promptly to these developments by taking advantage of the geographic position of the city in an innovative manner. Being surrounded by long coast lines, Copenhagen has the conditions necessary for creating wind energy. Furthermore, the EU directive »Directive 96/92/EC« (of the European Parliament and of the Council of 19 December 1996) led to the deregulation of the electricity market (Bier 1999). Thus, a wind park named Middlegrunden – with a total capacity of 40 MW – was installed on Copenhagen's coastline in 2000 (Sørensen et al. 2002). Through a unique financing concept, the investment is shared 50/50 by the municipality and the citizens, who act as shareholders (Global Site Plans 2012). Public projects such as this demonstrate Copenhagen's current role as a technological test field.

The Øresund Bridge between Malmö and Copenhagen was completed in 2000 (Falbe-Hansen; Nissen 2000) and in the following years, the transfer of both jobs and goods between Sweden and Denmark increased. Since then, Copenhagen has become increasingly economically and socially integrated with Malmö and the surrounding Swedish cities (especially Lund with its University and the future European Spallation Source – ESS). This combined metropolitan area is referred to as the Øresund Region. In 2002, the opening of the first public harbour bath in the center of the town improved the quality of life for Copenhageners and increased the attractiveness of the city for tourists. During the same year, Copenhagen was able to enhance mobility within the inner city by opening the first Metro lines, 1 and 2. The decision to develop the »Nordhavnen« (Northharbour) area was made in 2005. The plans for this new development area were able to withstand the building crisis in 2007/2008.

The year 2009 was an important year for Copenhagen's transformation towards sustainability: the Copenhagen »CPH 2025 Climate Plan« (see chapter 3) was approved and the World Climate Conference was held in Copenhagen.

In 2010, Frank Jensen, the successor of Jens Kramer Mikelsen (from the same political party, the social democrats), was elected as the new Mayor of Copenhagen. In 2011, the national government introduced the »Energy Strategy 2050«. Major cloudbursts in the same year demonstrated the vulnerability of the city to extreme weather events, after which the »Climate Adaptation Plan« was adopted. As a result of these events, sustainability issues became a top priority on the city agenda.

2.2 POPULATION STRUCTURE, ECONOMY, EDUCATION, AND SOCIAL ASPECTS

The City of Copenhagen is the largest municipality in the Kingdom of Denmark (Kongeriget Danmark). With its 549,000 inhabitants (as of 2012) it contains almost 10% of the entire Danish population and is part of the:

- Urban area around Copenhagen with about 1.2 million inhabitants (Ministry of Foreign Affairs of Denmark 2013).
- Capital Region of Denmark that is – since the Local Government Reform from 2007 – with around 1.7 million inhabitants the biggest of the five administration regions in Denmark (Region Hovedstaden 2012).
- Øresund Region, an economically important region including parts of southern Sweden, whose population reaches about 3.7 million inhabitants (Øresund Region 2010).

In figure 1, the population and its density (in pers/km^2) in each of the regions is shown (as of 2012).

Copenhagen's population grew by around 9.1% during the past ten years (from 2002 to 2012). Since the year 2007, the number of Copenhageners has consistently increased by approx. 1,000 persons per month. With a population of 500,531 inhabitants in 2002 and 549,050 in 2012 (City of Copenhagen 2013), the population of Copenhagen is estimated to grow to over 650,000 persons in 2025 (City of Copenhagen 2013).

Reasons for the increase in population include an increase in the birth rate, but also the immigration of young people and families to Copenhagen. The city's current population structure (as of 2012) consists of 77.8% Danish people, 7.5% immigrants and descendants from western countries and 14.6% immigrants and descendants from non-western countries (City of Copenhagen 2013).

As a result of these developments, the city's built structure will need to be adapted to the population increase, as new homes will be required each year. This is generally perceived as an opportunity to increase public and private investments in Copenhagen. Also, in response to the challenges of population growth, the City of Copenhagen has included urban development issues in its overall development plan (City of Copenhagen 2012c).

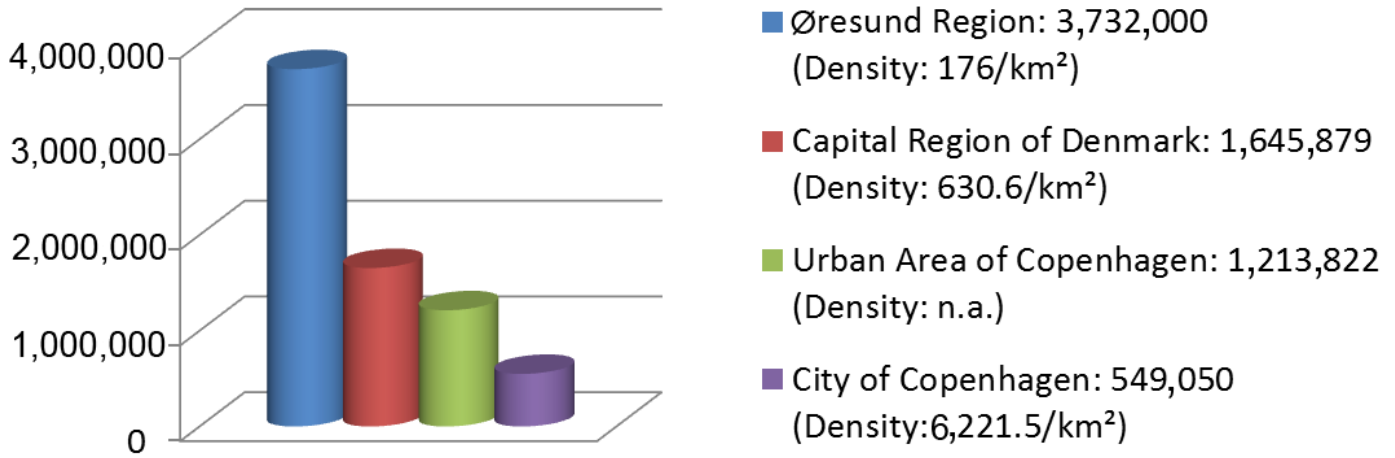


Figure 1: Characteristics of the different regions around Copenhagen in terms of population size and density (Øresund Region 2010; Ministry of Foreign Affairs of Denmark 2011; DAC 2012)

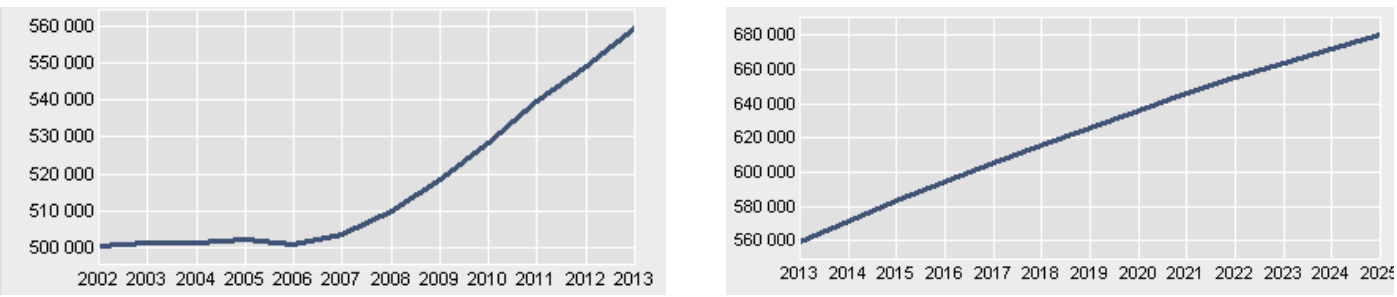


Figure 2: Overview of the population in Copenhagen (Population figures from the censuses and population projections 2013 by municipality, sex, and age; Danmarks Statistik 2013)

Economy
Copenhagen is the economic and financial center of Denmark and a strong economic region in Northern Europe. After steady growth, its per capita GDP was EUR 43,842 in 2012 (compared to EUR 34,309 in 2002, EUR 23,555 in 1992 and EUR 12,890 in 1982) (Danmarks Statistik 2013). With the completion of the bridge in the Øresund strait, linking Copenhagen with Malmö in July 2000, Copenhagen enhanced its geostrategic strength as Northern Europe's center and an important transit city, connecting the northern countries with the rest of Europe (Falbe-Hansen und Nissen 2000).

The Øresund Region, a strong economic network, is governed by the »inter-governmental Nordic Council of Ministers« and the Øresund Committee, which consists of local officials from both countries and has existed since 1993. The success of the new cross-border region can be seen in the estimated number of commuters (13,000 as of 2009) crossing the Øresund-bridge every day (City Mayors 2011). Plans to connect the Øresund Region to Hamburg using the so-called Femern link (Norddeutscher Rundfunk 2013) are meant to lead to a great expansion of the trading area. As estimated more than ten million people would form part of this economic region (City of Copenhagen 2012c). Thus, the region around the City of Copenhagen is the only Danish region which provides access to a whole European city system. With no other region in Denmark able to compete in this regard, Copenhagen is both the forerunner and test bed concerning nationwide programs and technologies (COMET-Project 2004). Furthermore, the inhabitants of Copenhagen are considered comparatively well-educated (Danmarks Statistik 2012).

In 2009, the labour market in Copenhagen was comprised of a total of 350,664 workplaces. The largest portion (17.72%) of these jobs were located in the »real estate activities and other services« sector, followed by the »human health and social work« sector at 15.37% and the »transport and communications« sector at 15.25%. Additionally, the following sectors also held a significant share of the total jobs: »wholesale and retail trade« at 10.49%, »public administration, defense/compulsory social security« at 9.99% and »arts, recreation, extraterritorial org. etc.« at 7.47%. It is worth noting that the public administration, which contributes almost 10% of all workplaces, is an important employer in Copenhagen. However, the primary »agriculture, forestry, fishing and quarrying« sector provided only 0.18% of the total number of workplaces in 2009 (City of Copenhagen 2013). These numbers demonstrate that the economy in Copenhagen is mainly service-based. While the service sector plays a crucial role in Copenhagen's economy, the primary and the secondary production sectors are underrepresented. The cleantech sector is another important part of the economic structure in Copenhagen. As the driving economic force in the city, green industries generated a turnover of more than EUR 30 billion in 2010. The Copenhagen Clean Tech Park is comprised of more than 610 companies and, in 2010, approx. 34,000 people were employed in the cleantech sector (OECD 2012).

2.3 ENERGY IN COPENHAGEN AND DENMARK

The energy market in Copenhagen is only a small part of the total Danish energy market. However, of the approximately 5.5 million people living in Denmark, 1.2 million people are located in the greater Copenhagen area (the Hovedstadsområdet). The management and organization of the national energy market has a huge influence on Copenhagen and vice versa. Since Denmark plays a role in connecting the northern with the central European market, energy policy is strongly related to the inclusion and acceptance of all relevant stakeholders and levels, ranging from customers, distributors, transmission facilities, and producers to international grid connections.

Energy Resources. Denmark's natural gas and oil fields, located in the North Sea, provide a large share of the nations total energy production (of around 887 PJ in 2011). In 2011, crude oil provided 470 PJ, natural gas provided 265 PJ, incinerating solid waste (non-renewable) provided 17 PJ and RE provided 135 PJ. Denmark's energy self-sufficiency is over 100%. The Danish territory, land and sea, is covered with concessions to explore oil, gas and wind energy. The proportion of RE consumed makes up around 22% of total energy consumption (Energi Styrelsen 2010). On a regional level, only few energy resources are available in the Copenhagen area, of which the only significant source is wind energy.

Electricity Market. In Denmark, electricity can be traded both bilaterally between generators/traders and distribution companies/consumers/traders and via the Nordic Power Exchange (Nord Pool) (Nord Pool Spot 2013).

Energy Use in Copenhagen. Copenhagen's overall consumption of electricity in 2010 was 2,510 GWh (an increase of 5% during the past five years) and its heat consumption in the same year was about 5015 GWh (City of Copenhagen 2013). This means that 5,280 kWh of heat energy and 1,340 kWh of electricity are consumed per inhabitant and year.

Energy Efficiency, Goals and a Renewable Energy Sources Target. The consumption of RE is expected to increase fairly steadily in the coming years, with one scenario depicting an increase from 146 PJ in 2009 to 216 PJ in 2020. A contribution to growth comes from the expansion of wind power, solid biomass and biofuels. The Danish Government has set a target for Denmark to use 100% RE in the energy and transport sectors by 2050 (Energi Styrelsen 2012).

In Denmark, energy taxes on electricity and oil were introduced in 1977. Since then, the taxes have been increased several times and taxes have also been placed on coal and natural gas. In 1992, these taxes were supplemented by CO_2 taxes. The promotion of energy savings and the reduction of CO_2 emissions are the main reasons for implementing the taxes which influenced efficiency measures in a positive way. From 1979 a new era with public heat planning began. The plans define in which areas the various types of heat supply should be prioritized and describe where future heat supply installations and pipelines should be located.

Efficient Electricity and District Heat Production. The development and expansion of DH systems and Combined Heat and Power (CHP) plants can be attributed to a strong political will. The use of surplus heat from large electricity plants for DH has been promoted by state subsidies (Act from 1977). During the 1980's and 1990's, many DH plants were converted to CHP production, mainly gas fuelled. This development was enabled through government-led heat planning, which established a framework for local authorities. A financial incentive to promote investment in CHP conversion was provided through an electricity generation subsidy for small-scale CHP plants. The use of biomass for electricity production and for CHP has also been supported by subsidies to small scale plants and new regulations for the large power plants to convert to biomass (before the liberalized electricity market was formed). After liberalization of the electricity market, large power plants using biomass are now supported by subsidies in the form of feed-in tariffs. Added to this is the indirect effect of energy taxes on fossil fuels for heat production, making these less attractive.

2.4 BUILDINGS IN COPENHAGEN

Copenhagen municipality includes over 47,000 buildings with nearly 300,000 residential units. The total floor area of all buildings amounts to 36 million m² with roughly 22.3 million m² of that being residential floor area. By far the highest share of this area, amounting to 90%, is located in multi-family houses, followed by single family houses with at 7%. The remaining 3% of residential floor area is located in terraced houses and similar buildings.

72% of the floor area in Copenhagen's buildings is owned by private individuals, partnerships or housing associations including freeholds flats, 11% is owned by non-profit building societies, 9% by public authorities and 8% by limited liability companies. 98% of the building stock is supplied by district heating (DH).

For new public buildings and buildings to be built on sites owned by the city, including the new development areas in the municipal master plan 2011, the city requires an energy performance (EP) standard that is one step ahead of the current national EP requirements defined in the Danish energy frame. That means, these buildings must now already adhere to the EP requirements set for 2015 (see Copenhagen's Climate Plan).

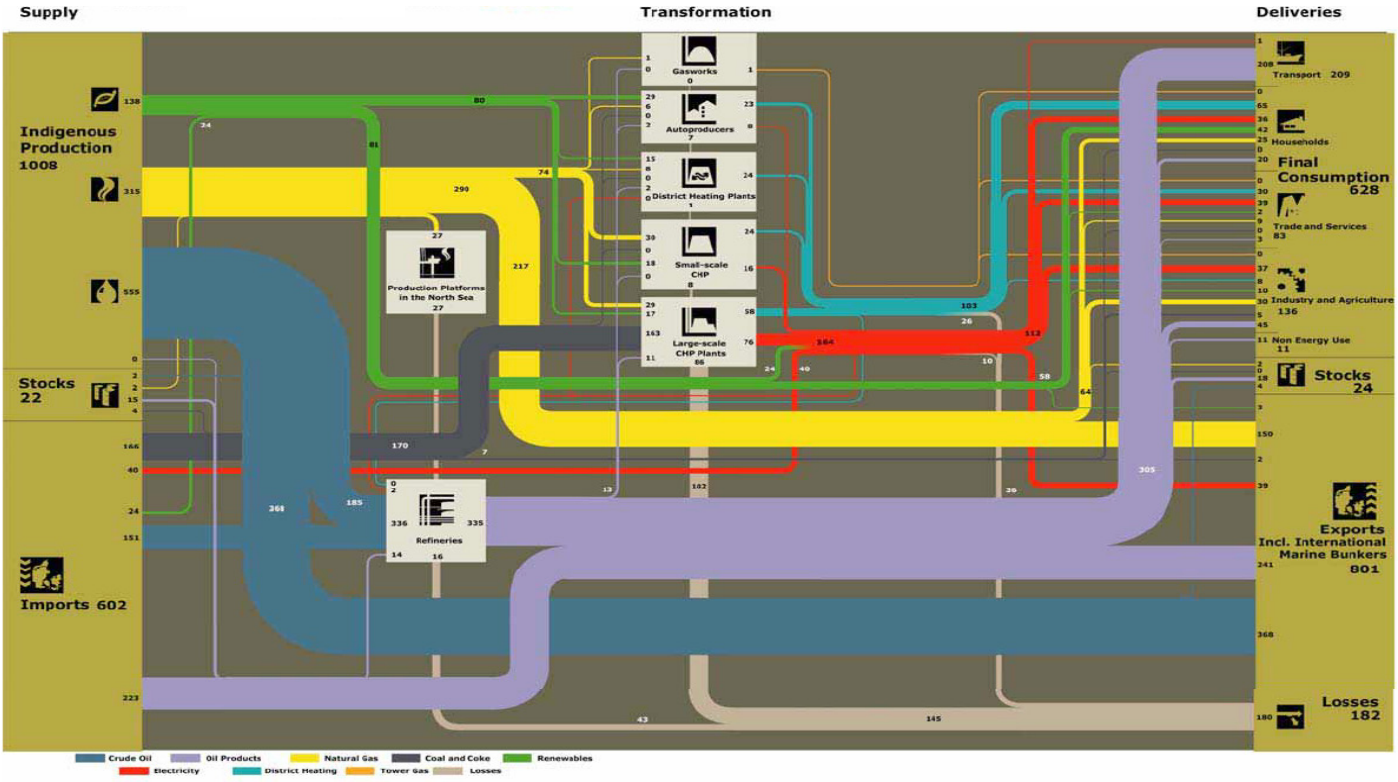


Figure 3: Danish Energy Flows in 2010. All figures are in Peta Joule (PJ) (Energi Styrelsen 2011)

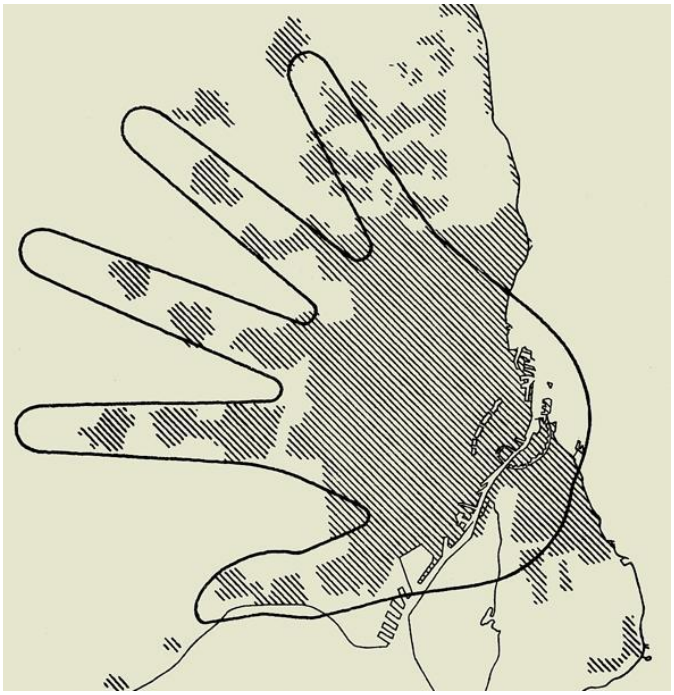


Figure 4: Five finger plan from 1947 (Danmarks Naturfredningsforening 2013)

Figure 5: S-train map of Copenhagen from 2009 (DSB 2013)

In terms of existing buildings, renovations do seem to include energy efficiency of the building envelope. However, the focus, especially in the city centre, is more on preserving the original architectural design, upgrading the residential quality and improving the social sustainability of the area through the provisioning of urban spaces suitable for meeting and relaxing in (see Copenhagen: Solutions for sustainable cities, City of Copenhagen, October 2012).

Major renovations of the quarters in and near the city centre took place in the 1990's. The Vesterbro area is a prominent example of this. Energy efficiency improvements for existing buildings focus mostly on exchanging the windows and improving the insulation of the roof. Solar collectors or pv installations can only be added if the street view of the building is not altered. Thus, the logical approach to reducing the fossil energy consumed by Copenhagen's buildings is to increase the proportion of renewable energy sources used by the city's DH and electricity network (see chapter 2.4).

Responding to Copenhagen's growing population, two large urban developments (Ørestad and Nordhavnen) have been initiated. Both consist of a mix between residential and office buildings. The development plans, their implementation and the lessons learned are described in one of the practice examples.

2.5 MOBILITY AND PUBLIC TRANSPORT IN COPENHAGEN

Copenhagen is known as a bicycling city. In fact, the city has had a vibrant bicycling culture for many decades and also provides state of the art bicycling infrastructure. In addition, an increasingly practical, attractive and powerful public transport system has been developed in the past years and will continue to be expanded until 2018 and later. According to Copenhagen's agenda, individual vehicle traffic will be reduced and combustion engines will be replaced in a step-by-step manner with eco-friendly vehicles, such as electric and hydrogen cars. Public transport also plays an important role in the Copenhagen Climate Plan (City of Copenhagen 2012a).

Copenhagen is integrated into Denmark's well-constructed, toll free, motorway system, which connects the city through bridges and tunnels with various Danish islands and the neighbouring countries of Sweden and Germany. The largest bridge – the Øresund Bridge – carries railroad and automobile traffic. It connects the city of Copenhagen to the city of Malmö on the Swedish mainland, and has been in operation since summer of 2000.

The five finger plan formed Copenhagen in the shape of a hand (see figure 4). The development started with the construction of s-train commuter rail lines along the fingers. Urban development followed this local traffic. Highways and roads were built in a ring structure, connecting the fin-

gers. The development of the Øresund Bridge added a sixth finger in the late 1990's.

Vehicular Traffic: Cars are very expensive in Denmark, since there is a tax of up to 180% of the sales price on every car sold. Parking spaces are also very limited in Copenhagen. However, many Copenhageners still have cars but use them mainly for longer distance travel when leaving the city. Together with suburban vehicular traffic, this leads to critical congestion during peak hours on the radial arterial roads leading towards the city centre. Therefore, a congestion charge around Copenhagen – similar to that in Stockholm – was discussed in 2011, but was then abandoned one year later due to a political deadlock with the suburban municipalities.

Public Transport: Public transport in Copenhagen consists of the s-train system, the Copenhagen Metro and city busses. Together, they serve more than half a million people each day. A tram may be built in the near future.

The first s-train was opened in 1934. Today, the s-train serves 357,000 passengers per day on some 170 km of dual tracks and has 84 s-train stations (see figure 5 for a s-train map of Copenhagen).

The Metro began operating between 2002 and 2007 with two lines (M1 and M2). These driverless light trains supplement the larger s-trains with a 20.5 km long rail system.

Bicycling: With a share of about 33-50% of total transport (depending on the statistics used) bicycling represents the largest mode of urban passenger transport within inner Copenhagen. Even though its bicycling culture never ceased completely, Copenhagen faced huge losses in the share of this type of mobility in the decades following World War II. The bicycling culture underwent a renaissance after massive demonstrations in the 70's, asking for improved conditions for cyclists once again. Today, bicycling in Copenhagen is considered the most reliable and convenient way of getting from A to B. Just 1% of cyclists refer to an ecological motivation for getting on their bike.

2.6 WATER IN COPENHAGEN

Copenhagen's drinking water comes from seven waterworks based in the surrounding municipalities, where groundwater is extracted. Due to the high quality of the groundwater, the treatment processes are kept simple and no chlorine is added to the water. Since the 1980's, because the groundwater resources are limited, measures have been taken to reduce the consumption of drinking water (see chapter 4.3). It is estimated that about 2% of the water consumed in Copenhagen comes from secondary sources (mainly rainwater harvesting and groundwater of secondary quality). Until 2017, this ratio is expected to increase to 4% (Københavns Kommune 2012b).

Wastewater is collected in a combined sewer system and treated in two large wastewater treatment plants, before it is discharged into the Øresund. By improving the sewer system and constructing large reservoirs for the storage of water during rainfalls, sewer overflows into the harbor have been reduced to an extent that the water in the harbor now meets quality standards for EU bathing water. In the past years, overflows have once again become more frequent due to extreme rain events (see chapter 4.4). Cloudburst events led to severe damages in Copenhagen in 2010 and 2011. Thus, measures for storm water management are currently being developed. The main objective is to uncouple large areas from the sewer system while simultaneously increasing the liveability of the city by creating more green (= planted areas that retain rainwater) and blue (= ponds and streams that retain and discharge rainwater) spaces.

2.7 PRODUCTION & LOGISTICS IN COPENHAGEN

In the past decades, especially during the 80's and 90's, the production and logistics sector in Copenhagen has gone through a major transformation. Companies formerly based in the city center, such as Carlsberg, and other heavy industry, including various harbor activities, has moved to outside the city area. A result of this development is that, today, Copenhagen has a strong tertiary industry sector. With the change of Copenhagen to a sustainable city, the local industry became very focused on environmental and life science technology. Now, Copenhagen is a center for green growth. The city has a goal of averaging 5% annual growth in GNP until 2020 (City of Copenhagen 2012b) In pursuing this goal, Copenhagen will test new green solutions, thus, the city acts as an international showcase. The different participants and their mutual relationships need to be regarded as a complex network in which the city itself takes part as an important stakeholder, shaping the relevant framework conditions and making a significant contribution, for example through control mechanisms and their own needs for individual solutions.

2.8 SECURITY IN COPENHAGEN

Among the urban security community the term 'all-hazard approach' is put on the agenda when developing new solutions to tackle the security challenges within the sustainability paradigm. Sustainable resilience must enable cities to better prepare for, react to, and recover from any kind of disruption or crisis, be it caused by powers of nature or malicious intent. Copenhagen is not known as a European hotspot for organized crime, transnational terrorism or major drug trafficking (European Commission 2012). Although the city has a strongly diverse population (ethnically, culturally, and in terms of religion) and notably he-

terogeneous city districts, neither organized crime nor acts of terror (except in unique individual areas and cases) are top priorities on the resilience agenda of the city. In view of Copenhagen's geographic position and its exposure to extreme weather events, naturally caused disasters such as storms, cloudbursts and sea floods are top priorities on the city administration's resilience agenda (Eurostat 2013).

Resilience, as the capacity to better cope with such extreme events, is interpreted as a fundamental pillar of the city's overall sustainability definition, which is absolutely unique. The most prominent proof of this holistic interpretation of resilience can be seen in the city's ambitious climate adaptation plan (see chapters 4.4 and 4.6), which, in 2012, was amended by a Cloudburst Management Plan (CCMP). Therein, Copenhagen's administration unequivocally defines clear measures and steps, linked with a significant budget, to increase the city's resilience against such events. With respect to integrating comprehensive risk management procedures into the planning of large urban developments such as Nordhavnen, Copenhagen follows a strongly integrative approach, making the involvement of all relevant stakeholders (all relevant administrative bodies of the city as well as all security relevant organizations) a prerequisite throughout all planning and implementation phases. Improving the protection of the city against natural disasters will be the dominant issue on the city's security agenda in the foreseeable future. Aside from increasing physical protection measures, there is a tremendous interest in improving the city's capacity to model and simulate the effects of both disastrous events on the one hand and the effectiveness of installed protection measures on the other. (Eurostat 2013)

2.9 SPECIAL GOVERNANCE ACTIVITIES IN COPENHAGEN: AN APPROACH TO E-GOVERNMENT

As the capital of Denmark, the City of Copenhagen has been taking measures to attain a leading position in many fields. It is thus considered a frontrunner in the development and implementation of new technologies and processes. An example is the implementation of a nation-wide digitalization program. This requires that previously personalized citizen services are increasingly provided via the internet, in the form of self-service. Four decentralized service centers for specific topics were set up in 2004 under the government of the former Lord Mayor Jens Kramer Mikkelsen. In addition, over 30 citizen services were made accessible via the internet at that time (City Mayors 2004). The basic idea behind this digitalization, which is based on a nation-wide program and was introduced by the Ministry of Finance, is to harvest the potential for cost reductions inherent in the consistent application of ICT technology. The amount of savings expected as a result of the national program, which is being launched in waves starting in 2012 is about DKK 350 million (EUR 46.937 million; US$ 62.269 million) each year until 2015 (The Copenhagen Post 2012).

In order to implement this plan, Copenhagen developed two different strategies. The first is the »Copenhagen IT strategy 2010-2014«, where the focus is on improving municipal tasks such as training the employees in issues about the use of IT and electronic communication as well as information management, IT development and quality documentation. However, the strategy also aims to train employees in IT and to make electronic communication accessible to them (Københavns Kommune 2013). The second strategy is the Service and Channel strategy named »Citizen.2015« (Københavns Kommune 2013). It was created in addition to the mandatory steps which make up the »eGovernment strategy 2011-2015« that was adopted by the Danish government (Aarhus Kommune 2013). With investments of about EUR 4 million (DKK 30 million; US$ 5.345 million) in 2010 – when the first program called »Citizen.2012« was launched – the City of Copenhagen managed to achieve cost reduction measures amounting to about three and a EUR 0.5 million (DKK 26 million; US$ 4.632 million) per year. A second budget round enabled cost cuts of more than EUR 6.5 million (DKK 50 million; US$ 8.909 million) – with an investment of the same amount. The background for the efficient implementation of this investment is an analysis of the individual usage of the various public services. Focusing on the costs of each communication method, it turns out the visit in a »citizen center« (in other words: community center) is the most expensive at about EUR 10.5 (DKK 80; US$ 14) per visit, while the use of e-solutions is the most inexpensive method, costing only about EUR 0.60 (DKK 5; US$ 0.89) per use. Digital solutions, thus, turned out to be very cost efficient. For this reason Copenhagen is planning on using 30 different solutions to digitize the communication with its citizens. Of these solutions introduced by the government, which are based on infrastructural measures such as a digital letterbox for each citizen, the first ten have been introduced since December 2012. The next ten solutions will be carried out by December 2013 and the final ten are expected to be in use by the Citizens of Copenhagen by December 2014. With this approach, municipal budgeting will be shifted from administration expenditures (»cold hands«) towards welfare services like schools or healthcare (»warm hands«) through cost savings.

Various provisions are made to move the civil user away from cost intense services and processing, such as personal handling or letters, towards more effective methods including digital formulas or standardized and autonomous e-mails. For example, nowadays it is more difficult to reach the municipality via post, while writing e-mails is promoted. Not only the City of Copenhagen, but also its citizens, benefit from the 30 mandatory e-solutions being implemented. At least 80% of the population are considered to be »digital citizens«; they are able to use the new online-based technologies for citizen services. The remaining 20%, who are expected not to use the e-solutions because of age, language, mental or other health issues,

receive support from the city. They can either continue to visit a physical citizen service bureau or they receive assisted support through a free training program to understand the digital services which are provided by the city. In order to increase the willingness and capability of the citizens to use the offered digital solutions, these are promoted in a variety of different types of media.

Communication channels include, for example, the press, radio spots and posters on bus stations. The main argument is that the use of these solutions saves time for the citizens as they avoid coming to the service centers. The shift towards the use of digital media is monitored each month and, for the period currently under review the objectives havenot only been met, they have been exceeded. This may also be influenced by the fact that the program is mandatory nation-wide. As there are no tax reductions or other monetary incentives for the citizens to join the program, it is of high importance that the e-solutions are seen as the most comfortable and easy way. A knowledge base provides guidance to the caseworkers who can advise the citizens on the phone in a structured manner. Another internet-based support system is a tool for »Co-Browsing« which makes the screen of the citizen visible for the service assistant who can thus guide the citizen through the system on a confidential level without saving the information. Not only are the citizens trained, but also the city's own personnel, including 45,000 employees in seven administration departments, are included in the promotion of the program. In 2013, altogether 3,000 courses served to transform caseworkers into digital ambassadors in order to promote the program within the municipality and to the citizens.

The link to sustainability issues can be discussed from three perspectives. Economically, the digitalization strategy leads to cost reductions and an improvement of the existing citizen services (specific citizen groups can be served in a more efficient way). Environmentally, the preservation of nature is an idea behind the digital initiatives, since reductions in paper production and transport (letters etc.) lead to less environmental damage and socially, the increased welfare services and the savings in time for individuals have to be mentioned.

The goals of the Copenhagen »Citizen.2015«-strategy are more ambitious than the nationwide digitalization strategy of Denmark. Therefore, the most effictive initiatives will be transferred to other municipalities in Denmark.

2.10 POLITICAL SYSTEM, LEGAL CIRCUMSTANCES, AND CITY PLANNING

Copenhagen is the Capital of the Kingdom of Denmark, which is a constitutional monarchy with parliamentary democracy. Therefore, it is the location of the parliament, the government and also the queen. Since the Social Democratic Party has been the leading party in Copenhagen for decades, decisions and the implementation of various initiatives are made possible or even accelerated.

2.10.1 Political Framework and Decision-Making Bodies

As is the case for each municipality in Denmark, the City of Copenhagen basically consists of a City Council: representatives of political parties. The City Council elects a mayor and forms several committees for specific topics. These political centers of decision making are supported and served by the administrative institutions which are subdivided into specialized departments. The departments are again subdivided into sectors. Figure 6 gives an overview of the political decision-making bodies in Copenhagen.

Upon first sight, the planning hierarchy seems complex. In the following paragraphs, the political and administrative systems – as well as their interdependencies – in Copenhagen will be briefly described.

City Council: The City Council is the highest political authority in Copenhagen. Chaired by the Lord Mayor, it has 55 members and provides a framework for the committee responsibilities that each mayor is leading. Within the City Council decisions concerning the overall tasks for the committees are made. Furthermore, almost all strategic plans, visions and policies are adopted by the City Council before implementation by the respective administration(s) begins.

Lord Mayor: This position describes the highest mayor of the capital city. As the other six mayors, the Lord Mayor also is responsible for the senior management of one of the committees' task areas. Since 2010, Lord Mayor Frank Jensen is responsible for the senior management of financial management (Københavns Kommune 2013). Mayors in Denmark are elected indirectly by the City Council and are incumbent for four years (LGDK 2009).

Chairman: Seven mayors – amongst them one lord mayor and six mayors, each with authority for a specific area of administrative and committee management – share responsibility for the City of Copenhagen.

Committees: The City Council selects the members of the finance committee and six additional committees where the chairman of every committee is one of the mayors. Every committee makes decisions in its field of work but the overall decisions are being made by the City Council. The committees hold meetings in which they prepare information regarding the decisions to be made by the City Council. The meetings are not open to the public. The reason for this is that the members thus have the chance to engage in a free and open debate in the conferences. However, it is possible for small groups to get an audience

at a meeting to provide the members with information (Københavns Kommune 2013).

The **Finance Committee** consists of 13 members and is in charge of »the overall coordination of local government affairs«. Its tasks include the municipality's financial planning, general planning tasks and additional tasks such as, for example, buying and selling real estate, municipal enterprises, tourism and international affairs. The Finance Committee works together closely with the Finance Administration, which is responsible for the daily administration of tasks (Københavns Kommune 2013).

Administration: As mentioned before, administrations in Copenhagen are divided into 7 sectors. The areas each administration is responsible for is described below:

- Culture and Leisure Administration: about 2,300 employees are responsible to ensure leisure and culture services for the population meet public service standards.
- Children and Youth Administration: is primarily responsible for staff law and negotiations, day-care institutions, educational and leisure time activities in schools, educational psychological advice, and health and environmental issues for children and young people as well as in youth and adult educational topics.
- Health and Social Care Administration: is responsible for public health in Copenhagen, such as nursing homes, home care units, the local senior citizens offices and adult dental care.
- Social Service Administration: is responsible for families as well as young and adult people with special needs, socially marginalised groups (dealing with drug abuse issues, homelessness, and alcoholism), as well as for the contact and co-ordination of social and disability centered tasks and internal services like organizational and staff development.
- Employment and Integration Administration: is responsible for all three job centres and all three

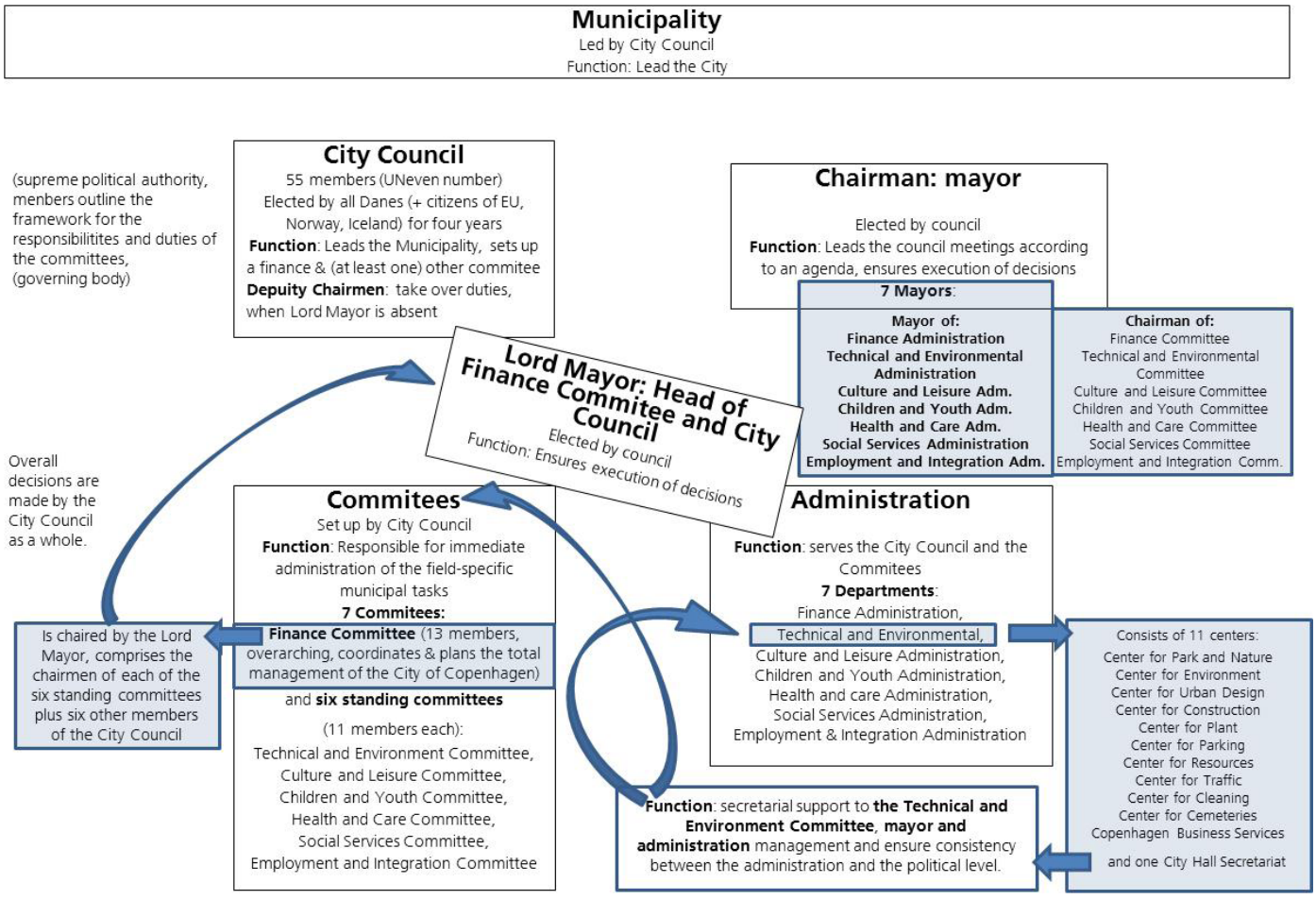


Figure 6: Planning hierarchy of the City of Copenhagen (City of Copenhagen 2013; City of Copenhagen 2013; City of Copenhagen 2013; City of Copenhagen 2013; City of Copenhagen 2013; KL 2009)

qualification-improving employment centres in Copenhagen, the centres for benefit payment and language centres for teaching Danish to adult immigrants.

From an environmental point of view two further administrations are very important in the decision making process. These are:

- Finance Administration: is tasked with the day to day administration duties and works closely with the financial committee. It is responsible for the strategic communication (within the Finance Administration and across the seven other sectors of the City of Copenhagen) of communications policy, publications and the intranet and internet contents. Organizationally, the finance administration consists of five different staff functions (Management Secretariat, Administration Secretariat, City Council Secretariat and Lord Mayors' Secretariat) and four user-oriented centers (Finance and Analysis Centre, Urban Development and Infrastructure Centre, Citizens' Service Centre and Corporate Service Centre). These centers include amongst others responsibilities for financial management tasks like the cities overall budget, the accounts, prognosis and analysis, the development of debt and liquidity as well as the monitoring of the comitees and the relations with regional, national and industrial players. Furthermore, traffic and infrastructure as well as urban development issues and the citizen services and information (digital administration, local commitees, user democracy models) and the fire and rescue service focsed on »personal injuries and damage to property and the environemt« by the fire brigade are responsibilities of the Finance Administration. (City of Copenhagen 2013; City of Copenhagen 2013; City of Copenhagen 2013)

- Technical and Environmental Administration: This administration works on urban district planning and development (building projects and urban renewal) of infrastructure (City of Copenhagen 2013), which includes a particular responsibility for the inclusion of environmental issues and urban life issues in the decision making process of project plans. As can be seen in figure 6, this administration consists of eleven different centers with various different tasks.

City Hall Secretariat: provides secretarial assistance (supports political and professional activities, ensures consistency between the administration and the political level) to the Technical Environmental Committee, the Administration of Directors and also the Lord Mayor (City of Copenhagen 2013).

2.10.2 Budget Planning

When, in 2012, the budget was negotiated and approved, about EUR 40 million were planned for activities that paint a picture about the sustainability focuse in Copenhagen, including »intelligent street lighting, transport, and solar energy projects in the city« (Copenhagen Cleantech Cluster 2013b). In September 2012, the budget plan 2013 was released by Lord Mayor Frank Jensen. The main focus was placed on schools, children and green investments. As a consequence, several schools are scheduled to be renovated and school hours are to be increased. This will cost about EUR 0.5 million (DKK 4.1 million) annually. The monetary support of lunches for about 2.000 children is another action planned. Also, the Copenhagen Climate Plan was approved, with estimated costs of over EUR 40 million (DKK 300 million; US$ 53.485 million) from 2013 to 2016. Furthermore, traffic is planned to be reduced, especially on one of the busiest streets of Copenhagen. Thereby, the conditions for cyclists, pedestrians and public transport will be improved. This activitiy is allocated with about EUR 20 million (DKK 115 million; US$ 26.740 million (The Copenhagen Post).

The reason for such a sustainability-»friendly« budget situation lies in the political past of the City of Copenhagen. In the past decades, certain political events led to positive economic development in Copenhagen, while in the 1980's the city was in a bad economic and environmental situation caused by the crisis in both the harbour and production industry. One turning point was in 1989, when Jens Kramer Mikkelsen was elected as Lord Mayor of Copenhagen. His program to overcome the crisis was based on debt-reduction, which led to cost-cutting of two percent on the spending side. Although the taxes in Copenhagen were able to be kept on the same level as national taxes, this program enabled the large scale reduction of unemployment (from 16.6% in 1994 to only 5.6% in 2003). In that same period, a consciousness about environmental issues was generated and green accounts were introduced in 1997 in order to promote environmentally focused issues in Copenhagen (City Mayors 2004).

2.10.3 Structure of Target Setting Through Plans and Processes

Urban planning tasks in Denmark are divided into national, regional, municipal and local planning activities. Although the large number of different plans, visions and policies thus generated may seem confusing at first sight, all the associated targets can be classified in a structural framework. This enables understanding of the different levels and cross-linkages of planning and implementation. It is notable that many of these targets – primarily on the municipal and local level – allow conclusions to be made about the relevance of sustainability issues for Copenhagen, since

certain keywords are often integrated into even the titles of the targets. Figure 7 gives a general impression of the structural layers and plan correlations at present (in 2013).

The highest planning level is national planning which is performed by the Government of Denmark. After every election, the Ministry of Environment creates a new National Planning Report which contains broad regional spatial development planning and municipality planning. The plan also covers special planning for the Copenhagen area. The National Planning Report is not like a written law. It is more a proposal of potential alternatives which will be debated by the Parliament (COMMIN 2008). The »National Interests« document is published every four years and provides an overview of legislation, national reviews etc.; usually they are not rejected by vetoes as they are cooperatively developed with the relevant ministries as well as the Danish Local Government Association Kommunernes Landsforening (KL) (The Agency for Spatial and Environmental 2009). Another important plan is the national planning directive, which contains binding rules on the contents of planning. It promotes specific projects and a certain direction for development. It also includes the Fingerplan, which has establishd specific rules for planning in Copenhagen. In 2007, 24 former counties were restructured into five administrative regions. These work in close cooperation with the government and the municipalities (LGDK 2009; COMMIN 2008). The municipalities in Denmark are not only responsible for municipal planning but also for the use of land. Therefore, Copenhagen's municipal planning strategy, the Municipal Plan (= communeplan), establishes frame conditions and also contains various guidelines for the quality of the environment in urban areas. Since the 1990's, the Development Plans provide objectives and requirements in form of District Plans, Local Plans, Neighborhood Plans and Action Plans. The latter are developed in cooperation with the economy focused Finance Administration and represent a basis for negotiation with the politicians on how the budget will be clustered for the following period.

The overarching plan for ecological development in Copenhagen is the Environmental Policy. It contains the goals for environmental achievement and was adopted by the City Council in 2003 (Københavns Kommune 2013).

The so called »cross cutting plans« are one level below ov-

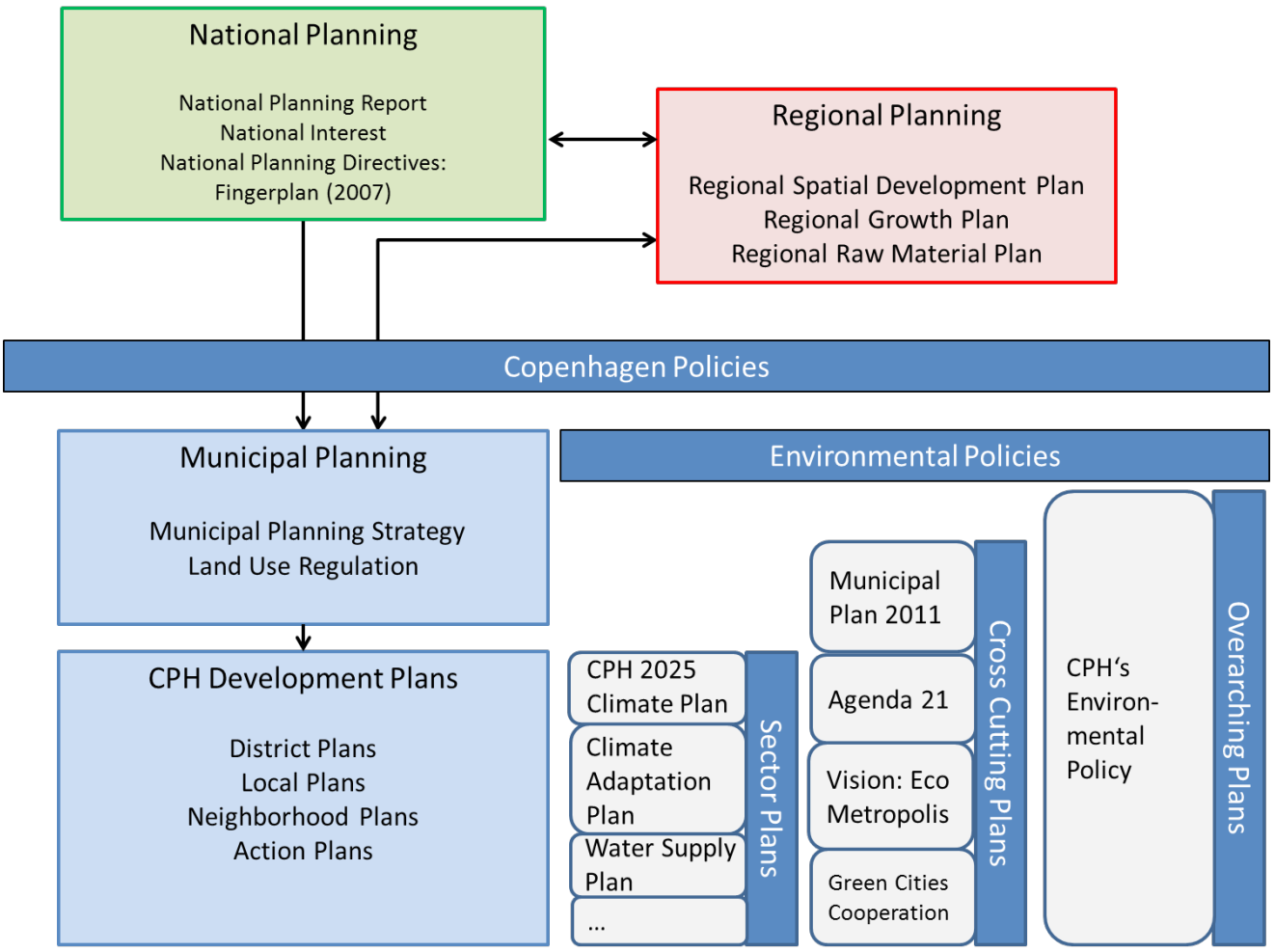


Figure 7: General overview of plans for Copenhagen (Skovbro 2007; Københavns Kommune 2013; NRPB; MLIT 2013)

erarching plans. One of these is called »Vision Copenhagen 2015« (Eco-Metropolis, adopted by the City Council in 2007) which provides 13 liveability and environmentally centered goals (partly developed in cooperation with the Swedish City Malmö) for the year 2015 (Københavns Kommune 2013; City of Copenhagen 2008).

Focusing on the »green life and quality of life« aspect, the Agenda 21 Plan contains 17 citizen-oriented activities which will be accomplished between 2012 and 2015. These activities do not have any funding in the annual budget. Their implementation is possible, however, by using synergies with other initiatives (which are included in the existing financial framework, the operating budget) and also through cross-financing concepts with funds like for example the one for the waste-management Plan 2018 (Københavns Kommune 2012a).

The next level, the Sector Plans, can be classed beneath the cross-cutting plans. At this level, the City Council has built 14 different plans. One particularly important plan is the »CPH 2025 Climate Plan« which is a holistic master plan and includes a collection of different goals in four areas: energy supply and consumption, green mobility and climate adaptation. The target is that Copenhagen will be the first CO_2 neutral city. It hopes to achieve this by 2025 (City of Copenhagen 2012a). Due to its high relevance in terms of the sustainable development of Copenhagen, this plan will be further described in chapter 3.

To protect the city from harm caused by climate change the municipality created a Climate Adaption Plan, which was adopted in 2011. Another sectoral plan is the Water Supply Plan 2012, regulating the assurance of high quality drinking water and how to conserve water resources (Københavns Kommune 2013). The remaining ten plans are all focused on a certain area and describe tasks which must be performed in the specific sectors in order to reach the city's overall goal to be the first crabon neutral capital worldwide in 2025.To sum up, urban development planning in the City of Copenhagen, which is nowadays strongly related to sustainability targets, is arranged in a multi-layered structure. Also, in terms of content, this structure continues to be used, as can be seen in the following (Personal Interview with City Archtitect, City of Copenhagen 2013):

1. **Higher level**: The main targets for urban development appear as key-words such as carbon neutrality, quality of life and green growth in the overall Municipal Plan, the CPH 2025 Climate Plan or the urban life vision »A Metropolis for People« (The municipality of Copenhagen, Technical and Environmental Administration 2011). These strategies apply to different areas within the city and all local plans must connect to them.

2. **Medium level**: The more specific plans and strategies contain the definitions of the overall targets, such as, for example, city life or good climate. Typically, they focus on a particular area and their main duty is to create coherence with the development projects.

3. **Focused level**: The most specific objectives or requirements are the definitions for a range of about five to seven projects at any time. Mostly based on action plans, these detailed descriptions of the goals and benefits focus on neighbourhood improvement.

Although the structure appears logical in this overview, the correlations are complex in reality. Frequently, different administrative departments and actors are involved in all levels of strategic and operative city planning, not least because the City Administration of Copenhagen constitutes 10% of the population. According to our interview partners from the City Administration of Copenhagen, this sometimes »chaos-driven« and bottom-up way of working together is not perceived as a barrier or challenge. Rather, this cooperative approach is seen as an opportunity to let new ideas arise and thus to create synergies. This may be attributable to the basically open Danish cultural background, however, such a cooperative mindset was not always the case in Copenhagen.

The first international ideas-transfer only became possible in the 1990's – in the field of City Architecture and Planning – when, in 1996, Dutch Architects were invited to provide some inspiration for Copenhagen. The results were positive and lessons learned included, for example, experiences related to diversity within the city. Thereafter, different networks were built up, such as, for example, a city architects network or a network of all mayors in the Nordic countries with regular biannual meetings. The aim is to discuss policies and strategies on an international level without being bound formally in a partnership agreement. Another example is a long lasting working group headed by Dr. Anne Skovbro, the Director of Planning & Development in the City of Copenhagen, which focuses on the Öresund region (Personal Interview with City Archtitect, City of Copenhagen 2013).

In that concern, citizens and other groups of stakeholders including politicians, investors or experts are considered inspirations, indicators for needs and also a necessary part of carrying out projects. Mostly, they are invited to give feedback in the early stages of project-related decision-making. The decision-making process in Copenhagen can, thus, be systematically portrayed as in figure 8.

In general, first strategic papers are prepared by the respective administration of Copenhagen. Once the City has invested some resources in a top-down-planning-process, the bottom-up-process can be initiated by the stakeholders.

In a second step, additional ideas and feedback are collected, for example, from the citizens. Often, the dilemma for the City of Copenhagen lies in the trade-off between planning and building up the projects independently and

Figure 8: Copenhagen's decision-making process (own graphic based on personal interview with city archtitect, City of Copenhagen 2013)

preparing the conditions to increase private initiatives. A top-down planning framework is often necessary in order not to overburden civil initiatives with the organization of big projects.

In the end of this process, the solution will be approved (for example by a feasibility study) by additional stakeholders. Those projects which are initiated by the municipality but then keep »working« through the citizens and other stakeholders are perceived as a successful result of this idealistic, cooperative urban planning process.

Such a top-down- and bottom-up-structured planning process can be exemplified by a local plan development process. Basically, four phases must be navigated until the final local plan is approved:

1. **Cooperation**: The actor who wants to change the cityscape (for example by building a new building), must provide a proposal to the developers for urban design (Center for Urban Design, CBD) within the City of Copenhagen. There, the proposal will be reviewed in terms of how it fits with Copenhagen's overall development strategy. In the case of concordance, both parties sign a cooperation agreement.

2. **Start Statement**: the CBD prepares a start statement and meanwhile the Technical and Environmental Committee (Teknik- og Miljøudvalget, TMU) provides first guidelines and identifies questions about possible subsidies, effects of the new building on the environment and on the surroundings.

3. **Local Plan Proposa**l: this will be prepared by the CBD and coordinated with the TMU before the citizen's are informed about the planned project. The citizens then have a minimum of eight weeks to discuss this detailed plan on the citizen's portal »be heard« on Copenhagens' website or in a public meeting.

4. **Final Local Plan:** After the consultation period, the local plan – including recommendations and other comments by the CBD – will be approved by the City Council. Afterwards, an adaptation process begins (led by the TMU) or the plan will be adapted by the City Council and published on the municipality's website. All involved stakeholders who submitted comments to the proposal will be informed of the adaptation of the plan (Københavns Kommune 2013).

Since many different political and administrative individuals on different hierarchical levels are involved in the discussion and decision-making process and many plans and strategies address sustainablitiy issues, it seems reasonable to conclude that sustainability plays an important role in Copenhagen. In order to successfully run the projects and strategies, responsibility for a sustainable way of life should be taken right down to the individual level. According to our interview partners, this individual responsibility (from citizens and members of local politics and administration) is one crucial success factor on the way towards a sustainable city. However, in order to better analyze the meaning of the big subject of »sustainability«, it is important to first identify which dimensions and key aspects are focused on in Copenhagen and how the understanding of sustainability is defined and implemented within each dimension.

3

3 SUSTAINABILITY IN COPENHAGEN

Sustainability is an important topic in Copenhagen. Almost omnipresent, the signs of sustainable development are not only embodied in visible infrastructural elements such as the network of cycling routes or the clean water in the harbour, but also in the mindset of Copenhagen's citizens and the city dministration. For example, the strategy of sustainability complies with the climate protection strategy.

In general, a universal and all-embracing definition of sustainable urban development in the City of Copenhagen states that it is »long-term environmental, social and economic development within the parameters of resources provided by nature« (Centre for Urban Development 2011). The City of Copenhagen thus did not define a specific sustainability definition but generated a consensus in following the three pillar model of sustainability (Aachener Stiftung Kathy Beys 2013) generally accepted today. This sustainability triangle places equal focus on the social, economic and ecological dimensions.

»The environmental dimension is about strengthening and protecting nature against pollution, actively counteracting the consequences of environmental effects, and ensuring that future generations have access to the same adequate natural resources as the current generations« (Centre for Urban Development 2011).

The economic dimension relates to ensuring »a stable economic basis for society's development, with a higher degree of resource efficiency through continued technological advances« (Centre for Urban Development 2011).

The social dimension is about building urban spaces and buildings which »accommodate quality of life, identity, the participation of the local population and the different needs of the area's current and future users« (Centre for Urban Development 2011). In our interviews, the City of Copenhagen emphasized that the social part is relatively strong compared to other cities, as all sustainability-related projects refer to quality of life and special strategies such as the city life strategy called »A Metropolis for People« (The municipality of Copenhagen, Technical and Environmental Administration 2011) are considered important.

The political decision-making has adapted to this sustainability framework and includes three elements: growth, liveability and sustainability (whereby sustainability is the newest element which has only formed part of this framework for the past three to four years). The basic approach is that these elements are of equal importance and mutually interconnected like a value chain, so that one element only can be delivered along with both others. For example the important goal of »CO_2 neutrality« should not only be analyzed froma technical perspective, but its influence on a liveable city (good quality of life for the citizens) and the contribution of »CO_2 neutrality« for business growth or innovation must also be guaranteed. This leads to an integrated political paradigm. Another example is »clean air«, an issue, which is being addressed in a strategic way. The environmental perspective is just one part of the problem. Another important issue is the loss of productivity and efficiency and also the social welfare loss, as the citizens may get sick or die earlier due to air pollution. Copenhagen's specific solution approach includes the collection of data, an analysis and ultimately the inclusion of a specific business case within the strategic documents. Also, the Copenhagen Cleantech Cluster became most successful in terms of job potential, turn-over, and activity exports in businesses, when the social part was included in the discussion. This approach demonstrates why not only one department, for example the Technical and Environmental Administration, is in charge of the sustainability strategies in Copenhagen. In our interviews, we found out that »sustainability« for Copenhagen does not only mean to simply introduce a »green plan«; it means that the overall plan(s) and strategies must refer with equal importance to all three elements: growth, liveability and sustainability.

In order to develop the appropriate solutions, Copenhagen uses an integrated »intelligent public demand« approach which has shown high potential through involving stakeholders such as universities and businesses. The idea is that investments will be engaged in if the solutions proposed by the stakeholders are both innovative and feasible to implement. The large number of ideas and new public service solutions thus generated is supposed to lead to innovation and new jobs. This smart city approach can be made use of in a way similar to a change of peoples' mindset, or even like a new method of city development. An important driver of this approach is the support by the Lord Mayor himself. In his function as president of EuroCities (for two years) he realized the importance of this integrated approach, which makes the establishment of innovative solutions (with a focus on green growth) easier in Copenhagen. Furthermore, our interview partners identified three milestones which have led to this strategic thinking:

1. Consequences of the COP 15 COPENHAGEN – UN Climate Change Conference 2009: In the course of this conference the UN-members stated that an all-embracing sustainability or low-carbon model

for city-economies does not yet exist on a strategic level. But on an operational level, such an interagted model or solution is urgently needed, as the cities like Copenhagen have to be run successful each day.

2. Population growth about 20% within one decade (ten to 15 years): Compared to other Danish cites, Copenhagen is growing very fast. This population growth influences the macroeconomic framework and in order to assure the best living conditions (which again maintains population growth), the Copenhagen must adapt to this growth by changing, for example, its infrastructure or decision-making processes.

3. Demand for business-friendly regulatory conditions: Investors from the private sector have a strong interest in a business environment that provides resources such as efficient and green energy at an inexpensive price. In order to attract new businesses or to keep and protect investments, the city identified the need to deliver a low carbon platform for investment and to re-invest the growth-factor (about 4% in 2011) in climate adaptation and low-carbon energy systems early on.

For the City of Copenhagen, going green is a new way of working against price fluctuations on the energy market. From this perspective, investments in sustainable energy seem to be very promising, stable and profitable, even if the pay-off only becomes noticeable after one or even two generations.

A common definition of sustainability or sustainable urban development in Copenhagen can thus be directly related to the key aspects within Copenhagens' »CPH 2025 Climate Plan«. This plan will be further described in the following section.

3.1 SUSTAINABILITY PURPOSE: THE CPH 2025 CLIMATE PLAN

The first version of the Climate Plan was developed in 2008 and introduced in 2009 by the Technical and Environmental Administration of the City of Copenhagen. It was developed in a bottom-up-approach and the focus was mainly set on carbon neutrality. As a consequence of the COP 15 Climate Change Conference, the plan received a lot of encouragement from the Danish Government and the Danish Association of Municipalities who decided to put climate-related issues on the agenda. The contents of the plan fit with Denmark's overall goal of becoming a long term fossil free society by 2050. The Climate Plan is not a legally binding document and was voluntarily introduced by the City of Copenhagen. Nevertheless, it shows how municipal initiatives can have an influence on national politics. Additionally, the commitment demonstrated by local politics was also a crucial precondition for the success of the Climate plan. Since only one of the 55 members of the Copenhagen City Council voted against the first Climate Plan, it could be adopted.

A revised and additionally developed second version, the CPH 2025 Climate Plan, is now one of the leading policies in Copenhagen and emphasizes achieving the paramount goal of carbon neutrality by considering all three sustainability dimensions (ecological, economic and social) equally. As can be seen in figure 9, the goal of the first Climate Plan was to reduce CO_2 emissions by 20% between 2005 (reference year) and 2015, which has already been achieved in 2013. When, in August 2012, the second version of the CPH 2025 Climate Plan was adopted by the City Council, the objectives were even more ambitious. The new overall target for Copenhagen turned out to be carbon neutral by the year 2025. CO_2 emissions are expected to decrease from 1.9 million tons per year in 2011 to roughly 1.2 million tons yearly in 2025, and the elimination of those emissions to zero is the focus of the CHP 2025 Climate Plan (City of Copenhagen 2012a). Our interview partners told us that this means that carbon emissions must be reduced by 2.0 tons per capita and year until 2025. Carbon neutrality, thus, can basically be described as a compensation of the emerging CO_2 emissions through the use of RE. In order to ensure comparability, carbon neutrality measurements will follow the UN-Carbon-Footprint-System. In Copenhagen, the calculations will take into account all carbon emissions within the borders of the city and those will be compensated by the construction of eco-friendly energy production sites, such as onshore and offshore wind parks, in and around Copenhagen.

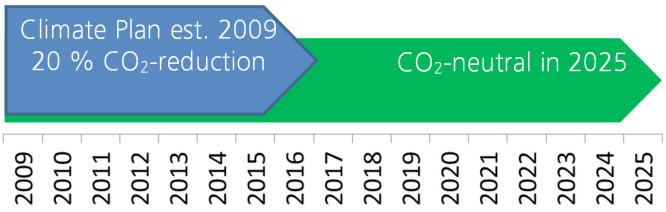


Figure 9: Planned CO_2 reductions for the City of Copenhagen (Jørgensen 2011)

According to our interview partners, the Climate Plan will be renewed every four years in order to include current developments.

The development process for the CPH 2025 Climate Plan: First, the potential for green growth was the selection criterion for the inititating 22 or 23 projects which were selected by the Technical and Environmental Administration. Then, groups were formed consisting of all administration-internal project leaders and a draft business plan was ela-

borated. At this early stage, relevant external stakeholders like industry, universities and other organizations were integrated into the administrative groups for three months, during the process of finding a focus. Citizens did not play a crucial role, and environmental groups were partly involved since the negotiations and coordination would be too complex to manage with more than 500,000 stakeholders within the process. Since the goal of CO_2 neutrality is very ambitious, it forces the City of Copenhagen to focus on big initiatives which involve stakeholders that are financially strong and technologically innovative. After the phase of verifying the projects in terms of criteria like market requirements, technology and prices, a proposal was prepared by the Technical and Environmental Administration. The focus lies on innovation aspects, which means that the potential to scale up, transfer or multiply the solutions should be present. With the aim of using Copenhagen as a test lab for technologies and solutions, innovative (public-private-) partnerships with universities or companies are founded. The approaches selected, however, should be easy to implement, so that they were again assessed by the stakeholders before being presented to Copenhagens' City Council.

The political commitment from the latter is a crucial precondition for the success of the Climate Plan. Since only one of the 55 members of the City Council voted against the Climate Plan, it was successfully adopted after just one and a half years of development. From the 17 initiatives composed of 65 to 70 projects which will be implemented, some have got a specific budget and some will be realized within the City Administration. An important point is the source of financing all these initiatives. The budget of the City Council cannot cover the costs of the initiatives (= direct investments) that are nine times higher than the city's budget. Estimations say that investments for Copenhagen's 2025 Climate Plan by private investments and funds will reach about US$ 4.78 billion (ca. EUR 3.51 billion) while the total cost savings and return on investment will amount up to US$ 475 million (ca. EUR 350 million) until 2025 (as of 2013) (Københavns Kommune 2013; GreenMedia 2013). Private investments therefore play an important role and thus they are necessary in order to implement the CPH 2025 Climate Plan. On an operational level, the implementation of the initiatives will be done in cooperation with the economy focused Finance Administration (headed by the Lord Mayor) and will be accompanied by an integrative, collaborative (multi-institutional) steering committee. During the implementation phase, the citizens are an integral part of the plan as they are the end-users of the solutions selected and their cooperation is necessary for the successful implementation and maintainance of the projects in Copenhagen.

The issue sustainability touches on various planning horizons in Copenhagen. Long-term planning covers all large scale initiatives, contains overall targets as well as primarily abstract visions, and focuses on the milestone 2025. However, in our interviews, it was stated that the specific goals of the CPH 2025 Climate Plan are only planned within a short-term-planning horizon. The projects are – similar to budgetary-planning – subdivided into four themes: energy consumption, energy production, green mobility and city administration initiatives. To ensure consistent progress, three implementation phases of four years each were defined. Pitstops occur in each phase, and secure the ongoing development of the project. They are related to the dimensions of analysis, demonstration and implementation (City of Copenhagen 2012a). A comprehensive roadmap ensures the progression of all initiatives within the CPH 2025 Climate Plan (City of Copenhagen 2012a).

The most important aspects of the Climate Plan are explained in the following sections:

Energy Consumption: In 2010, heat and energy consumption in Copenhagen caused 75% of the total CO_2 emissions. Taking into consideration that the city is expected to grow by 110,000 residents by 2025, it is very important to ensure that the needs of the growing population are met through the most efficient utilization of resources possible. The main initiatives include the development of a smart city for flexible energy consumption and the improvement of buildings through the promotion of solar cells and energy retrofitting.

Energy Production: The combination of several different RE sources ensures the energy system is flexible enough to meet varying energy needs throughout a 24 hour period. More than 100 wind turbines inside and outside the municipal boundaries are scheduled to be installed by 2025. Heat generation will be CO_2 neutral and based on biomass (change from coal to biomass), waste and geothermal energy.

Green Mobility: Transport causes a large proportion of the total carbon emissions. Green mobility initiatives include attempts to encourage the citizens to go by foot, take the bike or use the public transport system to get around in the city. In order to reduce traffic, the efficiency in public transport will be improved by a new metro line and technologically innovative systems, for example in the bus systems. There is also a large market for electric vehicles (EVs) since 96% of the trips in Denmark are shorter than 50 km. The use of alternative fuels and drives will be expanded: »The city has estimated that 20% to 30% of all cars and small trucks, and 30% to 40% of all heavy vehicles, will run on electricity, hydrogen, biogas, or bioethanol by 2025. By 2015, 85% of the city's fleet of 1,000 small vehicles will run on electricity, hydrogen, or biofuels« (GreenMedia 2013).

City Administration: The energy consumption of municipal buildings must be reduced and the city administration will convert to electric and hydrogen powered bicycles and cars. For instance, the share of electric cars in the city's own fleet will be increased by up to 85% within the next two

and a half years. Also, after a successful tender process, the entire street lighting network will be changed into SSL-technology (LED technology) (European Commission 2013).

According to our interview partners, the success of the sustainability-driven activities is monitored in Copenhagen. On a regular basis, just as with fiscal accounting, sustainability accounting based on a Key Performance Indicator has been established.The indicator is designed to provide information about the success of sustainability initiatives to the political level and also to create knowledge about the effectiveness of each individual solution. Sustainability accounting makes the decisions and the investments tangible, in contrast to ambitions and targets. Since the sustainability issues in Copenhagen are strongly related to the economy focused Finance Administration of the city, well justified investments (money, capacities) need to present a business case in order to meet the requirements of fiscal policies. Therefore, the use and also the publication of the sustainability accounting are perceived as very important in Copenhagen. These reports and evaluations are key to ensuring efficient learning processes and knowledge transfer amongst internal, but also external, players as far as possible on a national and international level (City of Copenhagen 2012a). The City Council developed these so called »Green accounts« in 2010, and they are designed not only as a tool for monitoring, but also for future planning. They give an assessment about the annual environmental, social and economic progress of sustainability in Copenhagen (City of Copenhagen 2011b). They also serve as a good example of an effective way in which a city can communicate its actions and steps (in order to create public awareness) within a holistic marketing concept which includes strategic plans and policies as part of a publicity instrument.

3.2 STRUCTURED PLANNING APPROACH: THE SUSTAINABILITY TOOL

A strategic planning instrument is necessary in order to ensure that all three sustainability dimensions (ecologic, social and economic) play an integral role in the decision-making process. The City of Copenhagen has therefore installed a »Sustainability Tool« which supports the implementation of initiatives and projects as part of, for instance, the Municipal Plan or the CPH 2025 Climate Plan. The Sustainability Tool was developed by the Technical and Environmental Administration in 2009, for use by the CBD. The Technical and Environmental Administration is – together with the Finance Administration – responsible for Town Planning issues within Copenhagen. The regional politicians' strong show of support for sustainability related issues, such as the climate plan, was also mentioned as the main success factor for the development of Copenhagens' Sustainability Tool. With the aim of providing a framework for city developers, planers and citizens, the Tool serves first and foremost as a checklist as well as a process and dialogue instrument. Thus, it facilitates the planning processes for long-term development projects in Copenhagen. Our interview partners stated that the use of the Tool is mandatory for urban development projects that span more than 50,000 m². It is a requirement for the planning of Copenhagen's municipal buildings, state-owned buildings, social housing buildings – which the CBD of Copenhagen supports – and for all urban renewal areas. For private owners it is not legally binding, however, the city is planning on engaging in dialogue with these private owners, if a big urban renewal project is planned. From 2009 until 2013, already about 14 projects have been supported by the Tool, which has not been updated since its first use. An adaptation could be conceivable if leading policies from 2009, which formthe basis for the content of the Tool, should change substantially. Sustainability issues are integrated into the Tool during the early phases of the planning and political decision-making process and not during the construction stage of these projects. The Tool consists of the three functions or phases, which are:

Dialogue: In the form of a checklist, 14 considerations within the Tool start a sustainability-focused dialogue between the City of Copenhagen and external developers and stakeholders, such as, for example, private land/building owners or architects (but not citizens). The three dimensions (environmental, social and economic) are integrated right from the first phase of the project. The considerations reflect Copenhagen's political goals and consist of: »Area use«, »Transport«, »Energy«, »Water«, »Material circulation«, »Green and blue areas«, »Social diversity«, »The urban space«, »City life«, »Identity«, »Business and Services«, »Municipal economy«, »Project economy« and «Durability«. The considerations are represented as key questions (related to the social, economic and environmental dimensions of sustainability) with sub-themes, which are open for discussion and which are enriched with additional information material such as, for example, detailed descriptions of innovative projects (Centre for Urban Development 2011).

Prioritising: The result of the dialogue should be the prioritization of the most important considerations for the specific project. According to our interview partners, these do not have to be all 14, but could, for example, consist of the five most important considerations for that specific project. The crucial fact is the argumentation of why the consideration (based on a score from 1-5; 1 is unacceptable and 5 is best practice or even innovative) leads to a decision. This serves as a basis for a program for the planned project and a number of first project proposals (Centre for Urban Development 2011).

Assessment: The City of Copenhagen will assess the integration of the prioritized considerations (from Phase »Dialogue«) in order to assure the requirements of the specific development area are being addressed. In a second step, the municipality tests to what extent the remaining consi-

derations have been integrated into the proposal and if the planned solution as such is feasible and brings synergies for the surroundings. This is not a precise, quantitative assessment and the result is visualized through a qualitative evaluation barometer with scores related to the selected considerations (and the three dimensions of sustainability) (Centre for Urban Development 2011). Scores of about 3.3 are average; scores of 4 represent a best practice example. In the interviews, it was stated that a more exact calculation would unreasonably complicate the planning process for medium size projects in Copenhagen.

The suggested, and detailed, plan proposal will be openly accessible for public discussion for a period of at least eight weeks. This is the first time citizens are integrated into the planning process. They can provide their opinion on the City of Copenhagen's »Be heard« homepage, specifically designed for this purpose (City of Copenhagen 2013), or in an organized public meeting.

3.3 FOCUS ON GREEN GROWTH

Copenhagen is an important growth engine for Denmark. The municipality's goal is to create 20,000 new private jobs and increase productivity by 4% until 2020. To reach these targets, the City Council is aiming to attract international business, investments, highly skilled foreign workers, tourists and large events (City of Copenhagen 2013).

The main industrial fields in Copenhagen are composed of green, smart, healthy and creative industries. To ensure growth in the creative industry (70,000 employees in this sector), the city has set aside a budget of about EUR 2.5 million (DKK 18.3 million) for 2013 (Københavns Kommune 2013). Other strong industrial fields include the green solutions and welfare technologies sectors. To achieve the goal to becoming CO_2 neutral by 2025, the city has commited to invest approximately EUR 65 million (DKK 485.3 million) in the time period from 2013 to 2016 in green solutions. Future savings, for the city as well as for the citizens, are expected as a result of these investments in smart solutions, welfare technologies and improved services (Københavns Kommune 2013). Thus, green technologies are not the only focus; innovative solutions and technologies will also be implemented to improve the quality of everyday life (Københavns Kommune 2013).

Business Growth and International Cooperation

»Green growth« is the keyword that best describes the sustainability-driven economic development in Copenhagen. In line with the overall goal of becomig the first carbon neutral capital worldwide (by 2025), Copenhagen's economic structure is focused (amongst others) on the following areas: sustainable energy and water supply, a »green« transport system, and the energetic renovation of buildings.

Cooperative projects with universities and knowledge institutions and cooperation on the municipal and national levels (i.e. in the C40-network) – as well as investments from the public and private sector – enable great access to technological potentials. On the energy infrastructure market, for example, the fusion of many small capacities has led to large scale solutions, such as the DH system which is operated and controlled by a municipal company and which is constantly being improved in terms of carbon neutrality. The City of Copenhagen has realized that offering control of the basic business infrastructure is a strong attraction for investments and a major factor in Copenhagen's competitiveness (in terms of location) compared to other cities. Another success factor is the city's extremely (pro-)active communication of these unique, ambitious and foremost business-friendly conditions to the relevant stakeholders. For instance, the largest IT-companies in the world were received in Copenhagen with the aim of demonstrating the vast possibilities available in the city and to convince these companies that the city's infrastructure is suitable and attractive for foreign investments. Thus, the municipality sees itself as a test bed for pioneering and innovative eco-friendly solutions. In the future, once these solutions have been successfully implemented in Copenhagen, the adaptation of these projects to other cities should take place. The national, and particularly the international, export of the solutions is an important goal for Copenhagen (Københavns Kommune 2013). An interviewee provided impressive numbers regarding this function of the city: two thirds of all smart city tests in Europe take place in the Greater Copenhagen Area.

To improve its overall industrial growth, the city focuses on seven business policies. The first one is that the city wants to provide a better service to businesses by reducing processing times and the development of digital solutions. The second policy is to ensure enough infrastructural and urban development takes place to improve the quality of life in Copenhagen. To provide young highly skilled workers and graduates from universities with employment, the city launched the project »Growth Academician«. The city also helps companies and graduates with recruitment and offers a job rotation system which provides space for the training of newcomers. Another focus is to make it easy for entrepreneurs to start a business, to transfer knowledge and to promote innovation. This is accomplished by offering free courses and events for entrepreneurs, by providing educational institutions and also by improving collaboration between businesses and schools. Another way of transfering knowledge and increasing cooperation between businesses are so-called business clusters. These already exist in the IT/finance, cleantech, life science, maritime, and creative industries. Yet another policy ensures that taxes are kept consistently low for both employees and businesses. The final of the seven policies is about international labour, tourism, investments and schools. Copenhagen would like to be an

open city for highly skilled foreign workers and foreign investments and provide activities and attractions for tourists (Københavns Kommune 2013).

Institutionalized Business Growth: the Green Growth Network

In order to develop its main industries, the municipality works in close collaboration with its international partners and networks. One objective of this active networking by the City of Copenhagen is to attract investments and create export opportunities for businesses in the region (Københavns Kommune 2013).

The city's networking activities began very early on, compared to the spread of consciousness about sustainability issues. This indicates that economic aspects were on the agenda in 2001 when the Copenhagen Business Network started its activities with about 50 company members. The focus at that time was mainly on registration, permits, controls and comparably new environmental management systems. When Copenhagen's first Climate Plan was developed around 2008, the focus of this B2B-network changed towards the smaller companies and towards energy consumption. The aim was to demonstrate how companies could do better business by both improving their environmental data and lowering their emissions. According to our interview partners, about 40,000 companies in Copenhagen held a share of about 70% of the electricity and 35% of the heat consumption in 2008. Energy consulting was one approach of figuring out how much energy-saving potential the companies had. However, the implementation of the initiatives from these energy reports was a major obstacle. In addition to the lack of money for financing climate initiatives and the respective knowledge, the biggest barrier for the companies was a lack of time. That is also why meetings were not as successful as checklists and case studies about innovative solutions and cross-industry partnerships (where events are jointly financed). Another key success factor for this innovation-centered approach was to involve society, i.e. to use tourist and educational institutions to inform young people about environmental issues. Modern social media was used as a distribution channel for new ideas and to connect different companies and industries. Another initiative was the first »creative summit« (held in 2012) which addressed young engineers and business organizations as an innovation-driven target group. The 300-400 participants introduced new approaches to problems relating to the Climate Plan, for example. So far, the activities of this network – which today is called the »Green Growth Network« – have succeeded in encouraging companies to rethink their existing business models in favor of sustainable solutions (i.e. changing processes). Run by four employees of the Technical and Environmental Administration of Copenhagen, the network is currently comprised of about 1,000 member companies from different industries. Most, however, are from the tertiary sector, since services are the largest part of the Copenhagen economy. The main goal is to lower the energy used by service companies by 20% until 2025. NGO's from specific branches, such as for example fishing, are integrated in the network, citizen groups are not. Therefore, the network is an intermediary between the municipality, the state and the economy. It helps companies allocate money for sustainable initiatives in electricity consumption, and also provides them with some marketing and the opportunity to learn from one another, according to our interview partners.

4

4 PRACTICE EXAMPLES

4.1 DISTRICT HEATING IN COPENHAGEN

District Heating (DH) has a long history in Copenhagen. The first systems were installed in the beginning of the 20th century. The Metropolitan Copenhagen Heating Transmission Company (CTR) headquarters are situated on the site of the first DH facility in Copenhagen. In the central districts of Copenhagen, the building density allowed for the efficient connection of more and more buildings to the DH system over time. Today, more than 400,000 households in Greater Copenhagen are connected (Andersen; Elleriis 2000).

After the oil crisis of the 1970´s, Denmark promoted several actions as a response to the situation. One such action was the establishment of CTR in 1984. The joint transmission system for Greater Copenhagen, CTR, was founded by five municipalities: Copenhagen, Frederiksberg, Gentofte, Gladsaxe and Taarnby, with about 270,000 households connected. **CTR** cooperates with Vestegnens Kraftvarmeselskab I/S (VEKS) in order to ensure more balanced systems and optimized efficient operations.

VEKS was also established in 1984 and is a company shared by eleven municipalities in the Western part of the greater Copenhagen area and is a transmission company supplying heat to 20 local DH companies at Vestegnen. The local DH companies then resell the heat to private consumers, business customers and institutions. In 1984, the municipalities, owner of the companies CTR and VEKS could not find an agreement for a fusion of all DH facilities within one company. Today, in all daily operations, CTR and VEKS function like a single company and are dependent on one another.

Monopoly Business – No Competition

DH in Denmark is a non-profit business with well-defined delimitations to natural gas. Municipalities have the possibility of implementing the mandatory connection of users to the DH system. The responsibilities associated with DH are well defined: The Government is responsible for overall policies and for the CHP strategy to ensure maximum CHP in the grid. It sets the legislation and the fiscal framework to steer the market to optimize the use of DH. The municipalities are given the task of defining a heat planning scheme and organizing the implementation of DH. They are also responsible for motivating the connection to DH.

The heat supply act (Ministry of Environment and Energy 2000) describes the tariff structure and its basic principles: The non-profit tariffs define the split of cost between heat and electricity. This means that costs include fuels, operation, wages, administration, public service costs, financing expenses and cost depreciation. The prices from CHP are set to be reasonable. The average pool price for the distribution companies in 2011 was 101 DKK/GJ around 19.78 ct/kWh (CTR 2012). The ownership of DH systems in Denmark is split between the municipality (20%) and consumers (cooperatives) (80%), and includes more than 450 DH companies. However, the municipal companies are the biggest and cover approximately 80% of the total heating energy demand.

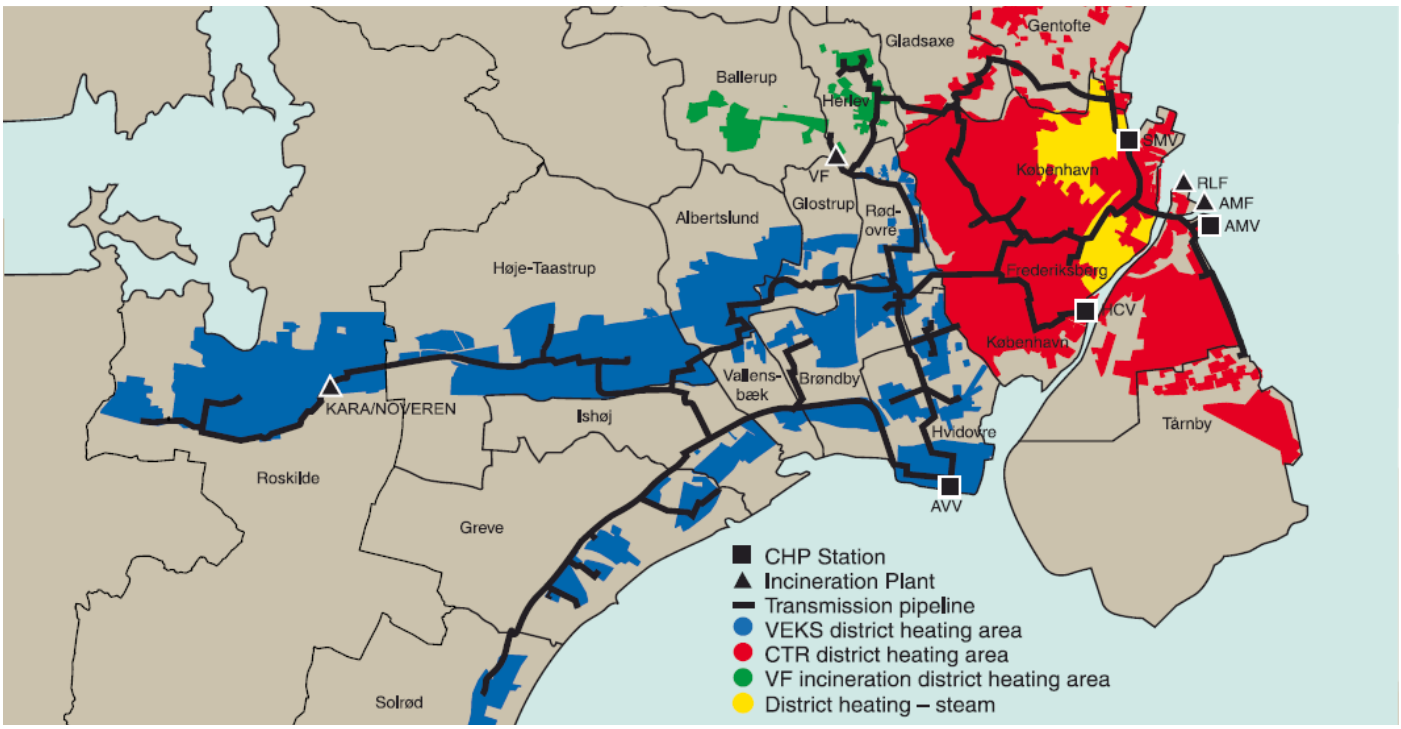


Figure 10: The DH system in the greater Copenhagen area; in red: CTR system (Danish Board of District Heating 2013)

Initiative and Goals
Throughout the decades, from the beginning of market regulation, various different goals and areas of focus have been set. At the beginning, a functional setup of all systems and stakeholders was focused on in order to make the space heating sector through DH more independent from oil and to ensure reliable prices. Then, the economic development of DH and the use of natural gas became a main focus. From the beginning of the 1990's, in response to the publication of the Brundtland report, the focus was shifted to the environment in general, with special emphasis on the reduction of sulphur in order to avoid forest dieback. The focus on CO_2 reduction came later, after the Kyoto Protocol. From 2000 onward, a restructuration of market players has been observed as a result of the deregulation of markets within the EU.

Climate and Climate Change
Today, there is an international focus on climate issues: the UN climate panel prescribes a 50-80% reduction of CO_2 emissions by 2050 in order to achieve the two degree increase in temperature target. Targets for the year 2020 within the EU are: 20% CO_2 reduction, 20% renewable and 20% energy efficiency. Denmark has shown leadership by increasing these EU targets.
Municipalities in Denmark have local climate targets and CO_2 neutral districts. The City of Copenhagen, as the first capital in the world, aims to be CO_2 neutral by 2025. The end-user energy demands must also be considered when addressing climate aspects.
DH aims to secure a reasonable development in heat price and energy efficiency in the long run and at the same time maintain security of supply.
Municipalities will emphasize the role of DH when talking about CO_2 reduction and RE with the local citizens. It seems to be realistic to reach 70% RE in the DH system before 2025.
Today, Copenhagen's main goals concerning CO_2 reduction are: CO_2 emissions are to be reduced by at least 20% in 2015 compared to 2005 and the city is to be carbon neutral by 2025. For both goals DH will play a main role in reducing CO_2 emissions.
Denmark believes it is able to cut its heating-related carbon emissions in half by 2020, and the heating supplies in Denmark can be virtually carbon neutral by 2030. How this might be accomplished is outlined in Heat Plan Denmark (Dyrelund 2009), a plan which is based on the assumption that carbon emissions in the CTR area can be reduced by 75% from 2006 to 2030. The Heat Plan was published by the Danish District Heating Association in late 2008 (CTR 2009).

More DH is one of the key ingredients required to achieve the ambitious goals described above and a nationwide effort must ensure that greater focus is placed on the use of DH. Other important topics to solve are: Increasing the number of carbon neutral energy sources for DH, transmitting the heat over greater distances, reducing heat loss in buildings and using new non-polluting types of heating, such as heat pumps and solar heating in areas that are too remote to be part of DH systems. In order for these efforts to succeed, the planning of heating needs must be combined with the need for electricity and waste removal – this concept is entirely in line with the heat plans of the 1980's that led to the large scale development of CHP nationwide and the creation of projects like CTR (see timeline on page 41).

More Biofuels at the CHP Plants
CTR, the Greater Copenhagen Utility HOFOR (former KE) and VEKS are currently looking into how Greater Copenhagen could achieve the ambitious goals concerning its energy supplies set by the municipalities. The result of these investigations in Greater Copenhagen was published in the summer of 2009. Preliminary assessments indicate that it is possible to remove two-thirds of carbon emissions from DH supplies by 2025 by increasing the use of waste and biomass as fuel for the power stations.

4.1.1 Measures and Activities

Setup and Substantial Initial Investments
One action was the establishment of CTR. A consortium of planners designed and planned a large scale extension of the DH system. From 1985 to 1987, which was the peak period of construction, excavation and pipe laying occurred throughout the city. In parallel, a tunnel under the harbour was dug to link Amager power stations with the city grid in order to realize the best possible DH availability for all districts. In 1990 another additional line through the North-Eastern districts was laid for better access to DH for these districts. In the near future, activities are planned to extend the DH grid into districts that currently have other heating systems.

Operation and Maintenance of the System
The main controlling centre of the CTR system is an operation centre that is manned 24 hours a day. From here, the heat supply is monitored and regulated using advanced computer technology that transports alarm signals, measurements, etc. from throughout the network. The Control, Regulation and Monitoring (CRM) installation has approx. 10,000 possible signals that inform about the process. In this way, the operation centre monitors the production, transport and delivery of the heat to the various delivery points. In reality, the CRM installation comprises six main stations, CTR's central control room and five municipal main stations, and approximately 30 sub-stations.

The Computer System and highly trained engineers monitor CTR's transmission network. Each of the municipal main stations is responsible for seeing to the actual operation and maintenance of those parts of the system that have been established in its municipality. This includes the close

monitoring of a number of sub-stations (installed in heat exchanger and pump stations, in the production units and, in one case, at a measuring station). In this way, all process control functions take place in independent sub-stations which can be operated independently from the rest of the system and which can carry out automatic regulation and sequence control.

Communication between the stations is carried out by an 80 km (50 miles) long fibre optic network. For security reasons, this network has been built as a double ring.

The system handles 18 municipalities with four integrated DH systems and a production of about 34,500 TJ (9,600 GWh) which represents approx. 20% of the heating demand in Denmark.

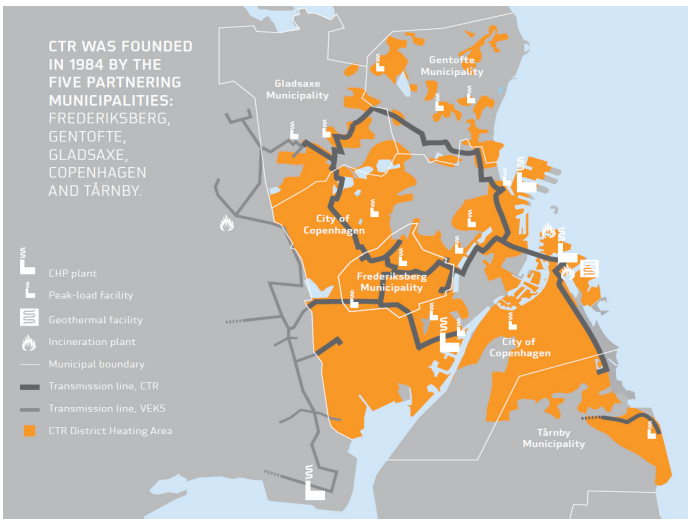
Another aim is the continuous yet low cost maintenance of the whole system and the replacement of inefficient parts through more high quality ones. Around 1.5% of the budget is used for maintenance and there is an economical reason for optimizing the system. All parts of the system- planning, construction, operation and maintenance- are continuously evaluated and improvements will be paid off due to the long runtime and the size of the system.

Energy Producers

The main power producing companies operating in the Danish market are Dong Energy and Vattenfall. The current market structure was designed in 2003–2006 by a number of mergers and transactions. Major fusions of energy producers changed the market structure and the agreement between and merger of DONG, Elsam, NESA, Københavns Energi, and Frederiksberg Forsyning to form Dong Energy was approved by the European Commission in 2006 and consequently came into force on the 2nd of July, 2006. However, the Danish Council decided that the Danish producer Elsam (now DONG) abused its dominant position in Denmark to raise prices during the period from 2003-2006 and caused some regulation adaptions.

Denmark has two separated transmission systems for electricity, of which the eastern one is synchronous with Nordic

Figure 11: Left: Avedøre Multifuel Cogeneration Plant owned by DONG Energy A/S (IDEA 2012); Right: Amagerforbraending extension and re-designing with ski slope on the rooftop (BIG 2013)



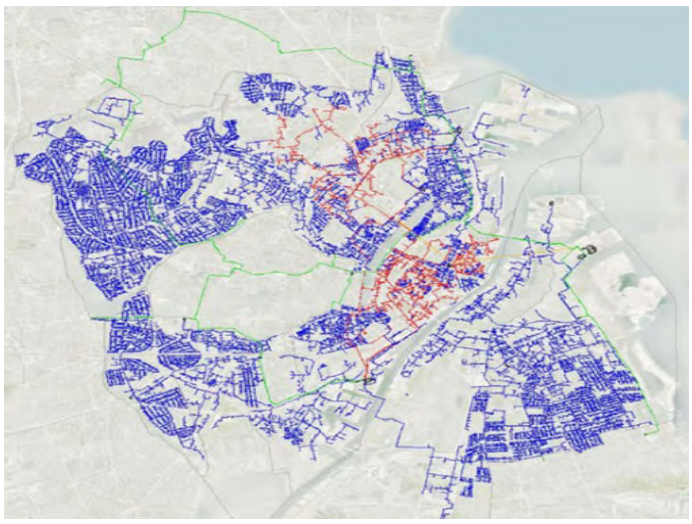


Figure 12: Left: Transmission system CTR (CTR 2009); Right: Distribution System HOFOR (Elsman 2009)

(former NORDEL) and the western one with the synchronous grid of Continental Europe. The Great Belt Power Link connecting the two systems was commissioned in July of 2010. The Danish power grid is connected to Norway, Sweden and Germany having 2,510 MW and 2,870 MW of export and import capacities in 2007 respectively. The Danish transmission system is owned and operated by Energinet.dk – and is owned by the Danish state.

Base Load Production

CTR retrieves surplus heat from CHP of the energy producers, which are: Amager Power Station, H.C.Orsted Power Station, Svanemolle Power Station and Avedore Power Station. Heat from waste incineration comes from the following two facilities: Amagerforbraending and Vestforbraending. In total there are four CHP facilities with 1,800 MW and two waste to heat facilities with 400 MW. These facilities are big and visible structures in the urban landscape of Copenhagen. In March 2013, the construction for the single largest environmental initiative in Denmark, the Amager Bakke Waste-to-Energy Plant, started, which replaces the adjacent outdated Amagerforbrændning plant and also provides the city with new recreational urban space. It was designed by Bjarke Ingels Group (BIG).

Transmission System

CTR is responsible for the transmission system. For peak load and reserve production on both the global and local grid levels, several facilities are installed at strategic sites: steam turbines, gas turbines, coal, oil, gas, straw, wood and several peak reserve units. CTR has a 54 km (34 miles) long pipeline which uses three booster pump stations, fourteen peak load units, and twenty-six heat exchanger stations to transfer the heat to the local DH systems.

The supply heat exits at 115-95 °C and returns at 60-45 °C. The transfer to the distribution companies occurs technically through heat exchangers and separated systems. A large section of the 54 km (34 miles) long pipe network has been laid as a ring. The decision to build the network in this form was based on a number of considerations regarding the economics of operation and the reliability of supply. The ring system makes it possible to draw heat from the most economical production unit at any one time and to reverse the direction of heat flow should a pipe rupture or a power station's supply be interrupted. Most facilities are situated underground and are invisible in the public space (CTR 2000; CTR 2004).

Distribution

Five municipal distribution companies, HOFOR A/S, Frederiksberg Forsyning A/S, Gentofte Kommune Kraftvarme, Gladsax Fjernvarme and Tårnby Fjernvarmeforsyning organize all distribution to the customers. The supply heat for distribution exits at 105-80 °C and returns at 50-40 °C. Tariffs and prices are also defined by the return temperature of the systems from the customers.

Legal Framework and DH Development

Several steps are shown in the timeline. These depict the long term activities required to develop an efficient DH system:

DH Begins	Around 1900
Frederiksberg first DH system from	1903
Copenhagen first DH system from	Since 1925
DH plants for small consumers	1960
Energy crisis	1973 & 1979
Most oil power plants converted from oil to coal	1970´s
All new power plants must be CHP	1976
No regulation	Until 1980
Regulation of the sector	1980
Heat supply act, 100% regulation of heating sector	1980
Economic development of heating sector (DH and natural gas)	1980´s
All municipalities prepare heat plans (CEP)	From 1980 on
VEKS established	1984
CTR established	1984
A new plant, Unit 7, at H. C. Ørsted Power Station opens	1985
Tårnby becomes first municipality to be supplied by CTR	1986
The tunnel underneath Copenhagen Harbour is completed	1987
The municipalities of Gentofte and Gladsaxe are connected	1988
The first phase of the decision from 1983 to enlarge power stations is realised	1989
The sixth and final stage of the transmission grid is put into service	1990
A heat accumulator is set up at the Avedøre Power Station.	1993
CTR concludes an agreement to buy heat from a future CHP plant, at Avedøre Power Station.	1994
Environment (Brundtland report, forest dieback), SO_2	1990´s
Liberalisation of power and gas	2000
CTR constructs a number of peak-load facilities	2000
Unit 2 of the Avedøre Power Station is put into service.	2001
Unit 2 at Amager Power Station is rebuilt to be capable of firing with biomass	2004

CO_2 Greenhouse gas emission focus	2005
Greater Copenhagen's geothermal facility is opened	2006
DH covers 60% of households	2006
The heat-load collaboration involving CTR, HOFOR and VEKS assumes the role of the coordinating load distributor for the power companies' CHP plants	2008
The newly renovated Unit 1 at Amager Power Station is put into operation	2009
DH climate award	2009

4.1.2 Objectives and Results

CTR has set a target aiming to make DH CO_2 neutral by 2025. All phases of planning, construction and operation are documented for the public on the web site. During yearly shareholder meetings, objectives are discussed and activities are planned and evaluated. The percentage of RE in the metropolitan region's DH system reached approximately 35% in 2008. Analyses on DH show that it makes economic sense to achieve an RE percentage of at least 70% in 2025, regardless of which scenario is in focus. However, this presumes that taxes still favour biomass in terms of heat production, and that biomass based electricity production is still subsidised (CTR, VEKS, Københavns Energi 2009).

Results

Average electricity consumption per capita in Copenhagener has fallen by about 3.5% since 2008 and amounts to approximately 1,340 kWh per year. However, this drop is not apparent in the total electricity consumption by Copenhageners, which has remained constant because the city has grown at the same time consumption has decreased. A reduction to 1,000 kWh per year seems to be feasible with a reasonable range of measures. All companies selling energy to customers and end users are legally mandated to make efficiency results available each year.

In 2010, 1 kWh of DH emitted 16% less CO_2 than in 2005. On the other hand, consumption of DH in Copenhagen was 20% higher in 2010 than in 2005 due to a cold 2010 winter. Household heating represents the largest fraction of energy consumption by Copenhageners at around 5,500 kWh per year. The energy consumed for heat in housing depends on many factors, including the size of the building, its age and maintenance; it also depends on the behaviour of the residents. The Danish Energy Savings Trust has stated that a building of 100 m² with low heat consumption uses 11.6 MWh of district heat per year, but the Trust has not set a target for heat consumption per capita. However, nearly all households are connected to the DH system.

Electricity savings have the biggest impact on the reduction of CO_2 emissions. Average carbon emissions per Copenhagen resident in 2010 were a little higher for electricity consumption than for heating consumption, and in terms of kWh, heating consumption is four-times higher than electricity consumption. This means that a reduction of one kWh of electricity reduces carbon emissions by four-times as much as a savings of one kWh of heating. In 2010, one kWh of electricity emitted 511 g of CO_2, while one kWh of DH emitted only 122 g of CO_2 (City of Copenhagen 2013).

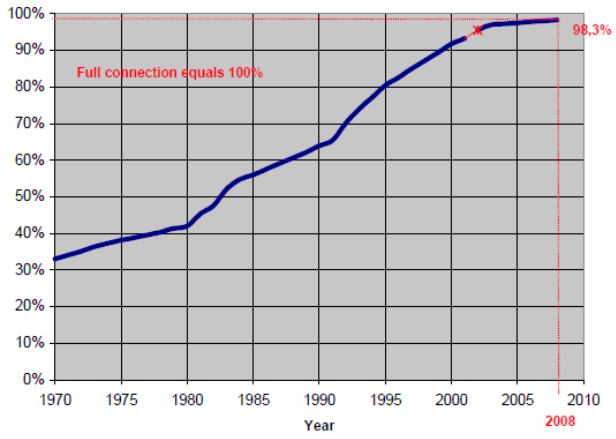


Figure 13: Connection to the Copenhagen DH system – percentage of heat demand (Elsman 2009)

4.1.3 Financial issues

CTR's yearly budget is published in financial statements & annual reports (CTR 2012). The turnover in 2011 amounted to DKK 1.9 billion. Total operating and maintenance costs in the transmission system during 2011 amounted to DKK 71.8 million. Of this, operation costs for supplementary feed water and part flow cleaning account for DKK 2.2 million. Annual maintenance costs account for DKK 69.6 million. The overall balance in 2011 was DKK 1,262.6 million. Investment expenditure for the entire transmission net currently totals more than DKK 3 billion, or US$ 500 million (US$1 = DKK 6). This has been financed primarily through foreign currency loans.

The overall assets of all systems plants, distribution systems, pipes etc. represent a high value, around DKK 3.5 billion, with long functional guarantees. Thus, DH in Copenhagen is a huge investment into long-lived infrastructure. Additionally, it is all publically owned and controlled.

It is easy and affordable to secure loans for DH companies' to finance DH systems and investments because of the public backing of assets and the security of operational income over very long periods of time. The fact that DH is a monopoly market contributes positively to this good access to affordable loans.

CTR Finances 2011	DKK (million)
Heating sales including sales of CO_2 quotas	1,918.4
Heating purchases including electricity for pumps	1,823.7
Profit on ordinary activities	94.7
Contribution margin	4.9%
Sundry operating expenditure	104.8
Capital expenditure	62.3
Interest payments	23.5
Earnings before depreciation, provision allowances and return on investment (net)	-10.1
Depreciation, provision allowances, yield from geothermal and return	-62.3
Profit/loss for the year	-96.2
Average pool price (DKK/GJ)	101.00
Accumulated deficit	-62.6
Trend Balance sheet	1,262.6
Long-term debt trend	796.1

4.1.4 Stakeholders

The main DH stakeholders are depicted in figure 14.

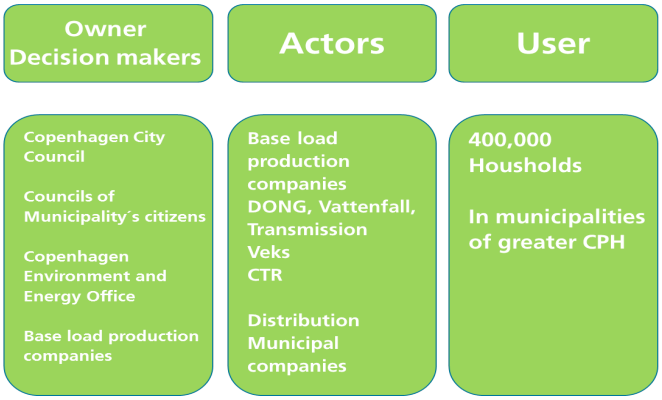


Figure 14: Stakeholder overview - DH in Copenhagen (own graphic)

The control of the stakeholder companies is managed by boards, often including representatives of publically elected parliaments. In fact, citizens – through democratic structures – effectively own and control the DH system. Exceptions to this are found on the level of power production with big energy providers like Vattenfall. These companies are limited in operation through strong legislative frameworks.

4.1.5 Challenges

Heating companies in Greater Copenhagen face some big environmental and economic challenges. In the coming years the various actors must make decisions regarding investments in CHP plants and waste incineration plants, the supply of converted steam areas in Copenhagen, conversion of individual natural gas customers to DH, changes in network structure and heat savings. Also, RE technologies such as geothermal energy, heat pumps and solar heating are on the agenda for many actors, and the interaction between these technologies and DH has not been sufficiently clarified and discussed between the actors (CTR, VEKS, Københavns Energi 2009).

4.1.6 Sustainability

The promotion of DH systems is part of the Danish Energy Strategy and of Copenhagen's overall activities towards reducing CO_2 emissions and investing in creating a better quality of life in the city.

Jan Elleriis, Vice-Director CTR, Metropolitan Copenhagen Heating Transmission Company

"If you have a thermal power plant based electricity system, like we have in Denmark and Copenhagen, the cost of a CHP based DH system on top of this is only marginal.

The very big issue to realize is that we in Denmark look on DH as a natural infrastructure like a tap water or a sewage system. It's not something where individual private companies can say this is a good investment or not. We see it as a public obligation to secure heat supply."

4.1.7 Transferability

DH can bring many benefits to a region when it is well managed. DH can reduce emissions, enhance energy security and promote economic development. However, it only makes sense if a well-designed policy framework exists.

Heat is a localised product, not a market commodity like oil or gas. DH can be part of a competitive market or it can be a monopoly service, depending on how the sector is structured and on the political environment in the country or city. Competition, by nature, forces efficiency improvements, but it is not always feasible to introduce competition in heating because of a lack of alternatives. Regulation can be a good policy choice in many situations, as long as the decision is made deliberately and with adequate consideration of the alternatives.

The transferability of the project and the approach is also dependent on other factors such as:

- Availability of a legal framework,
- Willingness to invest in a long term project lasting for many generations of political decision makers,
- Good financial frameworks and loan conditions,

- Awareness that DH should be a local service like sewage or drinking water,
- A participative local approach helps to implement complex projects with big financial volumes like DH,
- Risk of transferring the responsibility for CO_2 emissions from private households to municipal actors,
- A DH system, including all components, must be adapted to and specific in each city, dependant on local conditions.

4.2 MIDDELGRUNDENS WIND FARM – OFFSHORE WIND FARM OUTSIDE THE COPENHAGEN HARBOUR

Wind turbines have had a long history in Denmark and in Copenhagen it is quite established as well. It is not unusual in Denmark to use the wind for several purposes. In the 1990's, windmills for generating electricity became very popular on mainland sites. Today, more than 4,000 MW wind energy capacity is installed in Denmark, producing more than 10 TWh/y. In Copenhagen, a first facility with seven wind turbines was initiated in 1995, called Lynetten Windpower (Lynetten Vindkraft I/S 2013; see figure 15). It is located near the sludge incineration plant »Lynetten« which is located on the Eastern waterfront of Copenhagen's inner harbour.

The experiences gained through the Lynetten Windpower facility became a strong motivating factor for expanding on RE generation in Copenhagen. As there were only few suitable sites on the mainland, the idea was to design an offshore wind park not far from Lynetten The combination of public shareholders like Copenhagen Power with a cooperative and shared ownership was used for the setup of the Middelgrunden wind farm – a successful model. At this time, regulations for wind farms on-shore had been widely established whereas regulations and framework conditions for off-shore facilities were still in an early phase of exploration.

Initiative and goals: The idea of the Middelgrunden wind project was born within a visionary group of people in Copenhagen already in 1993. However, it took seven years and a lot of work before the first cooperatively owned offshore wind farm became a reality. The Middelgrunden cooperative was founded in 1996 and established 20 turbines; DONG Energy owns the ten northern turbines and Middelgrunden Wind Turbine Cooperative owns the ten southern turbines.

Thorough pre-studies, financed by a DKK 5.1 million grant from the Danish Energy Agency and power utilities, clarified all important project matters (planning, geotechnology, environment, etc.). Today, the 40 MW wind farm with twenty modern 2 MW wind turbines is producing electricity for more than 40,000 households in Copenhagen.

Figure 15: From top to bottom: Copenhagen Kastellet with historic windmill (Danishnet 2013); Lynetten Windpower, semi-offshore in the Copenhagen harbour (EMD International 2013); Middelgrunden Wind Farm (Middelgrundens Vindmøllelaug 2013); Copenhagen City and Middelgrunden offshore wind park site (Saskatoon Community Wind 2013)

The main goal was the operation of this offshore wind farm in direct visibility of the City and under local ownership (CEEO 2003).

4.2.1 Measures and Activities

The Cooperative: To establish this wind farm, a mix of complex activities and measures have been used. One important step was the collaboration of interested citizens with a clear vision and goal. An obstacle which had to be overcome was that only few regulations, procedures and laws had been established at that time for off-shore windfarms.

Stakeholers Envolvement: A lot of parameters and procedures were developed together with relevant stakeholders like ministries, the Energy Agency, the City of Copenhagen and others. This was possible because of the open minded structures and the support for off-shore wind farms amongst the public. The cooperative members shared coherent know-how in terms of legal, administrative, ecologic and technical knowledge.

Legal Framework Development: Based on a research project on off-shore wind farms and local ownership which had been conducted by one of the members, the idea of this type of wind farm was born and promoted. With the administrative and financial help of the Energy Agency this project was developed. The proceedings for approval were formulated and influenced by the cooperative. A compendium of measures and procedures have been fixed and are the basis of improvement of an off-shore wind farm. In 1996, a first application on principal approval was given; this represented the formal start of the project. The steps involved in the evolution of the wind farm are shown in the timeline below:

Interest group first meetings	From 1993
Cooperative foundation	May 1996
Application approved	September 1996
First public hearing, 27 turbines	June-Sep 1997
Second public hearing, 20 turbines	June-Sep 1998
Principal approval	May 1999
Third public hearing (Environmental Impact Assessment report)	July-Oct 1999
Final permit from Danish Energy Authority	December 1999
Contracts signed	December 1999
Construction initiated	March 2000
Casting concrete	April-July 2000
Starting work on seabed	May-June 2000
Placement of gravity foundations including the first 30 m section of the tower	October-November 2000
Placement of sea cables between turbines	November 2000
Placement of the upper parts of the turbines including rotors	November-December 2000
First turbines start production	December 2000
Commissioning	March 2001
Full operation year	2002
Replacement of converters (guarantee)	2002-2005
Operation planned at least until	2030
Prolongation envisioned; Durability of foundations	2060

Public Hearings: It should be noted that the public hearings and the corresponding adaption of the project took the most preparation time. This process was undertaken until widespread public acceptance was achieved. One big discussion point – amongst others – was the visual appearance of the wind farm. The proposals finally resulted in a design where the windmills were installed along a curved line. In the end, there were only few objectors to the project. The public hearings played an important role in ensuring the citizens accepted and supported the project.

The Environmental Impact Assessment of the wind farm at the Middelgrunden shoal was also discussed, covering topics such as: the project description; the Middelgrunden shoal today; alternatives to the Middelgrunden project; fuel consumption saved and pollution avoided; visual impact; dispersal of sediments during construction work; animals and plants; noise and traffic; water flow; accidents; decommissioning; surveillance program.

A discussion on how to implement a cradle to cradle principle was very important, even though it will not be applied in the near future. In parallel, all technical requirements such as cabling and grid connection as well as organisational requirements and responsibilities were fixed (Middelgrunden 2001).

The Final Approval was given in 1999 in accordance with the Energy Agency's approval scheme (Albrechtsen 2013).

The Implementation has been done according to the approval guidelines and assessments. The contracts were tendered within the EU. The best value for money offers were chosen.

Contracts were signed in 2000, commissioning occurred in 2001 and 2002 was the first complete year of operation. All transformers were changed due to functional difficulties; however, this occurred within the guarantee period and was thus covered. The transformers first chosen did not function as promised.

Through these changes, the cooperative has gained valuable experience relating to efficient maintenance and has since shared this knowledge with others (Larsen et al. 2005).

4.2.2 Objectives and Results

All phases of planning, construction and operation are documented for the public on the web site. During yearly shareholder meetings, activities were planned and evaluated. The main objective to run a wind farm in Copenhagen with local ownership was fulfilled. The website informs about Middelgrunden: http://www.middelgrunden.dk/. All experiences are shared with the public.

4.2.3 Financial Issues

The project started with finances from the cooperative. The planning phase was financed through citizens' prepayments: approx. EUR 30 per share. This helped during planning phases of the project, until all shares had been sold. It is guaranteed that all electricity produced by the project will be bought by the grid; at the beginning this included subsidies, but today it is based on market prices. The cooperative guarantees the transparent and cost effective management of the wind farm. The board works on a volunteer basis; only the shareholders (around 8,600) receive shares of the profits. Through the cooperation with Dong Energy, several risks were able to be shared. In return, Dong profits from the effective maintenance activities of the cooperative as well as from the public hearings during the approval process.

The yearly budget is published and accessible to the public and shows that the wind farm produces around 45,000,000

The total investment in the wind farm	EUR (mill)
Wind turbines	26.68
Foundations, including changes after the tender to reduce the time on sea	12.94
Grid connection, off-shore	4.51
Design, advice and planning	2.98
Wind turbine cooperative	0.80
Other costs 0,64	0.64
Total investment	**48.55**
Overall yearly budget in 2012	2.24
Overall yearly expenditures in 2012	0.83
Result/ depreciation in 2012	1.41

Figure 16: Middelgrunden's investment (Middelgrundens Vindmøllelaug 2013)

kWh/y and gains around 36 ct/kWh. The prices vary since the Nord Spot Market (Nord Pool Spot 2013) organizes the energy market in Denmark. Peak load prices in Copenhagen area are around 40 ct/kWh whereas off-peak prices are around 29 ct/kWh with variations throughout the year.

The grid is state owned in Denmark, and regulations allow for prioritizing feed-in of RE, such as wind. The grid is managed in such a way that no wind turbines must be switched off, even during wind peaks.

The wind farm has an allowance to operate for 25 years, with the possibility of prolonging and upgrading to more efficient turbines.

4.2.4 Stakeholders

The main stakeholders are depicted in figure 18. The Middelgrunden Cooperative with its 8,500 members is the main stakeholder and has generated a widespread under-

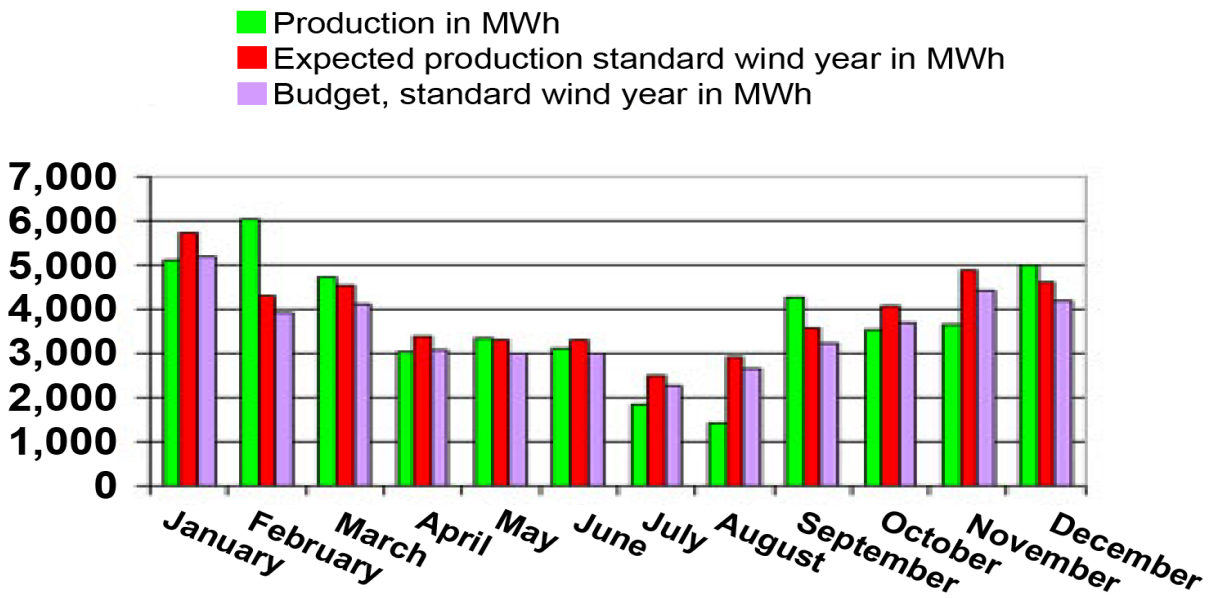


Figure 17: Middelgrunden's electricity production (Middelgrundens Vindmøllelaug 2013)

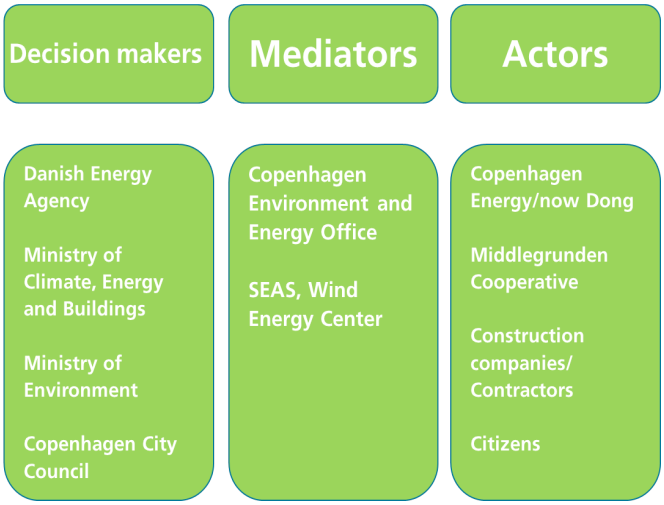


Figure 18: Actors Scheme - Middelgrunden Wind Farm (own graphic)

standing for and social acceptance of the chosen location and layout of the farm. The cooperative was also a strongly motivated player and driving force behind the project in general. Recent regulations regarding wind turbine installations restrict ownership to locals living in close proximity to the construction site.

4.2.5 Challenges

Within Danish energy policies on wind energy, a goal of 50% of the total electrical production coming from wind energy by 2020 has been set. This goal is challenging since vast financial resources must be mobilized and on shore sites are limited. Very large off-shore wind farms are planned and tendered. The size of these farms is so big that it seems to be difficult for cooperatives to participate in procurements. The visible impact and noise produced by wind farms is a problem for on shore sites, but strong regulations in Denmark are defining the limits of these variables. Grid response through reactive power production facilities on fluctuating wind energy is mandatory as well as grid connections with neighbour countries for a balanced supply.

4.2.6 Impact Factors

One activity was the promotion of wind energy: first on mainland sites, but later also in off-shore installations. Also, new gas fields in the North Sea were exploited. These activities resulted in strengthening national potentials and acted like an incubator to promote knowledge generation and human resources related to new techniques in this field. New regulations for the energy sector are now facilitating the production of energy on a national level, reducing Denmark's dependency on energy from other countries. Market regulations and feed-in regulations were important in facilitating these wind energy developments. The political climate also changed in favour of these new ideas, as

Source: Hvidovre Vindmøllelaugs 2013

Erik Christiansen, Director, Formand, Middelgrundens Vindmøllelaug

"People are enjoying being member of a cooperative. In the new regulations only citizens nearby construction sites can invest. This is a limiting factor because for bigger investments, there will be not enough money in some regions. Investors from a bigger region are needed, to reach the big goals for renewable energy production – this regulation is contra productive".

did broad support by the citizens. This positive environment has helped drive the Middelgrunden initiative forward.

Denmark is a culture of transparency and public discussion processes are considered important. This has been critical for local acceptance as well, since the project is, in fact, owned by the citizens.

Short decision pathways between the project owners, the technical decision-makers and the political decision-makers have helped to realize the project in an efficient way.

Both sides – project owners and administration – were in possession of sufficient technical knowledge to engage with the project effectively.

4.2.7 Sustainability

This project is part of the Danish energy strategy, which states that 50% of electrical production should be generated through wind by 2020. The Middelgrunden wind farm has been evaluated through an extensive environmental impact assessment. Even deconstruction and renaturation are outlined in case this facility is one day no longer in use. The owner structure, including more than 8,500 individuals, guarantees efficient and effective operations as well as continuity. The wind farm delivers electricity to approx. 40,000 households in Copenhagen and is one visible piece of the renewable power supply.

4.2.8 Transferability

The transferability of both the project and approach is dependent on various factors and should be developed in respect of below mentioned points. In this case, cooperatives and local ownership of projects have good reasons for being established:

- Local ownership creates local dialogue and ac-

ceptance.

- In countries with a legal and financial environment that enables local project developments, local investment can play a major role.
- Local ownership raises public awareness. During the establishment of the Middelgrunden project more than 50,000 people received information.
- Local ownership solves problems and conflicts.
- Private investment promotes cheaper and better technologies.
- Local production requires less transmission lines and saves electricity.
- Local turbines are democratic, citizen participation in decision-making.
- Local production makes sustainable development understandable and visible.
- Local ownership gives people opportunity to act for sustainable development.
- This local approach can be used to implement complex projects with large financial volumes.

4.3 REDUCING WATER CONSUMPTION IN THE CITY

In Denmark, fresh water resources are limited. There are no major rivers running through the country and it has no large lakes or dams. For its water supply, Denmark relies on groundwater resources (figure 19). Copenhagen is the most densely populated area in Denmark and thus has the greatest challenges in supplying its citizens with high quality drinking water. In the 1960's and 1970's, water consumption in Copenhagen increased so much that the available groundwater in the region did not suffice. Water from a lake had to be treated to complement the groundwater. However, upon realization of the limitation of water resources, measures were also developed on the demand side. Since the late 1980's, the per capita water consumption in Copenhagen (as well as in the rest of Denmark) has decreased strongly. The lake water treatment plant was closed in 2009 because it was no longer needed, although the population in Copenhagen has continued to increase rapidly.

4.3.1 Measures to Reduce the Consumption of Drinking Water

A reduction in the consumption of drinking water has been achieved through measures on different levels:

Awareness-Raising Campaigns: In the 1980's, the concept that water is a limited resource was new to people in Copenhagen. Nowadays, everyone in Copenhagen is aware that water is a resource that should not be wasted. This is the result of decades of water saving campaigns, in schools and kindergartens and on the community level. The campaigns started in the late 1980's with advertising on buses, taxis and trains, distribution of pamphlets and posters, and transmission of information through local television and radio. Charlotte Storm, Water Saving Consultant at HOFOR (Hovestadsområdets Forsyningsselskab – Greater Copenhagen Utilities), says: »People know they have to save water, but do not always know the reason why«.

Increasing the Price of Water: Although many people know that saving water is somehow important, the motivation to reduce drinking water consumption is higher for most people if it affects them economically. Therefore, in 1994, the Danish government introduced a national tax on drinking water. Currently it amounts to about EUR 0.73 per m^3 (14% of the total cost per m^3 water).

Metering of Water Consumption: Higher costs per m^3 water can only be effective if water consumption is measured on the household level. In single houses, a water meter is mandatory by national law. In apartment buildings, only one water meter for the whole building is mandatory. Flat owners are encouraged to monitor water consumption for each apartment through subsidies provided for the purchase of individual water meters by HOFOR.

Water Saving Installations: In the course of the awareness raising campaigns, people were also informed about water saving installations like toilets, washing machines, and taps. HOFOR subsidizes the costs of these installations in private households.

Detection of Leaks: HOFOR puts constant effort in the systematic detection and elimination of leaks in the supply network. Additionally, the pressure in the supply network is controlled with the objective to keep it on the same level during both day and night. This results in a stable loss rate in the range of 7-8%, which is relatively low compared to other cities.

4.3.2 Objectives and Results

The main objective regarding the reduction of water consumption was and is to secure the water supply for Copenhagen from locally available groundwater. As the resource is limited, the demand had to be adapted to fit the availability of water. For the future, the objective is to keep the water consumption stable although the population in Copenhagen is projected to continue growing rapidly.

In a water supply plan, which is developed by the city administration every four years, objectives for the per capita consumption are given. For 2010, the objective was 110 l/cap/d – this target has been met, currently the average water consumption in households adds up to 104 l/cap/d. The water supply plan 2012 sets the following targets for the average water consumption of households: 100 l/cap/d in 2017, 90 l/cap/d in 2025 (Københavns Kommune, Teknik- og Miljøforvaltningen Center for Miljø 2012). For comparison: In 1987, the average water consumption in Copenhagen households was 170 l/cap/d.

4.3.3 Financial Issues

The costs for water supply and wastewater treatment must be recovered through fees to the customers. Since the targets for reducing water consumption are set within the water supply plan, measures towards reducing water consumption can be paid for from these fees. Therefore, the costs for the reduction of water consumption are paid by the consumers through the water fees collected.

The price for water in Copenhagen consists of a fixed tariff per water meter in addition to a price per m^3 consumed. In 2013, the fixed price was about EUR 64 once a year, while the price per m^3 of water was EUR 5.25 (for water supply and wastewater disposal). Therefore, a family with three persons consuming the average amount of water must pay EUR 692 per year for water here.

4.3.4 Stakeholders

On national level, the liberal-conservative government enacted a new water law in 2009 (Vandsektorloven). To make the

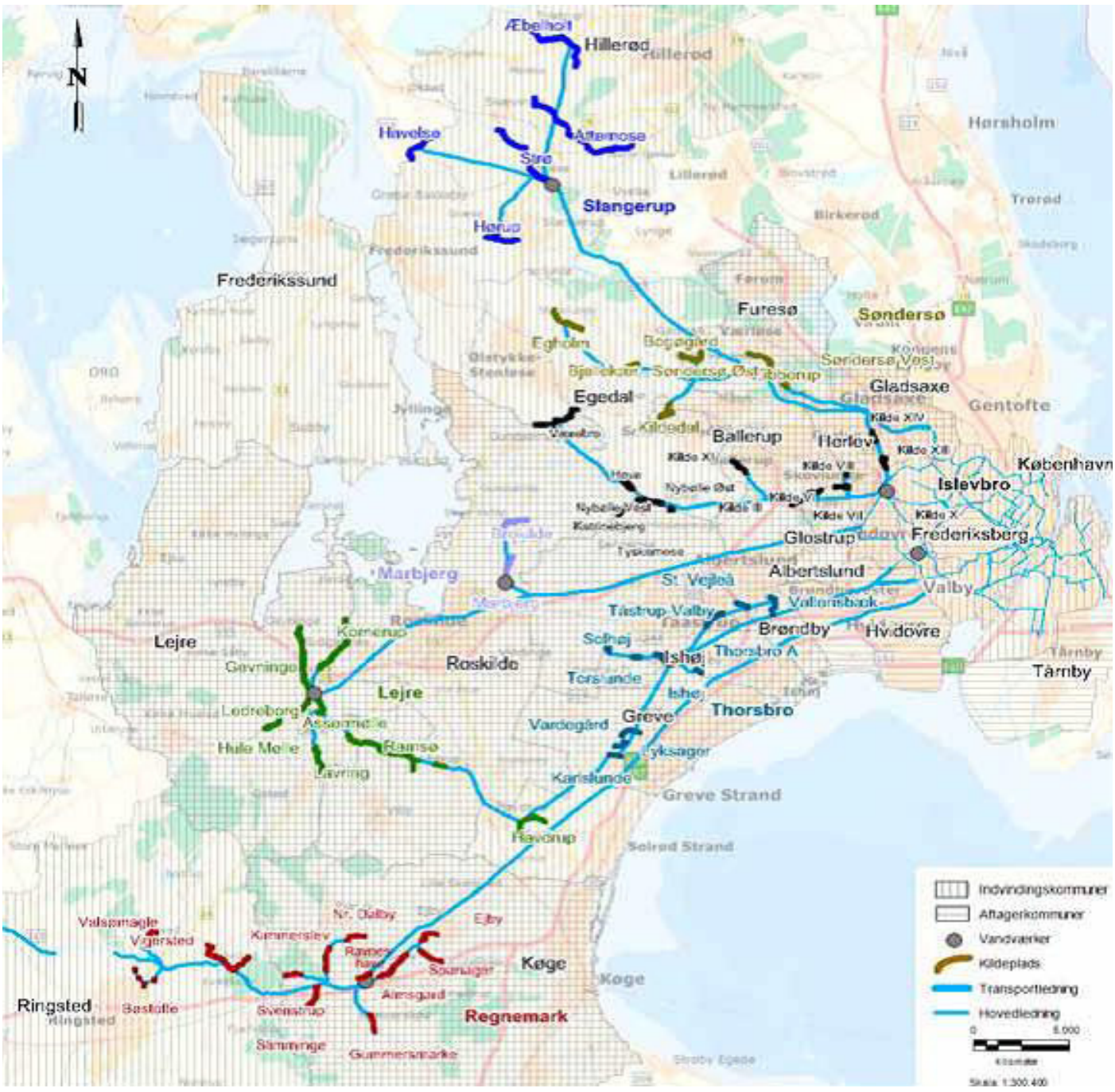


Figure 19: Overview of groundwater sources and transport to Copenhagen (Københavns Kommune, Teknik- og Miljøforvaltningen Center for Miljø 2012)

prices for water more transparent and the water supply more efficient, a **Water Supply Secretariat** based at the Danish Competition Authority has been set up (DANVA 2011). It checks whether the water utilities in Denmark calculate their prices based on the cost recovery principle and whether they work efficiently.

DANVA (Danish Water and Waste Water Association) is a national association which has a membership of 166 water companies (DANVA 2011). Since 1999, it carries out voluntary benchmarking surveys and publishes the results each year. These surveys also serve as a measure to improve the efficiency of the water utilities.

For Copenhagen, the authority responsible for water supply is the **Centre for the Environment** within the Technical and Environmental Administration. Here, the water supply plans are developed in coordination with HOFOR.

The operations of the water supply have been sourced out to a company owned by the municipality. Until 2012, the company was called Københavns Energi, but in the context of increasing pressure towards more efficiency in water supply, there has been a fusion with seven other utilities and since 2013 **HOFOR** is operating the water works and the supply network for the area. Additionally, HOFOR is also responsible for the discharge of wastewater, DH, cooling, and gas supply, and for the operation of the wind parks in Copenhagen.

In regards to the **private sector**, there are companies who adapt their products to the requirements associated with the objective of saving water. For example, the company Johs. Tandrup A/S, located in Allerød, around 30 km north of Copenhagen, produces taps and showers. They are specialized in water saving installations and currently export over 95% of their products.

4.3.5 Challenges

According to Charlotte Storm, the goal of achieving an average consumption of 90 l/cap/d by 2025 will be difficult to achieve without more prevalent use of secondary water sources. Currently, rainwater is the most popular secondary source in Copenhagen. The collection of rainwater from roofs and its supply in the households for toilet flushing and washing machines is regulated on the city level. Installations for rainwater harvesting are subsidized by around EUR 1,300 per installation. Since the installation in a new house costs around EUR 5,000, and the costs are even higher in existing houses, such investments are in most cases not economical and so rainwater harvesting is not used widely in Copenhagen.

A new city regulation will further limit the installation of new rainwater harvesting systems. This regulation states that for new buildings within the city, with a roof slope of 30% or less, green roofs are mandatory in order to retain rainwater, counter the urban heat island effect and make the city more attractive. Rainwater harvesting from green roofs is prohibited, thus, if regulations do not change, the amount of rainwater as a secondary source will not increase.

Currently, the consultant company Rambøll is developing a concept for the utilization of secondary sources such as grey water recycling that can be applied in the development area Nordhavnen. These technologies have also not yet been realized in Copenhagen on a relevant scale.

The efforts described above should be viewed in the context of the expected population growth in Copenhagen. Even if the goals for reducing per capita consumption are met, the total consumption would only be kept stable, and would not decrease. In future, climate change may lead to reduced groundwater regeneration, as more heavy rains that run off quickly, and longer periods of drought are expected (City of Copenhagen 2011a).

Another challenge often discussed in the context of reduced water consumption is the increased retention time in the pipes leading to recontamination and hygiene problems problems. To guarantee the supply for firefighting, the diameter of the pipes cannot be reduced too much. According to three HOFOR employees interviewed, a deterioration of water quality has not been detected in Copenhagen thus far, although water consumption per capita has reduced significantly and chlorine is not used.

4.3.6 Impact Factors

The key factor contributing to the successes seen in reducing water consumption between the 1980's and today was the fact and the realization that high quality fresh water is a limited resource in Copenhagen and in the rest of Denmark as well.

It was a long journey from the time some experts realized this fact until a real reduction in consumption was seen. A highly functioning administration must develop, choose, and implement the appropriate measures. The limitation in water availability could have been solved by transporting water from southern Sweden or more elaborate treatment processes (even going as far as seawater desalination), but the decision was made to concentrate on the management of demand.

In the long term, the water saving campaigns influenced strongly the behavior of the consumers. Charlotte Storm explains that the chlorine which had to be added to the treated lake water had a strong effect on public perception of the problem, because people did not like the taste of chlorine in their water.
Another important impact factor was the introduction of a national water tax in the 1990's. This was done with the purpose of increasing overall water prices and led to a reduction of consumption. Emma Matzen, Manager of the Copenhagen Crown hotel, stressed that costs are the main driver for

facilitating savings in water and energy. On the other hand, citizens in Copenhagen have a higher than average level of education, are aware of ecological and innovative issues, and are proud of the achievements their city has made in the field of sustainability – according to Jörgen Edström, Head of Section Strategy and Development at HOFOR.

Responding to the growing demand, private sector enterprises like Tandrup developed innovative solutions for water-saving household installations, which, assisted by the subsidies from the utility, have become standard equipment in Denmark and in other countries across Europe.

4.3.7 Sustainability

Water is an essential resource. A sustainable city should therefore manage water in a way that ensures its supply is guaranteed in the future as well today.

The withdrawal of groundwater is an ecological aspect of a sustainable water supply. If withdrawal is higher than the regeneration rate, the groundwater level will drop, affecting the surrounding ecosystems by drying out swamps and creeks and causing changes in plant life. If the groundwater is of a high quality, treatment is simple. If additional surface or seawater would need to be treated to drinking water quality, the consequences would include high energy consumption, utilization of chemicals, and creation of wastes like sludge and brine which must then be disposed of. Therefore, the utilization of groundwater without withdrawing more than is regenerated is the most ecological friendly way of ensuring a healthy water supply.

It is also the most economical approach, as costs for the treatment of groundwater are comparatively low. Measures to reduce water consumption may cost money, but this investment pays off in the long run and is low compared to the investment necessary for new treatment plants. Through the introduction of the water tax, the Danish government even generates income that can be used elsewhere.

The higher price of water may be considered a drawback in terms of social considerations, since water is a basic need which must be affordable for everyone. On the other hand, at 0.5 cents per liter tap water is still far cheaper than bottled water. To supply tap water in a constantly high quality is an important social aspect for sustainability. A reduced consumption of an essential resource is a contribution to the resilience of a city.

All in all, the reduction of water consumption is a strong contribution to all aspects of sustainability in Copenhagen. The effect is mainly local. To address sustainability on a global scale, the water footprint would have to be reduced, taking account of the water consumption caused by the production of imported products. This topic has not been considered in this study.

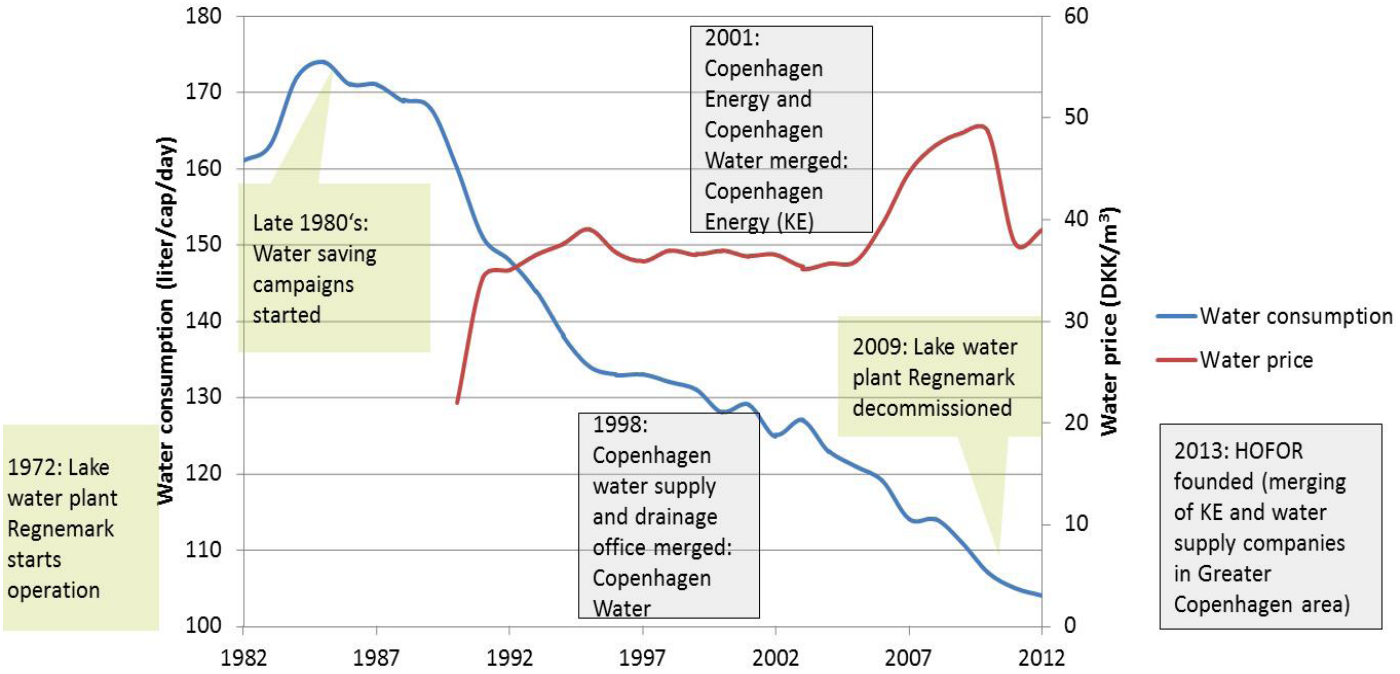


Figure 20: The development of average water consumption and the price for water supply and wastewater disposal in Copenhagen (own graphic based on information provided by HOFOR 2013).
Water consumption: average consumption in private households in Copenhagen; water price: price a person has to pay per m^3 water in Copenhagen, including wastewater treatment and taxes, adjusted on basis of Danish consumer price index (Danmarks Statistik 2013).

4.3.8 Transferability

In principle, this practice example is transferable to any other city, since drinking water is essential everywhere and the measures taken do not require large financial resources or complex technology.

Compared to Germany, where the average water consumption is 121 l/cap/d, Copenhagen has indeed achieved a great deal (104 l/cap/d). On the other hand, Saxony (a German state) has an average household consumption of 84 l/cap/d. This low consumption is caused by the fact that nearly all the houses changed their installations after the German reunification in 1990. Additionally, there is a strong awareness of the importance of saving water in the population. This shows that even without the utilization of secondary sources even lower water consumption may be possible in Copenhagen in the future.

What about cities where water of high quality is not a limited resource? Here saving water makes sense as well due to the energy demand for treatment of water and wastewater and for the transport of both.

What about cities where there is so little water available that even with saving the supply cannot be guaranteed? Here the topic »secondary sources« becomes more urgent, in addition to measures for saving water such as described for Copenhagen.

4.4 ADAPTATION TO CLIMATE CHANGE

Most climatologists now agree that our planet's climate is changing due to greenhouse gas emissions caused by humankind. The consequences of climate change are difficult to predict and vary depending on the region. Especially in densely populated cities, climate change can have a strong impact on living conditions. In Denmark, the summers are expected to become warmer, which will be an issue in densely populated areas where heat is stored (urban heat island effect), and the number of extreme rain events per year will increase.

In Copenhagen, climate change adaptation has been tackled systematically since 2008 according to the precautionary principle. Before any measures could have been implemented, Copenhagen was hit by severe cloudbursts in the years 2010 and 2011, pushing the topic of climate change adaptation high on the political agenda and accelerating the process of adaptation.

Since Copenhagen is situated at the sea, one might assume that a rise in sea level would be the greatest concern. A risk assessment carried out by the administration of the City of Copenhagen, however, shows that until 2060, flooding caused by storm water will probably be a bigger threat (figure 21). Therefore, storm water management is currently in the spotlight in terms of actions concerning climate change adaptation.

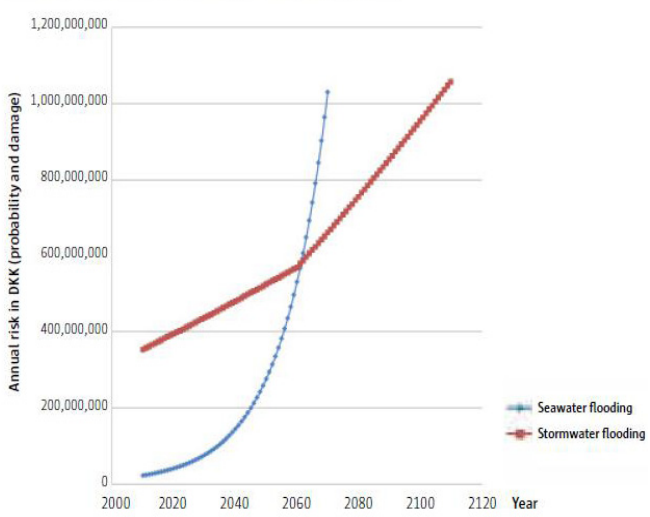


Figure 21: Comparison between the risk from storm water and sea water in Copenhagen (City of Copenhagen 2013)

Copenhagen is not the only city in which the topic of climate change adaptation is currently in focus. The Danish government wants all municipalities in Denmark to develop climate adaptation plans until the end of 2014 (Government of Denmark 2012). It is expected that a number of good solutions for stormwater management will be developed in Denmark in the coming years, many of them transferable to other countries.

4.4.1 Development and Objectives

The idea of developing a climate adaptation plan for Copenhagen was born during a meeting of the C40 Cities Climate Leadership Group in Tokyo in 2008, where representatives of other cities presented their work on similar plans. In 2010, the Copenhagen Climate Adaptation Plan was completed, and approval by the City Council followed on August 25th 2011. Between August 2010 and August 2011, three heavy rain events hit Copenhagen, which statistically only occur every 20, 100, and 1,000 years, respectively. The heaviest cloudburst came down on July 2nd, 2011, with more than 150 mm rain in two hours, causing insurance claims of nearly one billion Euros, and a hospital only minutes away from evacuation.

These cloudbursts suddenly made the topic of climate change adaptation very urgent for the Copenhagen City Council. »Instead of the planned EUR 335,000, they granted a budget of EUR 7 million for 2012« explains Lykke Leonardsen, head of the Department for Strategic Planning in the Centre for Parks and Nature (Technical and Environ-

mental Administration). As a next step, the administration needed to develop a so-called Cloudburst Plan quickly, which was approved in 2012. Here, methods, priorities, and measures for stormwater management in Copenhagen are described and the city is subdivided into 26 catchment areas. For each of these areas, detailed implementation plans are currently developed.

Overall objective of the current activities relating to climate change is to make Copenhagen more resilient against heavy rain events and to protect the city's basic infrastructure. At the same time, the measures taken should make the city more livable (»green and blue«) and reduce the urban heat island effect. The idea is not to adapt the capacity of the existing combined sewer system to the changing rain patterns, but to reduce the amount of stormwater entering the sewer system through local, decentralized solutions. This means that the city quarters will be renovated one by one, decoupling parts of the runoff area and constructing parks and watercourses to retain stormwater. Additionally, in many parts of the city new flow routes for extreme rain events will be created (see chapter 4.6).

4.4.2 Procedure and Measures

According to Lykke Leonardsen, climate adaptation is the »new kid in the class«, meaning that the way this topic interacts with other planning issues such as groundwater protection, wastewater management, town planning etc. has yet to be defined. Also, the experts involved – such as engineers and landscape architects – must learn to cooperate and to understand the approaches used by the other disciplines.

To test this, a pilot project for climate adaptation will be carried out in Skt. Kjelds in the coming years. This is a densely populated quarter in the inner city with an area of 133 ha currently occupied by roads and houses (figure 22). The planning process shall start in 2013 with intensive participation of the residents. As this quarter is in need of renovation in any case, the adaptation to climate change will go hand in hand with urban renewal.

The plan is to reduce the surface area from which the stormwater flows into the sewer system by 30% through so-called Sustainable Urban Drainage Systems (SUDS). The water from these surfaces will be retained and infiltrated into green areas along the roads, into small streams and into storage tanks, from which the water can be recycled. During heavy rains, the water will be discharged on the roads towards the harbor.

Additional measures addressed in the Copenhagen Climate Adaptation Plan concern the installation of backwater valves to protect basements from water in the sewers, pumps to get rid of stormwater even when the sea level rises, and a differential bill for stormwater as incentive for disconnecting private areas.

A solution for disposing of excess water which would be considered only temporarily is the opening of combined sewer overflows to the harbor. Jan Burgdorf Nielsen, project manager for climate adaptation in the Centre for Parks and Nature, explains: »We have closed 60 outlets during the last 15 years, now the overflows become more frequent again.« The city does not want to risk its achievements in the improvement of water quality to EU bathing water quality in the central harbor (Clauson-Kaas et al. 2008).

4.4.3 Finances

Because adapting to climate change is a cross-sectoral topic, measures are financed through diverse stakeholders. The climate change plans have been set up and financed by the city of Copenhagen. Measures in context with stormwater management are carried out by HOFOR and are paid for through water fees. If roads or parts of the city have to be renewed anyway, large parts of the costs are taken over by the stakeholders responsible for these issues, even though they might additionally serve climate adaptation.
Lykke Leonardsen estimates an increase of water fees by about DKK 50 per month for an average family living in an apartment in the city (almost EUR 50 per capita and year), which would mean an increase of 20% in water costs for

Figure 22: Skt. Kjelds, location of pilot project for climate adaptation in Copenhagen (own photographies by Marius Mohr)

a family of three with an average rate of water consumption. Although this means everybody has to pay a share for climate adaptation, in the case of heavy rainfalls the damages will be lower so the citizens stand to profit from the measures taken.

4.4.4 Stakeholders

The topic of climate change adaptation in Copenhagen has been driven by two persons from the Centre for Parks and Nature of the Technical and Environmental Administration, Lykke Leonardsen and her colleague Jan Rasmussen after their visit to Tokyo in 2008. They succeeded in convincing the members of the City Council that it is sensible to act pro-actively on this issue.

After the heavy rains in 2010 and 2011, additional staff members were assigned to work on climate adaptation. Currently, there are nine people from the Centre for Parks and Nature engaged with the issue. For the implementation plans, consultants like Rambøll are hired. In parts of the city where climate change adaptation goes along with urban renewal as is the case in Skt. Kjelds, the CBD is also involved. HOFOR – since it is the utility for water and wastewater – is responsible for the implementation of measures regarding stormwater management, assigning work contracts and consultancy tenders to private companies.

During the process of implementing measures, citizens are involved as well. They provide valuable information about water levels during flooding and are involved in a public dialogue during the development of the implementation plans for the different catchment areas. As Lykke Leonardsen explains, it is not always easy to convince citizens that measures cannot occur everywhere at the same time and that some people will have to wait until their area is scheduled for adaptation.

Water does not care about borders, so the cooperation regarding stormwater management between neighboring municipalities is very important. Research also plays a major role in climate adaptation; the Copenhagen University and the DTU are carrying out research projects in this context. In 2012, the foundation Realdania launched an initiative called »Klimaspring«, which aims to support companies developing new solutions for the management of extreme rainfall events in existing cities. These solutions should be applicable in Denmark as well as abroad and will increase the security in terms of flooding while additionally creating economic opportunities. Currently, proposals are being assessed.

4.4.5 Barriers and Challenges

A barrier that had to be overcome before work on the Climate Adaptation Plan could be started was the widespread perception that mitigation of climate change was the aspect to focus on, while adaptation was considered akin to surrender. After the heavy cloudbursts in 2010 and 2011, the topic has been given high priority in Denmark. If, however, there are no major cloudbursts in the next few years, or if other topics gain in relevance, it is possible that climate adaptation will lose out on the political agenda. The challenge is to maintain systematically working on a topic that is precautionary and thus depends on political will and public awareness. However, the most recent flooding events in Germany – after the historical cloudbursts of early June 2013 – resulting in unprecedented flood levels that left thousands of Germans unsheltered and caused economic damage in the range of multi-billions of Euros, are likely to keep this topic on the agenda in large parts of Europe.

On the other hand, the tasks are immense. Over the next decades, the entire stormwater management of Copenhagen needs to be remodeled. This leads to conflicts and differing opinions, for example should rainwater from metallic roofs be discharged into the harbor? Some say yes,

Figure 23: Left: Green roofs in Vauban, Freiburg (own photography by Marius Mohr); Right: SUDS in Augustenborg, Malmø(Kazmierczak und Carter 2010)

because it decreases the risk of floods and sewage overflows, and some argue no, because for example copper might be harmful to the harbor ecosystem. What to do about the infiltration of rainwater? Does it have negative impacts on groundwater quality and therefore affect water supply? Especially the handling of polluted road runoff in densely populated areas is a challenge for which no real solution has yet been developed (see chapter 4.5).

These challenges do not affect the use of technologies only. As Mikkel A. Thomassen, partner of a small enterprise called Smith Innovation which manages the Klimaspring project on behalf of Realdania, puts it: »To me a main barrier is that new solutions require collaboration between firms, sectors and knowledge areas that at present do not work together.«

4.4.6 Impact Factors and Framework Conditions

Copenhagen has a large administration with highly skilled and motivated employees. These circumstances are critical for ensuring that a topic which is merely precautionary and did not exist on the political agenda – as was the case for climate adaptation in 2008 – is taken seriously and dealt with in a systematic way. The idea to begin taking action was picked up from other cities, which shows that networking and exchange between city administrations on a global scale is important for discovering new developments early.

The damages caused by the rain events in 2010 and 2011 showed the public that the dangers of climate change were not just statistical, and made it much easier to get funding for measures to reduce damages like that in future. This has been amplified by the election of a new government in Denmark in September 2011, which has put climate change adaptation high on their agenda. Ida Auken, the Danish Minister of the Environment, is involved deeply into climate adaptation issues.

4.4.7 Sustainability

The climate change adaptation measures planned in Copenhagen focus on stormwater management. The ecological impact of this management will include reduced overflows of wastewater from sewers to streams and the harbor, and more green spaces and water bodies in the city. This will increase biodiversity in Copenhagen. Another ecological benefit will be that the infiltration and discharge of highly polluted rainwater from streets into the environment should be prevented.

In the Copenhagen Climate Adaptation Plan, economical calculations regarding potential damages versus costs for measures are analyzed in detail. Potential damages in the future are difficult to predict, so it is often not possible to evaluate whether measures to reduce them are economically sensible or not. However, the costs for climate adaptation are distributed evenly over all citizens and over a long time span, so each individual is only paying a small share, while damages can ruin individuals if no measures are taken. Moreover, since the City of Copenhagen plans to increase liveability through adaptation measures and since companies may be able to offer solutions that are proven to work in Copenhagen on the international market, the planned measures for stormwater management appear sustainable economically and socially, as well as in terms of resilience.

Although the impact climate change will have on Copenhagen in the coming years is difficult to predict, stormwater management is an important topic for cities and is a logical next step after most challenges regarding treatment of wastewater have been overcome. Wastewater treatment also becomes more sustainable (ecologically and economically) if it is not mixed with rainwater. Additionally, the existing wastewater treatment plants will only be able to manage the increase in wastewater from a growing population if the amount of rainwater is reduced.

4.4.8 Transferability

The transferability of climate adaptation measures in Copenhagen is limited by its dependency on the political and regulatory conditions and on the current and future climate. Globally, these framework conditions vary greatly. However, the need to adapt to a changing climate will increase in the future in most regions, and many areas will face more heavy rain events. In the EU, the commission adopted the EU Strategy on Adaptation to Climate Change in April 2013 (European Commission 2013a), encouraging all member states to develop their own climate adaptation strategies. Therefore, it can be expected that climate change adaptation will gain in importance at least inside the EU over the coming years.

Some examples of stormwater management that are currently being planned in Copenhagen have already been implemented in other countries. In Malmö, for instance, the Augustenborg quarter was renovated, and included Sustainable Urban Drainage Systems (SUDS), between 1998 and 2002 (figure 23). This quarter, built in the 1950's on an area of about 32 ha and 1,800 apartments, faced a difficult economic and social situation and frequent flooding from overflowing sewers in the 1990's. As a result of the renovation, the rainwater runoff rates have decreased by half and the newly created green space has improved the image of the area. Jan Burgdorf Nielsen says: »With Augustenborg, Malmö is years ahead of Copenhagen.« Another example for SUDS has been implemented in the neighborhood called Vauban, in Freiburg (Germany).

4.5 TREATMENT OF ROAD-RUNOFF – DUAL POROSITY FILTRATION

Construction of the sewer system in Copenhagen started in 1857 with the objectives of preventing diseases caused by feces and draining the rainwater out of the city (Sørensen et al. 2006). A combined sewer system was chosen, so household wastewater and rainwater were collected in one system. But since this led to a deterioration of water quality in the harbor and the Øresund, wastewater treatment plants were installed starting in 1904. In the 1990's, the wastewater treatment plants were expanded to include processes for nutrient removal, thus aiming to reduce eutrophication of the Øresund and the Baltic Sea. Today, the two central wastewater treatment plants Lynetten and Damhusåen have a capacity of 750,000 and 350,000 population equivalents respectively and discharge their effluent via two 1.5 km and 1.2 km long pipes into the Øresund (European Commission 2012b). By constructing large reservoirs for storage of rainwater, the frequency of sewer overflows into the harbor during heavy rain events has been reduced, resulting in very good water quality in the harbor most of the time.

In the last decades, there has been a tendency towards separating the discharge of rainwater and household wastewater, for the following reasons:

- Reducing overflows from combined sewer system.
- Increasing the capacities of the existing sewers and wastewater treatment plants so they are able to cope with population growth.
- Utilizing rainwater to improve liveability in the city instead of discharging it quickly.
- Adapting to more frequent and heavier rain events due to climate change (see chapter 4.4).

If rainwater falling on roads and metal roofs is discharged separately, additional treatment may be necessary to protect receiving waters and groundwater from pollutants that are transported with the runoff. Since the focus has been on treatment of household wastewater for such a long time, not many suitable processes for the treatment of this runoff exist, which occurs temporarily and with strong variations in quality and quantity. During the past decade in Copenhagen, a process for the treatment of road runoff in densely populated areas with a very high runoff quality called Dual Porosity Filtration (DPF) has been developed.

4.5.1 Development and Objectives

The issue of treating road runoff arose in Copenhagen during the development of Ørestad, where a green profile was aspired to. The intention was to discharge all the rainwater into a 10 km long system of channels with high ecological value. But the rainwater running off of streets can be polluted by many different substances, for example: lead, copper, chromium, zinc, pesticides, soot, PAH's, pathogenic bacteria, nutrients, organic substances and de-icing salts (Clauson-Kaas et al. 2008). By coincidence, Marina Bergen Jensen from the Department of Geosciences and Natural Resource Management at the University of Copenhagen met an engineer involved in the development of Ørestad in 2001. Together with Rambøll, she started to develop the DPF as a solution for the treatment of road runoffs.

Inspired by natural fractured soil, the DPF has thin compartments with high porosity for convective flow and compartments with low porosity for retention of contaminants. These are placed alternately on top of each other, supporting a horizontal flow (figure 24). The high porosity layers are kept open by a polyethylene structure, while the low porosity layers are filled with a mixture based on limestone grains (grain size: 1-3 mm). The water flows horizontally through the filter driven by gravity and then drains off after the rain event is

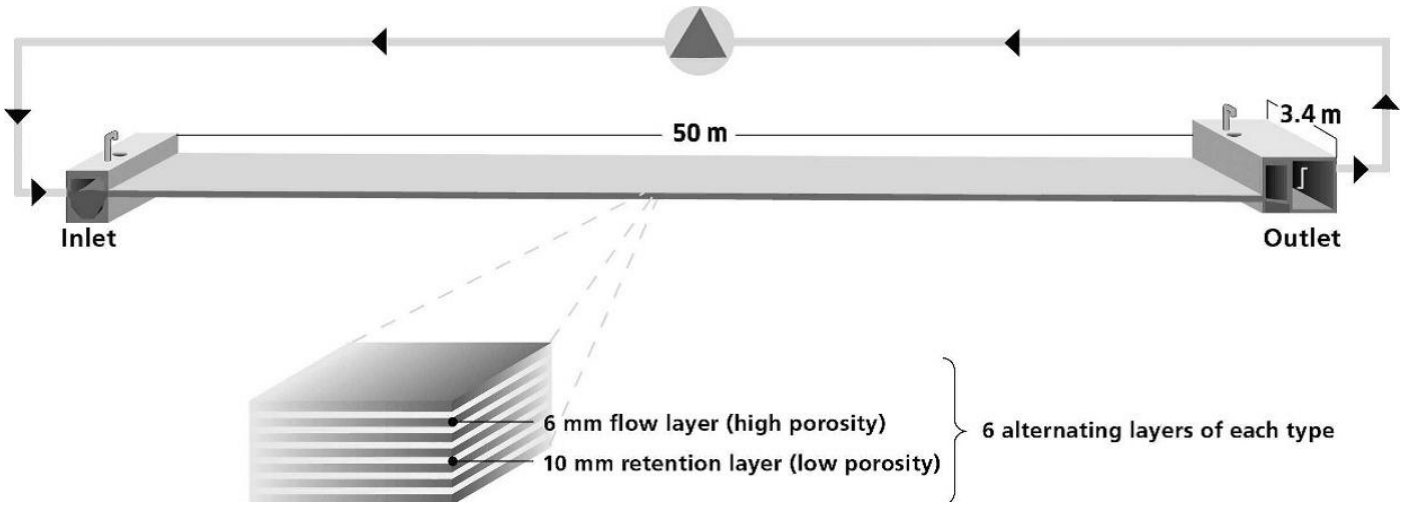


Figure 24: Structure of the DPF (Cederkvist et al. 2010)

over. The processes which purify the water are sedimentation, adsorption, and biodegradation (Jensen et al. 2011).

4.5.2 Procedure and Measures

In the beginning of the first development phase, lab studies about the contaminants in road runoff and methods to eliminate them were carried out by Marina Bergen Jensen and Rambøll. In the years 2005 and 2006, a pilot plant for the treatment of 1.3 ha road area runoff and a maximum discharge of 5 l/s was constructed in Ørestad (60 m long, 10 m wide). This plant contained two parallel filters, one with six pairs of layers and one with 18 pairs of layers. Starting at the end of 2006, this pilot plant has been operating and monitored for more than two years, proving, in general, that the concept works (Jensen et al. 2011).
Since this pilot plant was built as a prototype, the next step would have been to develop an optimized production line to lower the investment costs. This step has been delayed due to a lack of money. In 2011, it was decided to implement the Actiflo® process, a flocculation/sedimentation process by Krüger A/S, for the treatment of road runoff in Ørestad because this entailed lower costs than using the DPF process.

Simultaneously, a new project to industrialize the production of the DPF was initiated. This optimized model will be tested in another pilot plant which is being constructed in 2013 in Krogebjerg Parken in the Vanløse district to purify the runoff from ten to 15 roads (0.5 ha) within the course of climate change adaptation measures. This pilot filter is again 60 m long, but only 0.5 m wide and 0.5 m deep and has a capacity of 0.5 l/s. In contrast to the first pilot plant, the first third of the low porosity layers are not filled with filter material. This is thought to improve the back-flushing of settled particles. The tests are scheduled to start in August 2013.

4.5.3 Financing of the Project

At this time, a total of around EUR 1 million have been invested in research on and development of the DPF, while another EUR 250,000 will be required for conducting the tests to be carried out in Krogebjerg Parken. The funds were provided by Rambøll, the water utility (now called HOFOR), Realdania, the developing company for Ørestad (now called City & Port), the city of Copenhagen, the Danish Government, and the University of Copenhagen.
The investment costs for the polyethylene plates are currently estimated at around EUR 25,000 per 1 l/s maximum discharge. The costs for installation, filter material, retention volume, the inlet and outlet, transport of road runoff to the filter and the discharge to a receiving water body will be additional. Marina Bergen Jensen says: »There is no standard plant defined yet, so it is too early to define investment costs for the whole plant.« The life cycle of a DPF is expected to be around 20 years.

Operational costs arise due to the estimated need of flushing the filter twice a year and for the disposal of the accumulated sludge. The area requirements of the DPF are around 30 m^2 per 1 l/s maximum capacity. The filter can be installed underground, allowing for this area to be covered by a park, sports facilities, or parking spaces, or it can be aboveground or even designed to be urban furniture, e.g. a bench (30 m^2: 60 m long, 0.5 m wide, and 1 m high).

4.5.4 Stakeholders

According to all those interviewed, Professor Marina Bergen Jensen of the University of Copenhagen has been the main driving force behind the development of the DPF. Especially in the development of the first prototype, engineers from Rambøll consultancy also played a key role, contributing their experiences and requirements for reliable solutions to Marina Bergen Jensen's ideas.

Since the development of this new technology was triggered by the needs identified during the development process in Ørestad, the stakeholders involved include the development company (today City & Port), the water utility (today HOFOR), as well as the city of Copenhagen's Technical and Environmental Administration and Centre for Parks and Nature. Realdania and the Danish Government provided funding for the development of the filtration system.

Besides Rambøll, other private companies were involved as well: the construction companies NCC Construction Danmark A/S and Byggros; the German companies Funke Kunststoffe GmbH and PURUS Plastics GmbH in the first phase for developing the polyethylene parts; Wavin Group from the Netherlands for design of the polyethylene parts during the second phase.

The intellectual property for the DPF (Patent disclosure PCT/DK2003/000443) is held by the University of Copenhagen, but will be sold to the company taking over the manufacturing of the plastic materials when the development is completed.

4.5.5 Barriers and Challenges

It is important to differentiate between technical and non-technical challenges. The technical challenges include the high fluctuation in the quantity and quality of road runoffs. Although the DPF has been able to purify highly polluted influent to create a high quality effluent (see chapter 4.5.8), it may be necessary to bypass this step in the case of heavy cloudbursts. On the quality side, high concentrations of de-icing salt in winter are still a challenge to which no reasonable solution exists. Regarding maintenance, a fully automated back-flush has yet to be developed.

The non-technical challenges concern economic issues. In order to be widely implemented, the DPF process must

Table 1: Average removal efficiencies of the two parallel DPF and city of Copenhagen requirements

Parameter	Removal Effiviency DPF 6 (%)	Removal Efficiency DPF 18 (%)	Requirement (mg/l)
Suspended Solids	91.5	98.9	25.0
Phosphorous	73.4	78.1	0.1
Zinc	69.9	87.2	0.11
Copper	51.2	61.6	0.012
Chromium	39.4	44.4	0.01
Lead	88.9	97.8	0.0032

Source: based on Jensen et al. 2011

be comparable in price to other processes that could be applied, despite the fact that the runoff quality the DPF produces may be better. If the regulations are changed to demand higher runoff quality, low cost treatment processes for rainwater could not be applied because they would not provide the required water quality. To reduce the costs of the DPF, an investment into industrialized production facilities for the plastic parts must be made.

4.5.6 Impact Factors and Framework Conditions

The canal system in Ørestad has been designed to improve liveability in the area, adding value to the plots. Thus, for the developer, the main driver was of an economic nature. For the water utility and for Copenhagen's administration, the city's image as a frontrunner in terms of sustainability is an impact factor that makes these stakeholders look for innovative and ecologically friendly solutions. Simultaneously, they aim to support local companies by giving them the chance to create references on innovative solutions that can then be exported.

Christian Nyerup Nielsen, Head of the Department of Urban Water Management and Climate Adaptation at Rambøll, sees a chance for the implementation of the DPF process during the establishment of large cloudburst corridors on roads during the course of implementing the Cloudburst Plan. Although treatment is not realistic during heavy cloudbursts, the runoff from these roads must be treated during normal rain events if it is discharged into the environment. For Rambøll, the main driver for investing in this development was to acquire cutting-edge knowledge regarding rainwater management and treatment. And in this they have been successful, believes Christian Nyerup Nielsen.

4.5.7 Successes and Success Criteria

Again, there is a difference between technical and non-technical successes. As no version of the DPF has made it to the market yet, the non-technical, for example economic, success of the development cannot be measured. The technical success has been well documented during the pilot phase in Ørestad and published in scientific journals. From January until July 2007, samples were taken during 25 rain events in the inlet and in the outlet of the two parallel filters. The following table shows the average removal efficiencies of both filters for selected parameters and the city of Copenhagen's requirements for discharge into recreational canals.

The effluent from DPF 18 complied with the requirements in all parameters except copper and chromium, while the DPF 6 additionally exceeded the limits for suspended solids and phosphorous once during a relatively heavy rain event (Jensen et al. 2011). Chromium was not eliminated by the DPF as well as the other parameters; its concentrations exceeded the limits several times. Experiments carried out at the DPF in Ørestad showed that the addition of less than 1% ochreous sludge, a waste product from groundwater treatment, to the limestone in the low porosity layers improved the removal of chromium significantly (Cederkvist et al. 2010).

4.5.8 Sustainability

Under economic aspects, the sustainability of this practice example depends very much on the value that is given to clean water bodies in a city and which, as the example in Ørestad shows, can lead to higher values for plots in development areas. A social aspect of sustainability is the recreational value of water courses in cities, which must be weighed against higher water prices, should the costs for the treatment of road runoff be added to water charges.

The main sustainability benefit for this example is ecological. Christian Nyerup Nielsen stresses: »The DPF process is very effective; it does not consume energy, does not need any chemicals and it is built underground, so it does not need extra space.« It also helps improve the ecological quality and biodiversity in sensitive water bodies and protects the groundwater.

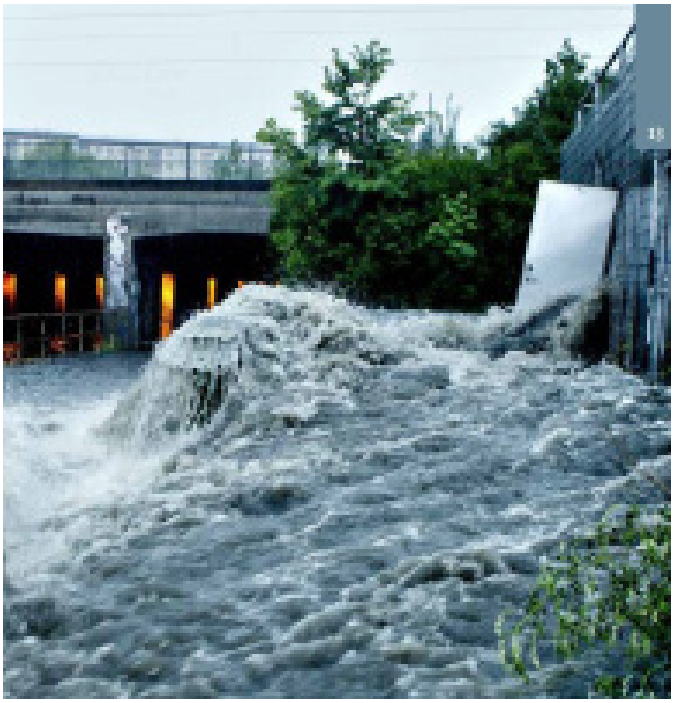


Figure 25: Copenhagen after the cloudburst in July 2011 (City of Copenhagen 2012d)

*The Danish Meteorological Institute defines such an event as »more than 15 mm of precipitation in the course of 30 minutes". As outlined previously, the rainfall event on July 2, 2011 resulted in water amounts of about 100 mm in one hour only (City of Copenhagen 2012d).

4.5.9 Transferability

How to treat road runoff is an issue for most cities in industrialized countries. Currently, different solutions are used, but most solutions are decentralized, such as adding a filter into existing gullies, with relatively high maintenance needs and relatively low removal efficiencies – especially for dissolved contaminants. Therefore, a solution like the DPF has a large market potential if the investment costs can be kept low. On the other hand, the market depends on regulations for the discharge and infiltration of rainwater. Currently, very few cases exist in which the regulatory requirements are so high that the high performance of the DPF would be necessary.

In regions outside the wealthy industrialized countries, the biodiversity of water bodies is not an important issue yet, and often there is so much untreated wastewater that road runoff does not matter. Here, the DPF technology could make a contribution to water supply, as the effluent is of a very high quality. Additional processes would have to be added, e.g. for disinfection – Marina Bergen Jensen already has contacts in Addis Ababa and Dar es Salaam, trying to make the technology transferable.

4.6 CLOUDBURST MANAGEMENT PLAN 2012 AND CRISIS MANAGEMENT

In light of the major crises the city of Copenhagen has recently faced, putting out large fires, managing major riots or reacting to criminal or terrorist acts as well as to major snow storms pale in comparison. With three massive cloudburst events* within just the past three years, each of which has resulted in massive damage to citizens, physical infrastructures and assets (see figure 25), the city's major priority lies with better preparing its citizens and built environment to more effectively and concisely cope with such events in the future.

Remarkably, within the context of the larger Climate Adaptation framework, designed to help push the city towards a more sustainable future, Copenhagen acknowledges disaster preparedness and disaster resilience as an integral part of a comprehensive definition of sustainability. Hence, the Cloudburst Management Plan of 2012 (further abbreviated as CCMP) is a direct offspring of the Copenhagen Climate Adaption Plan.

In sum, the CCMP clearly defines methods, priorities and measures to increase the resilience of the city in terms of defined categories of cloudbursts. It also identifies 'acceptable' damage levels after recurring events, based on sound risk analysis. Moreover, it assigns responsibilities to public and private actors, underscored by financial budgets necessary to deliver the respective resilience missions. Finally, it prioritizes the planned measures, draws very

precise links to emergency management operations, and uses the present political momentum unleashed after the disastrous events of the past three years to rally all relevant stakeholders in support of this ambitious endeavor. Uniquely, the city administration clearly states that implementing and realizing all proposed steps and measures will take up to 20 years time. This is a remarkable time frame in view of the typical half-time of relevant decisions made by policy-makers who are exposed to short and medium term election cycles.

4.6.1 Development and Objectives

The Copenhagen Climate Adaption Plan, which was officially already launched in 2010, identified the need for improved disaster resilience within the city, specifically addressing flood related scenarios caused both by extreme rainfall events as well as by storm surges pushing sea water inland (see chapter 4.4). However, this Climate Adaptation Plan clearly focuses on the prevention and reduction of damages through infrastructural measures, and thus disaster resilience is still only a minor element in the overall equation. Undoubtedly, the extreme rainfall events of 2010 and 2011 were powerful catalysts for pushing decision makers on the municipal level to beef up their (political and financial) efforts towards more comprehensively developing a strategic plan aimed at mitigating the consequences of such cloudbursts by adapting infrastructure to better cope with the enormous amounts of water. As an outcome, the CCMP was approved in 2012.

Under the auspices of Ayfer Baykal, Mayor of theTechnical and Environmental Administration, the plan outlines an organizational, financial and technical roadmap for the forthcoming 20 years. It aims at giving guidance to all involved stakeholders on when, what and how things need to be done to increase the city's cloudburst resilience.

Source: City of Copenhagen 2012d

Ayfer Baykal, Mayor of the Technical and Environmental Administration, Cloudburst Management Plan 2012

"In future, extreme rainfall events will increase in frequency and intensity. For this reason, we need to take adaptive action (…) We can never protect the city fully, but we can prepare the city far better for the floods than is the case today."

4.6.2 Procedure and Measures

Before going into details on concrete measures to be taken on various levels, the CCMP underscores the importance of flood mapping and risk analysis as the fundamental basis for an informed and sound decision making process on the administrative level when it comes to assigning budgets for adaptive measures. As a consequence, the city defines a 100-year rain event as the threshold for the category of events it aims at improving the protection against. The sewerage system is capable of handling ten-year rainfall events. As it has been decided not to extend the capacity of the sewerage system, in case of rain events with higher intensities than ten-year events, additional measures must come into effect. Furthermore, the premise of this risk analysis includes accepting a water level of no more than 10 cm above ground for 100-year events.

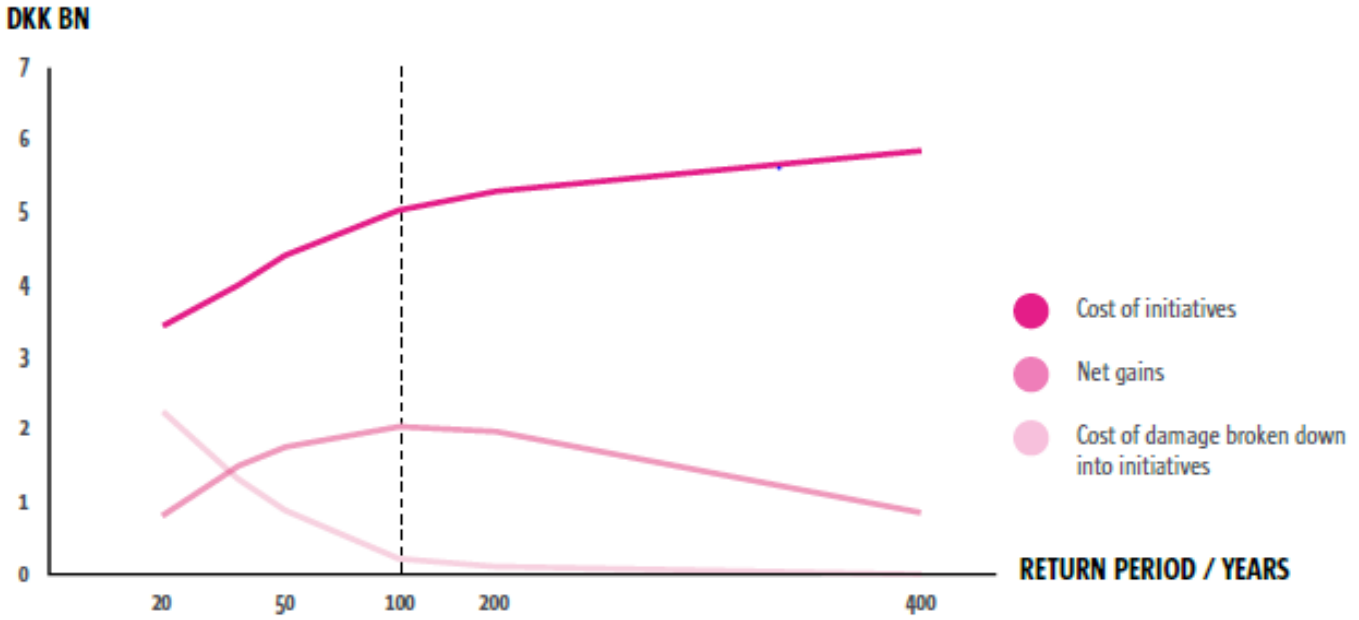


Figure 26: Cost benefit analysis for CCMP (Københavns Kommune 2011)

The main measure to be taken to improve the city's resilience against such floods is allowing for the drainage of massive amounts of water out to the sea.

The original solution outlined in the Climate Adaption Plan suggested to reduce the stress of surface drainage by evacuating large amounts of (surface) water to open spaces such as parks, sports grounds or open spaces. However, especially the events of July 2011 and subsequent calculations have lead the city to change its strategy. Instead, the major strategy of the CCMP is to substantially increase the city's capacity for draining the water towards the sea via

- new tunnel/pipe systems complementing the existing sewerage network (so far, waste and rain water are drained through the same sewerage system) and
- storing and draining excess water at ground level, for example by reopening streams, constructing new canals and using roads with high curbstones to lead pluvial flood water into these.

As outlined above, the CCMP completely overhauls traditional risk dimensioning for the city of Copenhagen, shifting the focus towards the 100-year pluvial flood event, whilst accepting the 10 cm water level on the surface. Not only will that level prevent water from entering basement windows, but fairly inexpensive reconstruction of roads and curbstones will allow for easier use of the former as drainage routes. From an economic viewpoint, the city has applied cost-benefit analysis (figure 26) showing that the greatest socio-economic gains of adaptive measures can be reached when using the 1 in 100 year event as the critical threshold.

With respect to ranking the various measures and initiatives, the CCMP follows an approach similar to that of the Climate Adaption Plan and includes the following considerations:

- Priority treatment for high-risk areas: these areas have already been identified and mapped within the Climate Adaptation Plan and ought to be improved before consecutive steps are taken.
- Low-cost high impact measures: areas such as Ny Kongensgade and Ved Stranden, where measures to facilitate drainage into the open sea are very easy to implement at fairly low costs, should also be prioritized.
- Include pluvial flood protection in all on-going and new urban development projects: Costs for adaptive measures can be limited by including such measures into the design processes for new urban developments and renovation planning of existing infrastructures, such as the road system.

4.6.3 Finances

Evidently, the citizens of Copenhagen are equally hit by the consequences of such pluvial floods as are publicly owned and operated infrastructure throughout the city. Hence, when it comes to financing the various adaptive measures, the CCMP underscores the importance of a sound burden sharing between all involved stakeholders. At the end of the day, the city suggests an investment mix, comprised of

- A municipal share

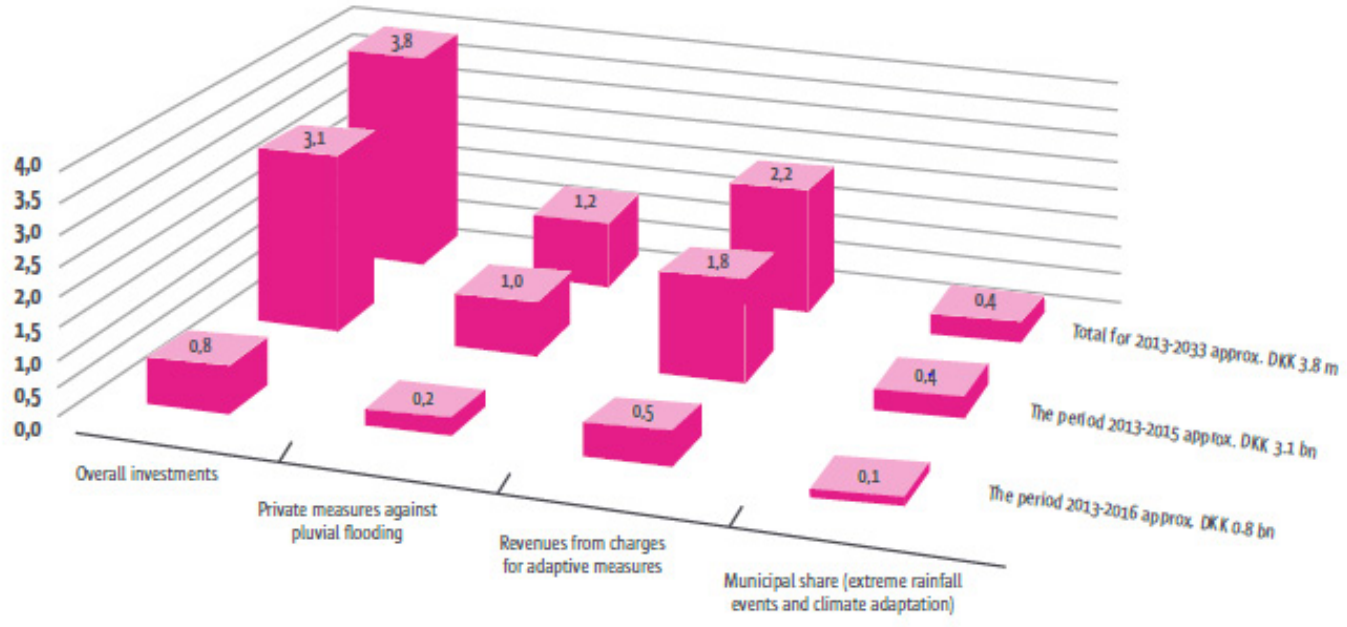


Figure 27: Finances to be committed to the CCMP 2012 (Københavns Kommune 2011)

- Revenues from charges (this means citizens pay for water consumption)
- Private measures against pluvial flooding

Figure 27 shows the composition of these three investment categories broken down in three different time periods. The overall investment for this 20-year plan amounts to DKK 7.7 billion.

4.6.4 Stakeholders

The key to success in this complex endeavor, as identified by the CCMP, is joint action taken by property owners, the utility companies and the city administration. For the latter, as is the case for the Climate Adaptation Plan, the issue of cloudburst management is headed by the Centre for Parks and Nature within the Technical and Environmental Administration, headed by Ayfer Baykal.

The administration is closely working with HOFOR the main utility company responsible for all water and waste water processes in the city, and in this case also the city administration of Frederiksberg (located southeast) as well as their local utility company, since all rainwater falling in Frederiksberg during a cloudburst, which must be drained to the sea necessarily must go through Copenhagen.

Finally, and probably most importantly, the city administration underscores the importance of all relevant security organizations and first responders playing a crucial role in the immediate aftermath of a major cloudburst. Whilst suggesting the measures included in the CCMP, the city concurrently overhauled its emergency and response planning procedures, including the command structures for all response forces with a crucial crisis management role. First introduced in 2011, the so-called 'Plan for Fortsat Drift' (the closest translation would be civil contingency plan) specifies communication and command and control procedures among the involved crisis groups.

Whilst the Fire Department usually plays a lead role in coordinating response operations in a major crisis situation, it is unique of Copenhagen to include all relevant departments within the city administration in their preparedness planning process. As Niels Ole Blirup, chief officer at Copenhagen Fire Department points out: »We have a committee comprised of representatives from all relevant departments at the city level (Technical and Environmental, Health, Finance, etc.) and our first responders. This permanent committee assesses the impact and then plans for any chosen possible crisis scenario for the city, disregarding the likelihood of the event.« Uniquely, at the beginning of each year, this committee choses four specific threat scenarios it aims at focusing on. That includes drafting comprehensive preparedness plans for each scenario as well as scenario-applied exercises involving all actors of the response communities as well as citizens.

4.6.5 Impact Factors, Barriers and Challenges

Climate Adaptation, including disaster resilience, is the center of focus for key policy-makers in Copenhagen and Denmark as a whole. Within the past four years, the city has mobilized massive resources in terms of finances, new administrative functions and policies towards labeling the city internally (public support) and externally as a European frontrunner in climate adaptation AND disaster resilience with an obvious focus on naturally caused disasters.

The topic has continuously gained momentum, tragically facilitated by the disastrous events of 2010 and 2011.

Because citizens have first hand experienced with what it means to be extremely vulnerable to the destructive powers of nature and as these memories are still very fresh, the administration has managed to translate this momentum into strategic long-term planning (the CCMP being the focal point of this). In spite of the fact that plans and strategies will undergo fundamental change and scrutiny by subsequent city governments (which in turn may and will have different priority settings), the city has paved the way towards a more disaster resilient urban system in a pragmatic way, involving all critical stakeholders and distributing the prevalent financial burden among all players.

4.6.6 Sustainability and Transferablity

As identified earlier herein, disaster resilience, and in this case specifically cloudburst management, has been identified by the city of Copenhagen as one critical pillar in its overall framework towards moving the city towards a more sustainable urban system. Hence, the understanding and interpretation of sustainability as a concerted approach that spans across numerous urban sectors and systems is by far broader than the more 'conventional' triangle-model of sustainability, where the focus lays on economic, social and ecological aspects only. Thus, although the overall target of becoming an entirely carbon neutral city by 2025 remains the top priority, the city fully acknowledges and with this CCMP pervasively underscores that disaster resilience is a key prerequisite for any other approach towards more sustainability. The roadmap towards implementing these measures over the course of 20 years, sharing the burden fairly between all stakeholders is also a balanced and modest approach that could be a model for other cities. However, it is always purely speculative how ambitious and financially well-equipped the whole field of disaster resilience would have evolved in Copenhagen had the disastrous events of 2010/11 not have happened on such a scale.

With respect to overall disaster preparedness, Copenhagen has clearly shifted its overall perspective from solely looking at scenarios in a probabilistic way asking 'what is likely to happen' to a rather anticipatory perspective loo-

king at scenarios that simply 'could happen'. Handling this approach on such an integrative level is time- and resource intensive and, one may conclude, strongly resembles a very Danish approach of solving complex challenges.

4.7 WORLD'S MOST BICYCLE FRIENDLY CITY

Copenhagen is famous for its bicycling culture and is seen worldwide as one of the best cities in which to ride a bicycle. In Copenhagen, cycling is described by most people as the most convenient type of urban commuting. Just 1% of the population says that they are using their bikes for environmental reasons. Copenhageners use their bike within the inner city for about 50% of their travels. 55% of all school children use the bike to go to school. In general, a mobile share of about 35% within the whole city is estimated. Thus, cycling in Copenhagen is not a niche for people with a specific conviction.

Most distances travelled within the city are short, the terrain is flat and the bicycling infrastructure is in very good condition and well-designed. Bicycling is becoming more popular and safer since the lanes were broadened. Frequent separation from car traffic and other infrastructural components help make bicycling more attractive as well. In addition to Copenhagen's regular cycle grid which contains about 350 km of paths, fast lanes will be installed and a Super Cycle Highway grid will connect the city with its suburbs. In the summer, public bicycles are provided by the municipality throughout the whole inner city for a deposit.

Copenhagen is even planning to improve its status as the world's most bicycle friendly city. The influencing factors in the past and near future are discussed in the next paragraphs.

4.7.1 Creation and Objective

To accomplish this high bicycling standard within Copenhagen, several steps were needed. Copenhagen – like many European cities – had a high share of cyclers back in the beginning of the last century. With the rapid development of cars, the global economic boom and especially

Figure 28: Impressions from Copenhagen's Bicycling Culture (Pictures 1, 3, 6: City of Copenhagen, Technical and Environmental Administration 2011; pictures 2, 4, 5: own photographies by Dominik Noeren 2013)

new urban planning approaches after World War II, bikes became less and less common on the streets. It was during the energy crisis in the 1970's that many Copenhageners engaged in demonstrations to reduce the suburban car traffic in the inner city (40% of Copenhageners lived in the City of Copenhagen). Since then, a slow but lasting process began to improve conditions for cyclists and to shift the perception from a car-friendly to a bicycle-friendly city. Especially during the 1980's, very controversial discussions took place between the different interest groups about whether, and how, to reduce the space allocated to cars. But the direction in favour of the bicycle was taken; in some years with less and in some years with more funding.

A new development took place after 2005 when a very high profile agenda for bicycling (increasing space, improving conditions, willingness to invest into cycling) was introduced and the vision to become »the world's best bicycling city« was developed.

Today, according to the numbers, Copenhagen has already achieved this ambitious goal. But permanent improvements are needed to keep the future objectives in focus. Bicycling is seen as one of the main aspects in the city's climate plan to reduce emissions in the mobility sector. Therefore, the municipality is working together with other stakeholders to achieve a modal split of 50% in 2015, to keep this share even in light of future emphasis on public transport and to strengthen the intermodality in the transport sector. Regarding the latter, first steps with the Danish State Railway (DSB) have already been taken. The aim is also to widen the geographical range in which bicycling is seen as the most convenient choice of transport. Therefore, the Super Cycle Highways grid will be built during the next years.

4.7.2 Measures and Project Implementation

According to Jens Loft Rasmussen, CEO of the Danish Cyclists' Federation and co-founder of the Danish bicycling embassy, two big moves were made to make bicycling more attractive in Copenhagen. A third step was also identified as important:

- Condensing the city's urban development in central areas instead of spreading out: short trip distances raise the share of bicycling. Even though these aspects are not seen as traffic projects they are extremely important.
- Raising the quality of the overall infrastructural net and conditions. With a share of up to 50%, cycle lanes are used by various target groups with all kinds of experience. To make all cyclists feel safe, the quality of the net must be exceptional.
- What seems to be highly important, too, is to inform people about the quality and convenience

Source: Andreas Røel

Andreas Røel, Head of the City Bicycle Program of Copenhagen

„Instead of lanes for overtaking I use to say ‚lanes for conversational cycling'. Bicycling is about lifestyle, liveability and socializing and will keep affecting the picture and the spirit of the whole city. »

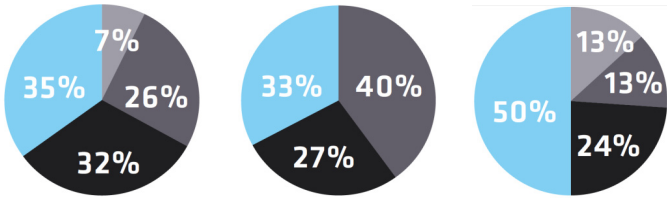


Figure 29: Distribution of trips in the City of Copenhagen; various diagrams. Light grey: walk; dark grey: car; black: bus/train/metro; blue: bicycle (City of Copenhagen, The Technical and Environmental Administration 2010)

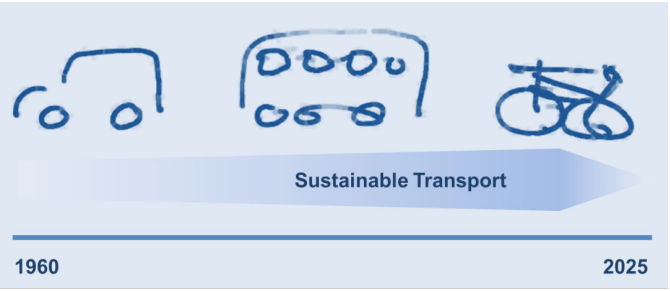


Figure 30: Greening of the transport sector (based on scratches from Jens Loft Rasmussen during the interview)

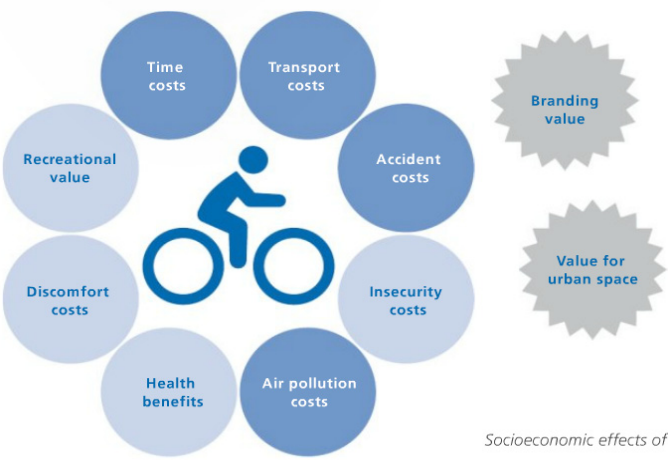


Figure 31: Systemic diagram of the socioeconomic effects of cycling according to the Danish Cycling Embassy (Andersen et al. 2012)

of bicycling within Copenhagen and let them take part at improvement and planning processes and in monitoring aspects and quality measures.

The following list gives examples of cycling infrastructure implemented to date:

Examples of Small Incentives for Cyclists in Copenhagen:

- Pre-green traffic signals for bicycles.
- Bicycle lanes continuing directly into the intersection, so that cycling is safer.
- Set-back stop lines for cars give cyclists an advantage.
- Homepage »tip us off«. Reparation and improvements concerning bicycling infrastructure can be reported by cyclists (1,016 reparation reports in Mai 2010) (Københavns Kommune 2013).
- »Bike Butlers«. Staff who help to keep the bikes in good maintenance at Metro stations.
- LED sensors to warn turning lorry drivers of approaching cyclists.
- »Bicycle rubbish bins«. Waste paper baskets mounted in an angle of 45°.
- Footrests at traffic lights for more comfortable waiting times.
- New urban development projects are often tagged as cycling projects (since they also create better conditions for cyclists).
- Optional idea: flexible shared parking place for bikes and cars (ELTIS 2013).
- Some streets with large bicycle lanes have synchronized traffic lights on 20km/h to increase the use of bicycles and increase cyclist safety.
- Bike to business: use your bike to go to work; fees for advertising, training and cycling related support are paid by the businesses: participation in 2012 leads to 12% increase in new cyclists (people who normally do not use their bike to go to work) amongst the participants.
- Snow removal and maintenance of bicycle lanes in winter is prioritised over the same for car lanes.
- Quality of bicycle lanes is permanently increased.

Large Infrastructural Changes:

- Increase the quality of the bicycle net (e.g. new harbour bridge: in the beginning 3,000 bicycles; today 11,000 bicycles a day).
- Installing »fast lanes« for faster cyclists.
- Broadening of the lanes.
- Super Cycle Highways: to connect the suburbs with the inner city by straight and flat highways for cyclists.
- Intermodality: Some years ago the DSB introduced flex areas in their regional s-trains (parts of the wagon where bicycle parking is possible).

4.7.3 Financing of the project

In general, bicycle lanes and other infrastructure are built by the municipality and, just like infrastructure built for cars, are financed through taxes (no specific bicycle tax is charged). But bicycling infrastructure is less expensive, since it requires less space for a higher grade of usage. Also, the volume of sales in the bicycling industry compared with the car industry is negligible, which is why this sector does not provide a business case for many stakeholders.

In 2008, Anders Fogh, the former Danish prime minister, changed his policies to focus more on environmental topics. This resulted, among other things, in a bicycling friendly policy including a bicycle fund which supports bicycling infrastructure projects all over Denmark. For Copenhagen, the fund is most significant due to its willingness to support innovative projects. For other, smaller, municipalities, the fund has been important for increasing interest in cycling.

In 2010, DKK 150 million (EUR 20 million) were invested in bicycling facilities within Copenhagen (City of Copenhagen 2010). According to the CPH 2025 Climate Plan (City of Copenhagen 2012a), the cost of implementing initiatives related to the City of Cyclists (as Copenhagen refers to itself) is estimated to reach approximately DKK 560 billion (EUR 70 billion) by 2025. Most of this (EUR 65 billion) will be used for the PLUSnet, consisting of select urban bicycle lanes, Super Cycle Highways and restructured routs of the most congested bicycle lanes. »The PLUSnet ensures a high level of quality for space, intersections and maintenance so that many cyclists can travel securely and comfortably at the tempo that suits each individual« (City of Copenhagen, Technical and Environmental Administration 2011).

However, financing a large infrastructural project should not be viewed solely in terms of return on investment. Socio-economic aspects must also be taken into account. According to calculations by the municipality, the net social gain by cycling one kilometre is about DKK 1.22 (EUR 0.15). By car the same distance represents a loss of DKK -0.69 (about EUR -0.08). Included are transport costs, security, comfort, branding/tourism, transport times and health but no ecological aspects nor taxes on driving.

4.7.4 Actors

The most important actors in both the historical and recent processes are:

- Population – for demonstrations, voting and cycling
- Municipality – (29 municipalities within Copenhagen) must find solutions together with govern-

ment and industries
- City planners – e.g. Gehl-Architects
- (private) funds and trusts
- Industry and private companies – competitiveness and CSR
- Cyclist Federation
- other interest groups in the areas (such as the health sector)
- Danish Ministry of Traffic
- Transport department on a state level

4.7.5 Barriers and Challenges

Such a long-lasting process has many challenges to overcome. One of the main problems identified was a traditional mind-set (and more or less conservative forces). The acceptance of and support for new developments was problematic. Examples of this were seen during the destructuralisation process of streets, where car lobbies and parts of the population were fighting against new approaches, during the slow redeployment of important administrative organs (e.g. the road department (ten years ago not one of the over 2,000 staff members were working on bicycle issues), during the obviously long process of introducing flex areas for bikes in the s-trains (DSB), and finally also in the form of policemen who did not support bicycle movements by using bicycles.

Other burdens come from other competing forms of transport. For example, the opening of the new Metro line in 2000 attracted thousands of people every day. Surprisingly, the market share of bicycling was only slightly affected and the total kilometres cycled even continued to grow.

In general, it can be said that a permanent improvement is needed to hold market shares. For example, bicycle lanes must be attractive along their entire length. If there is just one link missing or in need of repair, it is no longer attractive. Therefore it is important to think in a whole concept and not just in bits and pieces.

Costs (especially net social costs) for the various means of transport are not included in calculations which is disadvantageous for bicycling and does not reflect real costs.

4.7.6 Key Drivers and Framework Conditions

One of the frequently identified framework aspects is the bicycling culture which was never fully extinguished in Copenhagen. In the 1960's, the cycling modal split was down to 10%. With this little share it took a long time to restructure urban mobility towards the bicycle, but it was possible. In other nations where cycling was never en vogue or even abandoned almost entirely for a long time, there are often »lost generations« who are not able to bicycle. The bicycling culture has to be preserved in every generation. Otherwise people have to be educated and trained again.

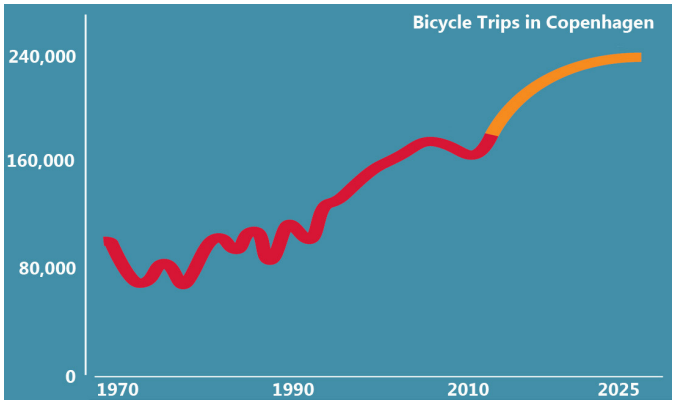


Figure 32: Development of the number of bicycle trips to/from the inner city (between 6:00 a.m. and 6:00 p.m. on weekdays) (City of Copenhagen, Technical and Environmental Administration 2011)

Other important framework conditions that affect a city's biking potential are the natural circumstances. In Copenhagen, the city is densely populated, travel distances are short, and the landscape is flat. »Bicycling in Copenhagen was invented by the ice-age« claimed one interviewee.

More recently, the general drivers promoting bicycling include: the positive image of Copenhagen, the green ambitions within the municipality and the political acceptance and financial support for the topic.

4.7.7 Successes and Success Criteria

The success of the world's most bicycle friendly city can easily be seen in the streets. However, in order to ensure transparency, Copenhagen also publishes the numbers and facts surrounding bicycle use in the »Bicycle Account« every other year.

The main criteria for success are reaching the set modal split, expanding the network, making cycling attractive for all ages and groups through increasing safety, security and good infrastructure and thereby fulfilling criteria related to health, liveability, ecology and sustainability as well. Certainly a business case must take net social gains into account.

The fact that the bicycling modal split is not dependent on GDP can be seen in its development during the 1990's where car ownership increased in accordance with GDP, but the share of bikers grew by 25% during the same time. This occurred because of the above criteria for success such as improving the bicycling infrastructure.

A future criterion for success for the coming Super Cycle Highway will be the acceptance in everyday life. Therefore, E-bikes may be an important component in the near future. Not only because they address a wide range of people, like elderly citizens, but also because the Super Cycle Highways

Source: Jens Loft Rasmussen

Jens Loft Rasmussen, Director of the Danish Cyclists' Federation

"We already have managed to create a city where it is safe, comfortable and the most easy and flexible way to go by bike from A to B. Not for every trip but for a huge amount of the trips that are taken. And as a development: seeing more and more kids on bicycles during rush hour is a sign that we are getting to a security and quality level where we even can attract groups that are not as experienced when it comes to cycling."

"People are not stupid. When people want to cycle give them a good, direct and safe route to cycle. Then many people will do it! It is not about an environmental consciousness, it is about convenience."

connect the remote suburbs with the inner city, which is often a distance of more than 20 kilometres.

Intermodality: Another side success of particularly importance is that the goal of increasing the combined market share of public transport and cycling has already been achieved in parts. As mentioned before: the market share of bicycles was just slightly affected through the opening of the new Metro line in 2000. In addition, the s-train increased their customer numbers when they offered so called flex areas and opened their trains for cyclists and offered free bicycle transport (since 2010 the transport of bicycles is free of charge which lead to an 8% increase in passengers according to an interviewee). Hence, through a combination of competitive public transport and very attractive bicycle infrastructure the coexistance of cycling and using public transport seems to be the most convenient way of urban commuting for many Copenhageners.

4.7.8 The City and Sustainability

Most people live within less than 5km of their workplace. To cover these distances in flat surroundings, bicycling is a very convenient form of transport. Therefore, the bicycle is competitive with other means of mobility. However, the city is expanding, and in the long run new mobility concepts will be required. It is clear that in order to ensure a sustainable transport system the future growth within this sector must take place within public transport and bicycling.

One promising idea which must still prove its sustainability impacts is the creation of Super Cycling Highways. Particularly since e-mobility is forecasted to become more and more popular in the near future, and will have its share in urban transport, these highways will hopefully become very attractive for e-bicycles, too.

The fact that bicycling in Copenhagen is not a new idea can be seen looking back over the years. The bicycling culture was never lost. The finding that bicycling in Copenhagen is not about being green (just 1% of all Copenhageners claim ecological reasons for their cycling ambition) is also a sign that cycling is not just a temporary habit. However, bicycling itself must also be adapted to new intermodal concepts.

4.7.9 Transferability of the Practice Example

Many cities are keen to adopt Copenhagen's bicycling concept which can be seen in the word: »Copenhagenize«. It was introduced to describe the process other cities all over the world are going through in adopting the Copenhagen bicycling model.

The Gehl-architects, who were also involved in the urban planning process in Copenhagen, are doing parts of this »Copenhagenization«. First, they analyse the local situation and find the fitting solutions by taking several aspects from the implemented and approved knowledge gained in Copenhagen. Ideas must fit the local needs. That is because the ambition to »Copenhagenize« has very different origins: the root to Vienna's ambition to increase the bicycling share comes from, for example, congestion in the city's public transport during rush hours. For London, it is more related to vehicular congestion and air quality. In many cities health aspects (such as clean air but also exercise) will very likely become much more important also in many areas of the westernised world, why also bicycling becomes a greater role.

The fact that Copenhagen is pretty good at 'selling' its bicycling concepts can be seen in Melbourne, which copied the bicycle lanes directly from Copenhagen. Therefore, they are called »Copenhagen lanes«. Another example is in New York, where the Mayor has hired Danish advisors for planning the city's future bike infrastructure. Like Jens Loft Rasmussen said: »You cannot transfer a system directly but you can learn from it and use good elements«.

4.8 ELECTRO MOBILITY

As in other countries, electro mobility in Denmark has been a promising and up and coming market over the past years, most notably in Copenhagen. Mainly driven by ecological, health and political considerations, electro mobility has a positive connotation on many levels and is generally supported by the municipality and the governance within the city. Therefore, it also plays a highly important role in the

city's future mobility concept (City of Copenhagen 2012a). Denmark itself does not have any large automobile manufacturing company and thus electro mobility is more a conceptual and infrastructural approach here. Therefore, the success of the concepts in Copenhagen is also highly dependent on the progress made by international car manufactures and the implementation of standardisations in the relevant fields.

The two main restrictions attributed to electric cars (limited range and high prices) are less crucial in Denmark than in other countries. In the case of the former, this is because the country is rather small and very centralized (3.5 million people of the total population of 5.5 million live within a 50 km commuter belt of Copenhagen (USA TODAY 2011); 100 km range covers 80% of users' daily needs (Trafi kstyrelsen, Center for Grøn Transport 2010). In the case of the latter, this is less critical in Denmark because electric cars are exempt from the usual registration fee of up to 180% of the acquisition cost of the car until 2015.

In general, electro mobility is understood to mean cars, bikes and public busses driven by a battery. Plugin-Hybrid-Cars are rarely mentioned in concepts and agendas but will certainly play an important role in the implementation of e-mobility. Hydrogen cars have already been in action as test vehicles for a couple of years and the first 15 serial produced cars were delivered to Copenhagen's Municipality this spring. According to Copenhagen's hydrogen strategy, the City will have 40 hydrogen cars by 2018. In the long-run, these cars will play a growing role mainly for urban transport.

Brand	**Model**	Jan - Dec 2011		Jan - Dec 2012	
		Volume	MS* (%)	Volume	MS* (%)
Peugeot	Partner	8	1.63	5	0.75
Tesla	Roadster	8	1.63	12	1.81
Mitsubishi	i-MiEV	95	19.35	25	3.77
Nissan	Leaf	12	2.44	73	11.01
Citroen	C-ZERO	116	23.63	86	12.97
Peugeot	iOn	128	26.07	90	13.57
Renault	Kangoo	3	0.61	120	18.10
Renault	Fluence	57	11.61	198	29.86
Others		64	13.03	54	8.14
Total		491		663	

MS* – Market Share

Figure 33: The number of electric cars sold in Denmark in 2011 and 2012 by make and model and the percentage of the market share held by each (Nederby Høj 2013)

As in many other countries, electro mobility has had its start-up difficulties in Denmark. The total market for private cars and light commercial vehicles in Denmark in 2012 was 194,669 sold units, thereof some 663 were EVs. This is equivalent to an e-vehicle market share of 0.34% (Nederby Høj 2013). Hence: the critical mass towards being accepted by end-users is not met.

Since electro mobility is a rather new topic, this chapter will concentrate on a few interesting projects evolving within the city boundaries which can be seen as example activities.

Figure 34: Impressions from Copenhagen's emobility sector (1-7: own photographies by Dominik Noeren 2013; 8: Tuxi 2013)

These projects are in various states of implementation.

4.8.1 Idea and the Objectives of the Projects

Copenhagen's objective, according to the Climate Plan, is to be CO_2 neutral by 2025. Individual transport is taken into account, but will be compensated by other sectors (e.g. overproduction of wind energy). Therefore, the targets for the individual mobility sector are:

- 2015: 12,000 electric cars on the streets of Greater Copenhagen (29 municipalities including the municipality of Copenhagen).
- 2025: 20-30% of all light vehicles are using new fuels such as electricity and hydrogen.
- 2025: 30-40% of all heavy vehicles are using new fuels, such as biogas, bioethanol, electricity or hydrogen.

Along with other considerations (such as noise, air quality and congestion) these targets set the baseline for all electro mobility projects within the city.

The following projects will be described in further detail:

1. **Municipality fleet**: In order to go above and beyond the above targets, the municipality decided to transform their own passenger car fleet into an electro mobility fleet. The objective of reaching 85% electric cars within the passenger fleet by 2015 was developed in 2011. Other vehicles, such as transporters, must be as ecological as possible.

2. **Tuxi**: Tuxi (TUXI 2013) will be a new urban mobility concept based on business to business (B2B) and business to private (B2P) car sharing and is aiming for 100% EVs in its fleet. Tuxi solves the problem of the lack of charging infrastructure by using a charging and maintenance service (charging as a service). This mobility concept is seen as a supplement to other urban transport systems.

3. **CLEVER**: CLEVER (CLEVER A/S 2013) is the leading electro mobility operator (EMO) in Denmark and in Copenhagen. They provide solutions for charging EVs by offering a growing, nationwide grid of charging infrastructure. From private charging spots including energy and quality monitoring and energy contracts to high-speed public charging spots in the heart of the city, CLEVER delivers a range of solutions both for charging the EV at home and on the road. CLEVER has also been running the largest EV experiment in northern Europe, with 200 EVs having been driven by 1,600 Danish families, each for a period of three months at a time.

4.8.2 Measures and Project Implementation

Municipal fleet: To achieve the above mentioned goals, the project – which involves all seven municipal administrations – was headquartered within the Technical and Environmental Administration. This was done for the following reasons: first, this administration had the best information on and concepts for the usage of their cars; second, they were author of the Climate Plan and were hence expected to act as an example. Although some say this political project was based initially solely on ecological principals, its success was seen as dependent on demonstrating a valid business case.

Therefore, procurement of all cars was centralised. The idea rapidly changed from a simple procurement initiative to a business development project, since EVs need charging infrastructure and charging infrastructure requires parking spaces. According to the project manager Richard Hoang-Gia Laugesen, smart charging will become highly important for grid management in the future. Fleet management is crucial because of the centralisation, monitoring and the more complex logistics of EVs. The importance of these processes can be seen by the fact that while collecting data on all cars within the administration fleet they found out that about 130 cars which were still on the inventory list were no longer in the administration's ownership.

Today, of the remaining 330 passenger cars (about 780 cars in total) 120 are already electric. Another 140 electric cars will be bought until the end of 2014. A tender for constructing charging infrastructure and fleet management will be posted in autumn.

Tuxi: The Tuxi project is in an advanced concept phase and has not yet been implemented. Although the project has not been »proven«, it has a high potential since it solves the main issues relating to urban charging infrastructure.

Similar to, for example, the car2go, the Tuxi concept offers a free floating urban car fleet but focusses on electric cars and the business sector (as a first step). Tuxi sees itself as a mobility provider that integrates with other urban mobility solutions, uses the same mobility card as for example public transport for authentication of registered users and offers billing by time and distance. Therefore, a car can be seamlessly used first for business and then later for private purposes. In concept the system is fully flexible and scalable and is made up of the following components: reservation and fleet management, billing, integrated intermodal route planning, car sharing, car maintenance and charging as a service. The charging service will be conducted as follows: parked cars will be picked up and taken to one of three planned service stations in Copenhagen (with fast charging devices), then brought back after charging and cleaning is complete.

The project is divided in three phases:

1. 150 cars: free floating car sharing for the public and a car pool bases round-trip service focused on exclusive B2B usage;

2. Integration of public transport elements such as the national RFID smart card (Rejsekortet), the national trip planning service (Rejseplanen) and the possibility of ordering a taxi, when no Tuxis are available.

3. Extension of the service to include Danish Rails: park Tuxis at train stations for combining long distance train rides with Tuxis for the final leg of the journey and urban commuting.

The service is expected to have 300 cars in Copenhagen and 450 cars nationally by 2015. As a Danish start-up, Tuxi is actively making acquisitions in many European cities (especially in France). Car manufactures as well as energy providers are desired as partners, not only as suppliers. In order to solve local and regional traffic issues, transport operators will be able to join local consortiums (e.g. energy providers, municipalities and transport operators) to run the Tuxi franchise.

CLEVER: CLEVER was founded in 2009 and is owned by five large utility companies. The business idea is to provide charging infrastructure to all of Denmark. The following products are offered: public fast and slow charging stations for all customers (non-CLEVER customers have a more expensive tariff); charging infrastructure for homes and offices. Most chargers are smart charging spots and allow services like load management, monitoring, history and support. In addition, the self-built software allows for the identification of vacant public charging spots in both the city and all of Denmark (restricted to the CLEVER charging network) and gives additional information about the individual's user profile. In the future, load management and ancillary services will be a part of the business model. The software solution developed is also sold to customers (even abroad) to manage EV hardware.

In 2011, CLEVER installed Europe's first commercial fast charger in Copenhagen. CLEVER was cooperating with Better Place Denmark until May 2013 when they stopped providing the service.

4.8.3 Financing of the Project

All the three projects identified are currently in different project phases and based on different financial concepts.

Municipal Fleet: Generally, the project is politically desired and seen as a show case. Therefore, financial disadvantages are certainly accepted. The financial assets are the following:

- No registration fee (of up to 180% of the acquisition cost if bought before 2015) for electric cars.
- Volume discount by centralizing procurement.
- Higher productivity in the administrations by centralizing procurement since they can focus on their core competences and do not have to procure cars by themselves.
- Additional savings through lower fuel costs and 20-35% less maintenance expenses (Diez 2012).
- Less noise and air pollution and therefore net social advantages.
- Savings, since about 130 cars are no longer incorrectly on the maintenance and insurance list.

Even taking these advantages into account, the expenses for EVs – including the charging infrastructure – are not small. In addition, the need for more in-depth administration (managing cars, charging points and parking spaces at once) showed obvious advantages right in the very beginning (e.g. identifying missing cars and dispensable charges) but will increase costs as well.

In general, this project is not a big business (about 300 electric cars) nor is it representative for other projects. However, it will certainly be a valuable example for upcoming projects in the region, generating useful experiences.

Tuxi: The Tuxi project has not yet been implemented and is still within a conceptual and networking phase. This phase is being privately financed by its developers. However, large investment is needed for the next step: car procurement.

Source: Richard Hoang-Gia Laugesen

Richard Hoang-Gia Laugesen, project manager in the Technical- and Environmental Administration

"Most important in change management is communication, communication, communication! »Why are we doing this?" and »What is in for you?" Often simple SWAP-analyses according to the stakeholders have to be done. Otherwise the result is irrational action driven by fear and doubt."

"Electro mobility is not a big business yet. When I look at the numbers of sold cars almost 40 or 50% of all electric vehicles in the last year in Copenhagen are bought by our administration."

Therefore, although different concepts are possible, the favoured option would be a partnership structure with car manufactures, energy providers and transport operators.

CLEVER: CLEVER is owned by five large utility companies: SEAS-NVE, SE, NRGi, EnergiMidt and Energi Fyn with some 2.7 million customers in total. They are seen as the best partners since they have the ability to finance the establishment of a company like CLEVER »which will not make money for years« (Lars Bording, CEO of CLEVER).

4.8.4 Actors

Municipal Fleet: the city of Copenhagen is the main actor in this project. Motivated by COP15 (15th Climate Change Conference 2009 which took place in Copenhagen in December 2009), Copenhagen initiated the Climate Plan for the city which includes very ambitious goals. Mobility and electro mobility represent one of the pillars within the program which was developed by the Technical and Environmental Administration under Ayfer Baykal (Mayor of this administration). All Administrations depend on centralized procurement and are restricted to purchasing electric cars. Highly important actors within the municipality are all car users since they have to accept the new guidelines.

Other stakeholders include the car manufacturers, the producers of infrastructure and fleet management providers. Research institutes also play a role within the analysis of the grid.

Tuxi: The founders of Tuxi have been networking in many cities, and the actors are always located within private companies (future customers), municipalities (door openers and partners for parking and charging issues) and car manufacturers (providers of cars and future partners). In addition, energy providers and other local transport operators are also important.

In Copenhagen Tuxi is politically supported by the Technical and Environmental Administration. Important is also the congestion commission (which exists out of various stakeholders involved in Copenhagen's transport sector) since they promote the ideas of electro mobility and car sharing. In addition the parking department, energy companies and the Danish Rail are future contacts.

CLEVER: CLEVER operates as a private company. It is financed and owned by energy companies. Therefore, smart charging processes and grid operators are highly important.

CLEVER's customers include: the municipality, organisations and private individuals.

4.8.5 Barriers and Challenges

Electro Mobility in general: General challenges for electro mobility in Copenhagen have been observed in the following areas:

- Economics: high prices for cars and additional costs for charging infrastructure, little choice of available cars, battery maintenance is often not organized yet.
- Technicalities: missing implemented standardisation for charging and communication, smart grid aspects such as grid management, more complex administration (parking exclusively at chargers), integrated aspects of charging, fleet management, reliability.
- Acceptance: prejudice towards electro mobility.

Municipal Fleet: One of the main challenges up to now has been a prejudice against electro mobility and centralized procurement. Up until 2011 cars were selected and purchased by the various administrations – often even by the individual drivers – themselves. When the decision to centralize procurement was announced, but not yet initiated, one administration bought some 70 conventional cars within four months, although they usually bought only three to five cars a year. People react with resistance when they fear losing rights they are accustomed to. Therefore, communication is an essentially important part of change processes. If one administration falls short of the goal of achieving a proportion of 85% EV in their fleet other administrations will have to compensate for this.

Another challenge is parking, and since 15-20% of the municipality's cars are parked in the streets, the charging problem will also need to be solved. In general, the upcoming challenges regarding parking and charging infrastructure were not mentioned during the political decision-making process.

Tuxi: For a start-up project currently looking for investors and partners the biggest challenge is certainly finding financial supporters for the idea proving the concept.

In addition, Tuxi has stated that the fact that cars are neither ready for sharing nor suitable for other mobility services as one of the main challenges. In other words, they are neither easily accessible to nor programmable by other parties. Another factor is the slow change of paradigm for car sharing – which is still faced with very little acceptance – in Denmark. According to Mr. Kragelund (Co-Founder of Tuxi) the reasons for this include the highly idealistic ideas about the value of owning a vehicle and the lack of experience with other forms of shared commuting. Therefore, creating

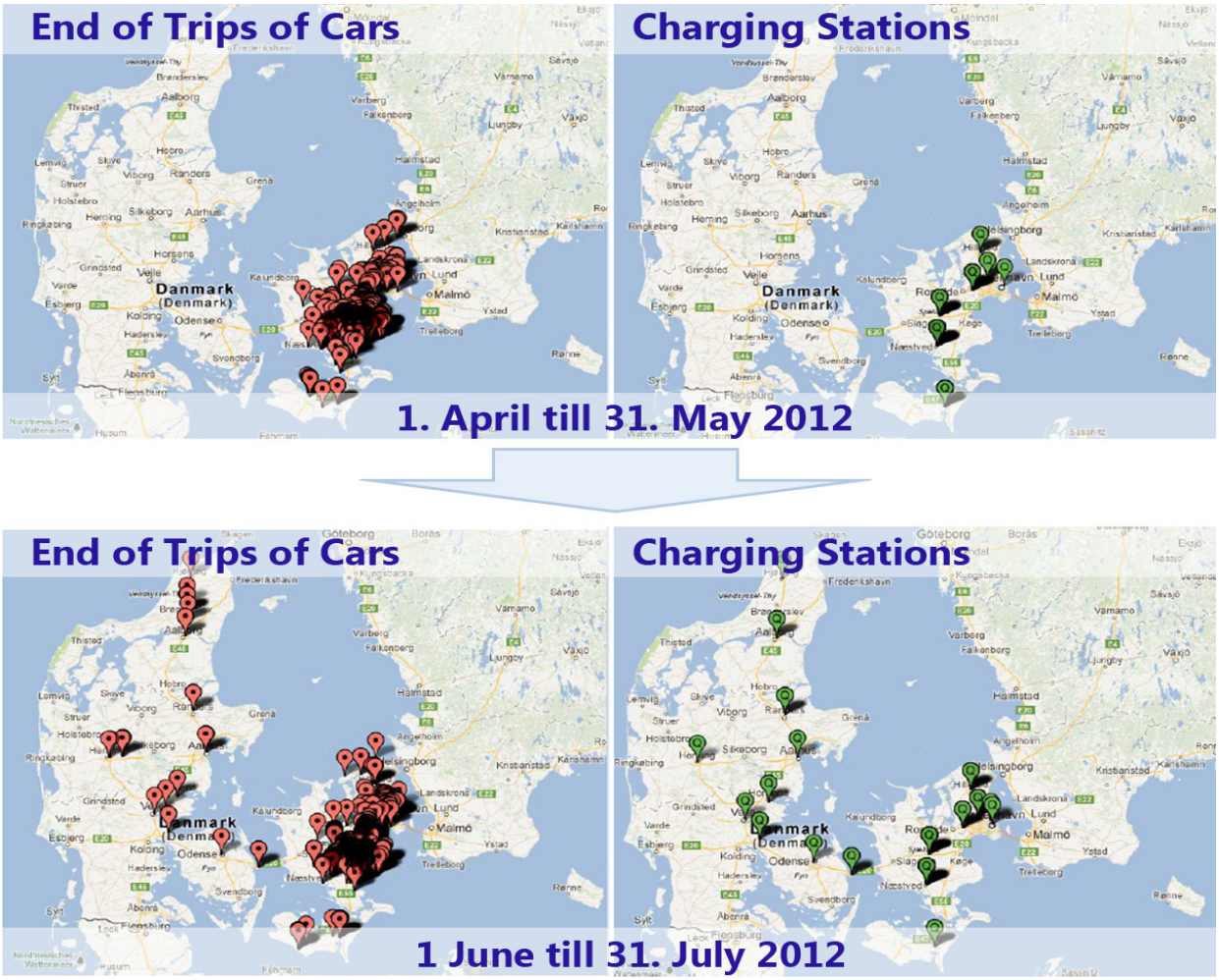


Figure 35: The importance of charging infrastructure in determining EV user behaviour. The green bubbles show the fast charging stations and the red bubbles depict customers' final destinations. The users increase their range as the infrastructure develops (Bording 2013)

a reliable service which is conceptually sound is crucial.

Although Tuxi provides for rapid charging of electric cars in urban areas (which can be seen as an advantage compared to car2go) the usual technical barriers for the large scale urban permeation of electric vehicles also hold valid for Tuxi. In addition to the benefit-orientation of the company, Tuxi is a public helper; a private company solving public urban mobility issues, which creates a dilemma of interests. This is a tricky situation for a small company with financial interests to be in, since municipalities in most regions are no financial supporters for start-ups.

CLEVER: CLEVER illustrates the typical case of the »chicken-and-egg« problem of electro mobility. In other words, the charging infrastructure must be installed before there will be enough users, which is in turn necessary in order to finance the expensive installation of the charging infrastructure in the first place. All of the above mentioned general aspects are therefore valid for CLEVER: economic burdens, technical difficulties (especially with standardisation) and user prejudices. However, according to Lars Bording (CEO of CLEVER), the most important aspect is European car manufacturers' commitment towards electro mobility, as this will result in making EVs affordable.

Figure 35 shows findings which demonstrate how important charging infrastructure is for EV user behaviour. During a one year field study by CLEVER, the following situation was shown: after charging infrastructure was installed on the other side of the bridge (between Zealand and Funen) people dared to cross the bridge – which they didn't before – even though the range of their EV was sufficient before.

4.8.6 Key Drivers and Framework Conditions

Municipal Fleet: The key driver for this top-down approach was the political decision to act as a role model for greening the transport sector, made within the municipality. At the same time, however, ecological aspects are just a side effect within Copenhagen's triangle-concept Sustainability, Growth and Liveability. These three factors give the orientation for

good concepts according to the cities framework (Interview with Claus Bjorn Billehoej; further details in chapter 3).

A tax reduction for electric cars can be seen as a beneficial framework condition. Negative key drivers include: the technical restrictions inherent to electrical vehicles and users' prejudices against the new technology.

Tuxi: Like all car sharing concepts, Tuxi is mainly motivated by two (idealistic) aspects: improving urban congestion and the little utilization rate of privately owned cars (since they are parked for 22 hours a day). Every day 140,000 cars come from outside into the city of Copenhagen. Just 15% of the drivers need their car again during the day within the city. Hence, reliable car sharing is needed. For Copenhagen, electro mobility is an important component of its climate action and protection plan. Another critical aspect is the intermodality of urban transport, wherein ICT based services are crucial. Tuxi's founders come from an IT background, which provides opportunities for enhanced services in this field.

Last but not least, electro mobility requires charging infrastructure. Within the next years, the investment for a city-wide charging grid is very uncertain, whereas frequently used fast chargers – such as those in the Tuxi concept – display promising potential.

CLEVER: A key driver for CLEVER, and the utility companies as its owners, is certainly the motivation to define and develop a new market in the future and to utilize the positive publicity in the meantime. The framework conditions are similar to those of the other electro mobility projects. An advantage CLEVER had until recently was its cooperation with Better Place, which ended in May 2013 because Better Place. gave up operation

4.8.7 Successes and Success Criteria

Municipal Fleet: The progress towards the aim of changing the conventional municipal fleet to a more or less green electro mobility fleet by 2015 can easily be measured by analyzing the number of EV in the fleet. However, the success of the project should also be understood on a different level: if it is seen as a success it will have a light house character. For the municipality, the learning that has taken place during this process is almost the most valuable success, since this can create other lighthouse projects in other municipalities. Therefore, a new mobility secretary (within the Greater Copenhagen region, which covers the 29 municipalities within the capital area) is focussing on motivating people, companies and the individual municipalities to switch to electric cars and to expand the charging network. The overall goal for the region is to have about 12,000 EVs on the streets of Greater Copenhagen by 2015. Therefore, a good story with multiple advantages must be told to the remaining 28 municipalities. Hence, the following can be seen as important aspects for success in this ambitious project setting:

- Identify/develop further financial and technical advantages (e.g. tax exemptions for hybrid cars can positively influence the picture).
- Good communication with all stakeholders (SWAP-analysis, »what is in it for you?«).
- A high level of project management is essential in order to succeed with the implementation of new technologies. These might influence habits, infrastructure, mobility and procurement.
- Use of fleet management and GPS solutions.

Tuxi: In any city, a concept like Tuxi is dependent on collaboration between the local or regional players, such as energy suppliers, municipalities, transport operators and others, to finance the local operation and gain access to an existing customer base.

Since the project is still under development, and not yet implemented, criteria for success can be defined as:

- Implementation
- Fulfilling phase 1 to 3 (see above)
- Contribution to private and municipal targets

CLEVER: CLEVER announced that in addition to the 50 fast charging stations (50 kW) and 110 charging spots they will put up another 100 22 kW charging stations in 2013. However, CLEVER itself is just at the very beginning of its activities. Therefore, the next step is to win over customers, which is highly dependent on the whole electric car industry.

4.8.8 Sustainability in Copenhagen's Electro Mobility Sector

Copenhagen aims for a strong reduction of individual traffic and a shift to bicycling and public transport. New forms of communication, such as video conferencing, represent an opportunity to reduce traffic which has only rarely been used. This opportunity might be of interest, especially for administrations.

Copenhagen aims to have a 100% RE supply by 2025. Electro mobility is an important part of taking this greening goal into the individual mobility sector. Conventional combustion engines must be replaced by ecological (e.g. electrically driven) cars. Hydrogen vehicles are also on the agenda. In addition to ecology (or sustainability) liveability is highly ranked on the political agenda, which is why noise reduction and air pollution are also important positive aspects inherent to electrical vehicles. These advantages also accompany the use of e-bicycles, in cases where they replace cars and not the usual bicycles (see also chapter 4.7).

One aspect which is obviously important, since it was mentioned several times during interviews, is that Denmark – and especially Copenhagen – defines itself as a perfect test field for electro mobility. The following reasons were given: the country is rather small and flat, it has relatively good charging infrastructure installed, tax incentives make electro mobility financially attractive, people are generally open-minded, almost 30% of the current electricity supply already comes from wind and – in case of problems with the new technology – car manufacturers will just displease a small proportion of their customers compared to an international market.

Source:
Anders Kragelund

Source:
Carl Nielsen

Anders Kragelund and Carl Nielsen, Founders of Tuxi

"Green does not sell, but green opens doors."

Source:
Lars Bording

Lars Bording, CEO CLEVER

"Green is not a selling argument, It has to make sense"

4.8.9 Transferability of the Practice Example

Municipal Fleet: The transformation of the municipal fleet was initiated by way of a political decision (Richard Hoang-Gia Laugesen said on the interview that: »the decision was made, someone has to fix it now«). Such 'top-down' approaches are easy to implement in almost all legal systems. More challenging is ensuring green energy production, which is the only valid way an ecological argument for the transition to electro mobility can be made.

As soon as this model must convince ordinary buyers of its validity, the business case becomes more important. Therefore, additional incentives (such as a free individual parking space for EV like in Amsterdam) can be helpful and the »you must« should be replaced by a »this is in it for you!« (Richard Hoang-Gia Laugesen). In general: 'Top down' approaches are faster than 'bottom up', but not as long lasting if people are not convinced.

Tuxi: The Tuxi concept is already being discussed with many cities, municipalities, car manufacturers and energy suppliers. The concept is scalable, very flexible and therefore, theoretically, very transferable.

CLEVER: The CLEVER concept is similar to concepts developed by other utility companies such as RWE in Germany or EDF in France. Once a promising electro mobility market emerges within the coming years – and the accompanying infrastructural challenges (including grid management) are solved – this model is transferable to other places with the same conditions.

4.9 GREEN SOLAR CITIES, VALBY DISTRICT

Valby is one of ten official districts in Copenhagen and is located in the southwest of the Copenhagen municipality. It consists of a mixture of different types of housing, including apartment blocks, row houses and detached single-family houses spread around the remaining part of the old Valby village. Additionally, past and present industrial sites, such as the Carlsberg brewery site, are present in the district.

The EU Concerto's »Green Solar Cities« project is using EU funding for a large scale PV implementation plan in Valby, Copenhagen. The plan was launched in 2000 with the long-term aim of supplying 15% of all electricity used in Valby – equivalent to 30 MWp PV – by the year 2025. The Concerto project itself has a shorter lifespan (from June 2007 to May 2013) and therefore also has smaller goals. By 2013, around 4 MWp PV were established. Additionally, new buildings and housing renovation projects with improved energy efficiency of 30-79% compared to normal practice were realized. The project is driven through the knowledge and enthusiasm of Kuben Management (project coordinator) and the Cenergia energy consultancy office (technical coordinator and initiator of the EU project). Although the building crisis in 2008-2009 had an impact on the project and resulted in changes in some of the components of the ten projects planned, the goals of the Concerto project may still be achieved.

The project is very interesting since it focuses on solar application – in part within single buildings and emphasizing private solutions – which is in contrast to Copenhagen's overall approach towards solving the energy supply challenge: through changing the DH system generation to biomass and the electricity generation to wind power.

4.9.1 Creation and Objectives

The project was inspired through a visit to a major PV implementation project in a newly built city district in Amersford in the Netherlands, to which Kuben Management – the project coordinator, Cenergia and community officials of Valby were invited. Once back from the trip, these ac-

tors wanted to initialize a similar project in Valby, which in contrast, however, is an existing district. Further inspiration came from the German PV feed-in tariffs. At that time, Copenhagen was not yet focusing on solar energy. The vision which was created outlined that by 2025 15% of all electricity used in Valby would be generated through solar energy. The total size of the PV arrays needed were estimated to be 30 MWp. As part of the implementation – and especially financing – the district applied for an EU Concerto project together with the partner city Salzburg-Lehen. The project was evaluated positively, and in June 2007 »Green Solar Cities« was launched.

The primary goals for Valby are listed below:

- 200 kWp PV will be integrated to match the electricity use of ventilation systems in 600 housing units.
- Solar thermal collectors will be combined with water savings to obtain 30-50% solar for domestic hot water (DHW) for 333 retrofit housing units and 50% for 70 nearly passive house rooftop apartments (36 kWh/m², year), while 200 new built apartments will get 30-50% solar DHW.
- An innovative and cost-effective biomass gasification CHP plant based on wood pellets will be implemented.
- 300 - 400 housing units will be renovated, with a 25% improvement in energy efficiency compared to a regular new-built.
- The use of a passive house standard will be demonstrated in new buildings.

A detailed project plan was developed by Kuben Management and Cenergia Energy Consultants and passed by the district council.

4.9.2 Procedure, Measures and Project Implementation

The project is structured into ten individual areas within the Valby district. Due to barriers, such as the building crisis, when due to the economical situation very limited investments into buildings were made, and delayed planning processes, several project components originally planned had to be replaced by other measures, partly on different buildings. The eleven locations involved and the measures finally implemented are listed below:

1. Lykkeboskolen: New sports hall with 896 m² PV integrated on the roof.

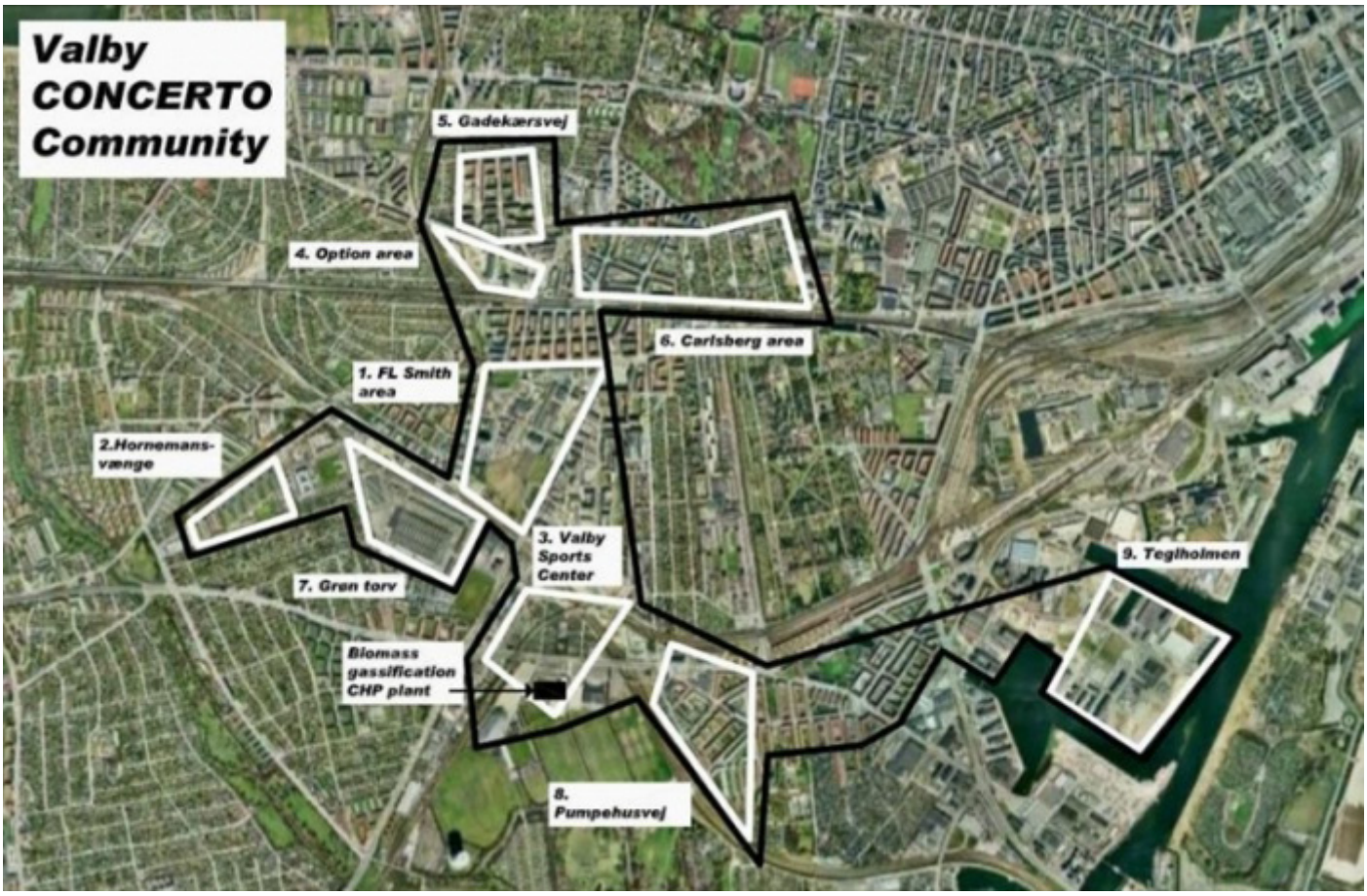


Figure 36: Map of Valby with the ten individual areas that were to be involved in the project according to initial planning (Green Solar Cities 2012)

2. Vigerslev Vænge/Hornemanns Vænge: Energy efficient renovation of six blocks with 288 apartments with 480 m² PV, 200 m² thermal collectors for hot water supply, 200 mm mineral wool insulation of the building envelope, ventilation with heat recovery and triple glazed windows.

3. Valby Sports Centre area with new Water Cultural House of 3,230 m²: State of the art in low energy measures for indoor swimming pools and use of PV.

4. Dronning Ingrids Plejehjem: new built elderly institution with 132 elderly dwellings and connected service facilities of in total 11,670 m² floor area with thermal collectors for hot water supply.

5. Henkel site II: renovation of a commercial building with 2000 m² floor area.
6. Ny Ellebjerg, KAB site: 82 new built housing units and kindergarten.

7. Valby main train station: new shopping center and combined housing for elderly people and families with 127 units (Langgadehus) and prefabricated roof top apartments. 200 m² solar heating system.

8. Valby Citizen Center: PV integration on a gable and in the roof.

9. Old Valby/Gl. Jernbanevej: PV installation and energy efficient renovation of brick masonry building of 16 dwellings adding four new dwellings on top of the building.

10. Pumpehusvej/Karensminde area: 36 new prefabricated low-energy buildings produced in Estonia and shipped to Copenhagen. PV integration on the roofs. New energy efficient primary school (Teglholmskolen) with 10,500 m² floor area.

11. Waste water sludge deposit: Large scale PV plant with 777 kWp (5,000 m² PV). The PV plant is replacing the planned biogasification plant which has been delayed so much that it could not be implemented within the Concerto timeframe (but is being implemented in another city (Hillerod).

Within the project, an energy renovation network was created that helped private building owners plan the renovation of their building. An agreement with the local energy supplier was made so that private building owners, for a time, received co-financing of 50% of the investment costs for installing PV on their roofs. This decreased the payback period to about seven years.

4.9.3 Project Financing

The project's financing was composed of several contributions: of the DKK 58 million (EUR 7.8 million) total investment in low energy measures and renewables in Valby, DKK 25 million (EUR 3.35 million) were financed by the European Union (through the Concerto project) and DKK 4 million (EUR 540,000) by the Copenhagen municipality. The remainder was comprised of private investments.

The project has had a direct impact on about 8,000 people, of which the building users (tenants and owners) have been the main beneficiaries. The operational costs of the newly renovated buildings and the buildings with solar energy contributions have been significantly reduced.

4.9.4 Actors

The project was initiated by Valby City Council together with Kuben Management (the project manager) and the energy consultancy Cenergia. Additional actors included planners and architects, energy supply companies, the City of Copenhagen, the European Union and of course the public – including private building owners who have invested in solar energy or renovation projects. There was a cooperation with the Local Agenda 21 in order to reach the private building owners and also Solar City Copenhagen, which was established in 2004 (Solar City Copenhagen 2013).

4.9.5 Barriers and Challenges, Key Drivers and Framework Conditions

The barriers mentioned by the project partners interviewed were a) the building crisis in Denmark that started in 2008 and b) delayed planning of parts of the building objects within the city administration. Both barriers made some of the planned building projects impossible to implement within the project time frame. Thus, alternative measures had to be found and planned that compensated the energy savings or solar energy gains. This resulted in additional work for the project manager and the energy consultancy and in additional negotiations with the EU Commission and most likely also with Valby district.

The key driver pushing the project forward was the ener-

Source: Jakob Klint

Jakob Klint, project coordinator, Kuben Management

"Generally when I talk to people they are very positive (about the project)… There is a network along the people that have PV panels on their roof, so there is a kind of movement."

gy, enthusiasm and knowledge at Kuben Management and Cenergia. These partners developed the project from the inspiration right through to planning and implementation. Especially Cenergia has much experience with highly energy efficient renovation projects and the implementation of solar thermal collectors and PV, as they participated in many International Energy Agency and EU projects on this topic.

4.9.6 Successes and Success Criteria

The Green Solar Cities project in Valby has resulted in 3,813 MWh/yr of delivered energy use savings when compared with the status before for the renovation or when compared with conventional new buildings. Of the total savings in delivered energy, 2,817 MWh/yr were contributed by solar energy. The remaining energy used by the buildings included in the Concerto project came to 4,243 MWh/yr.

Figure 37: Left: Artist's PV integration on the gable façade of the Valby Citizen Center; Right: Langgade hus (right). Langgadehus' solar thermal system is placed on the roof and not visible on the photo (own photography by Heike Erhorn-Kluttig)

Figure 38: Large scale PV plant on top of the waste water sludge deposit (© Jakob Klint, Kuben Management A/S 2013).

4.9.7 Valby and Sustainability

The Valby project did not aim to include all sustainability criteria. Instead, it concentrated on renewable energy generation and energy savings. Due to energy savings and solar energy contributions, CO_2 emissions were significantly reduced. A sustainable feature is also the continuity of the project. The PV installations on private buildings in Valby will continue on beyond the end of the EU project.

4.9.8 Transferability of the Practice Example

By providing successful examples that are visible to the public (e.g. the solar collectors) this project inspires private building owners to go even further than the Danish EP requirements and to not rely solely on comprehensive community solutions (e.g. improvements of the DH system). It can be replicated, in parts, in other districts in Copenhagen, and also in other cities in Europe. Alongside its partner city, Salzburg, it is presented as an exemplary project on the EU Concerto website.

4.10 ØRESTAD/NORDHAVNEN

Due to population growth, the City of Copenhagen's administration began development work for housing and offices in two large urban areas within the last twenty years: Ørestad in 1992 in connection with the bridge to Malmø and Nordhavnen in 2009. Both areas are/will be connected to the city centre by a metro line. On the one hand, money from the sale of land to the developers will finance the infrastructure including the metro, while on the other hand the metro lines will guarantee the success of the development for the developers. Although there are many similarities between the two development areas, there are some deviations in the planning as well. Ørestad is erected on green ground while Nordhavnen is built on a former industrial harbour area combined with newly generated land at the seaside. Ørestad's master plan is composed of large buildings with large green spaces between them. Nordhavnen has about the same density but generates this density with smaller buildings and smaller but locally devided common spaces.

4.10.1 Creation and Objectives

In the beginning of the 1990's, the Danish parliament passed several development acts: the bill on the combined bridge-tunnel Øresund Link, the bill on the development of Ørestad and the bill on building the metro as an upgrade to the public transport system of Copenhagen. There are close connections between these three decisions, because the link to Malmö (bridge) makes Ørestad the entrance area to Copenhagen providing much needed living area and working places, while the metro guarantees the success of the new urban development for the plot developers. On the other hand, selling the plots brought in the money required for building the metro.

In 1994 the architectural competition for the design of Ørestad's master plan was won by a Finnish architectural studio. The modern approach was chosen because it allowed for the concentration of buildings in four smaller districts with a relatively tall and dense building mass. Green areas were designed in between the buildings.

Ørestad covers an area of five kilometres in length and 600 metres in width (3.1 million m²). When completed, 60,000-80,000 people will be working in Ørestad (currently about 10,000 people work there) and at least 20,000 people will be living there. The various businesses that are already located in Ørestad include a TV broadcasting company, pharmaceutical companies and universities. The district consists of the following four quarters:

- Ørestad Nord (almost fully developed and in use)
- Amager Fælled (partly developed)
- Ørestad City (already in use)
- Ørestad Syd (first dwellers have moved in)

Nordhavnen is a kind of symbol for the development taking place in all of Copenhagen: a former industrial city developing into a centre of knowledge and the service trades. In the case of Nordhavnen, the development is from a harbour site into a mixed-function area. In 2007, the act on development of Nordhavnen was passed by the Danish parliament. In 2008, an international ideas competition with 180 entries was posted, to develop the urban strategy for the new district. The task was to fulfill the following six visions:

- An eco-friendly city
- A vibrant city
- A city of sustainable mobility
- A city by the water
- A city for everyone
- A dynamic city

The jury selected three entries as equal winners. Each was given two months to detail their schemes in close cooperation with the City of Copenhagen and By og Havn. The final winning design was submitted by COBE, Sleth and Rambøll and foresees a division of the area into a number of islets divided by canals and basins. The master plan is composed of an area of about 3.5 million m² with the capacity for 40,000 residents and 40,000 workplaces. The islets can be seen as independent local districts which can also be transferred into a development in several stages. The current area in focus is called Inner Nordhavnen.

Inner Nordhavnen will be representative of the entire Nordhavnen development and will be a densely built, compact district with many facilities and short distances.

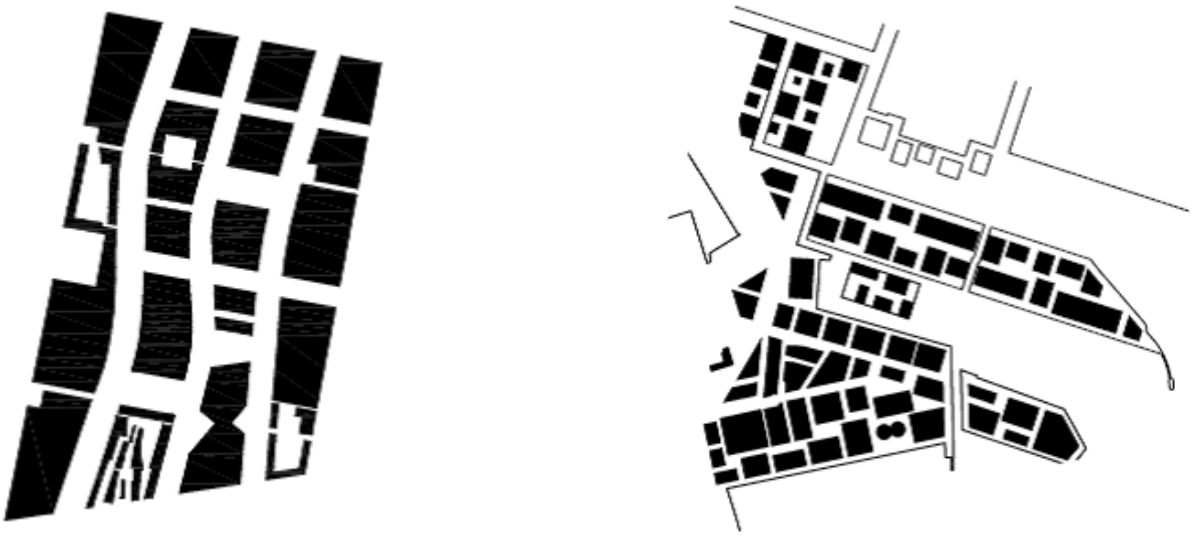


Figure 39: Left: Comparison of the building scale of Ørestad Syd; Right: Inner Nordhavnen (By & Havn 2012)

It will also include green spaces and open water. Walking or cycling will be the preferred forms of mobility in the area and the metro is there with the intention of replacing the use of cars.

4.10.2 Procedure, Measures and Project Implementation

As outlined above, both urban developments followed a similar procedure: development act, architectural competition, master plan and the sale of the plots to developers. In both cases, the sale of small plots for single buildings was not foreseen. The income generated through selling the plots was/is used to finance the infrastructure, including the metro. Both areas are mixed use and include housing, services, education and business.
In both Ørestad and Nordhavnen the citizens were included in the development planning right from the start. The ideas competitions and the subsequent integration of the results into municipal plans were presented to and commented on by the citizens and other stakeholders. Especially in Nordhavnen, the citizens already provided input during the ideas competition. The dialogue will be continued throughout the entire planning process.

Figure 40: Photo from the inside of the 8-Tallest building in Ørestad (own photography by Heike Erhorn-Kluttig)

The difference in the projects, besides Nordhavnen being located in the former harbour area and thus at the sea, is the way the dense plot ratio of about 1.8 has been (in Ørestad) and will be (in Nordhavnen) incorporated into the developments. While large (and tall) buildings such as 8-Tallet (Number 8) or Stævnen were built with large green or other urban spaces in between in Ørestad, Nordhavnen will concentrate on a so-called manageable or human scale level, with smaller building plots for small building complexes generating intimacy and proximity. A comparison of Ørestad South and Inner Nordhavnen is presented in figure 39:

Lessons learned in Ørestad and implemented in the urban planning of Nordhavnen are listed below:

- Scaling of buildings: The residents of Ørestad seem to appreciate the new district. There have, however, been comments from other citizens that point out that the sizing of buildings and open spaces is not adapted to the human scale, meaning they are too large and intimidating. In Nordhavnen the buildings will be smaller.

- Structuring of building plots and street arrangement: The open areas and the streets in the Ørestad district are often experienced as very windy. The reason for this is that the streets run com-

pletely through the length of each quarter, for example Ørestad Syd. The strong coastal winds, therefore, are not kept outside the building areas. In Nordhavnen, the street grid has been adjusted to avoid wind tunnels.

- Size of public spaces: According to a citizen survey, people prefer smaller public spaces for all aspects of vibrant urban life including meeting points and quiet spaces. This knowledge will be included in the development of Nordhavnen.

Furthermore, all designs have now been optimized to provide greatest disaster resilience through various disaster scenario simulations with respect to natural hazards (storms, floods). The overall goal is a built environment that is most adaptable to such challenges.

4.10.3 Financing the Project

For both developments the financing was based on the sale of building plots. The close proximity to the city centre and the »guarantee« that the development was supported by the new metro lines made the plots attractive for developers. Talking about the metro and the two urban developments is similar to the chicken and egg problem. What was first? In case of the urban developments they have both been possible only because and together with the metro.

It can be assumed that this kind of financing only works when a city is attractive to new citizens and continuously growing.

4.10.4 Actors

For Ørestad, a company was created which became the main developer. This company was also given responsiblity for the development of the metro, and called Ørestadsselskabet. The company existed from 1993 to 2007. At this point, the company was split into two new companies; one was given responsibility for the metro (Metrosleskabet) and the other company merged with the Port of Copenhagen to become CPH City and Port Development (By og Havn). The municipal plan for Ørestad was developed by a Finnish architectural studio which later merged with a Danish architectural company to become the architectural studio ARKKI.

In Nordhavnen, »By og Havn« is responsible for organizing the entire quarter and for selling the plots to developers. By og Havn is jointly owned by the City of Copenhagen (55%) and the Danish state (45%). The development plan is being worked out by COBE, Sleth and Rambøll.
Other major actors are the City of Copenhagen, the citizens and – particularly in the case of sustainably developing Nordhavnen – the energy companies DONG and HOFOR (previous name: københavnsE) as well as the Danish Ministry for Climate and Energy.

4.10.5 Barriers and Challenges, Key Drivers and Framework Conditions

The building crisis of 2008/2009 had an impact on both urban developments. The forward-thinking decision was made, however, to continue both projects, despite the significant delay of other urban developments in Copenhagen – for example the Carlsberg area.

The involvement of different city departments on issues such as, for example, sustainability and financing occasionally made the development process more difficult. For the past few years, however, a new approach within the city administration has helped facilitate communication between different departments.

By og Havn and the City of Copenhagen are the main drivers of the developments, as demonstrated by the quote by Rune Boserup.

4.10.6 Successes and Success Criteria

The sale of plots in Ørestad was very successful, the development is running fine and the metro was financed. In Nordhavnen's first development section, the Arhuskvartier, about 1,700 apartments have already been sold.

With the continuous growth in the number of citizens in Copenhagen, it is expected that both districts will be successfully developed, sold to investors and inhabited by residents and business companies.

4.10.7 The Ørestad/Nordhavnen Developments and Sustainability

Nordhavnen buildings will – like all new buildings built by the city of Copenhagen – now already have to fulfill the EP requirements set for 2015. Additionally, the plan is to include:

- smart energy (smart grid),
- smart houses (intelligent systems, installations, lighting, heat control and thermo-active elements),
- low energy street lighting,
- electric cars,
- low temperature DH (70 degrees feed),
- district cooling involving ground water and seawater,
- heat storage,
- geothermal energy (as focus on renewable energy sources other than wind turbines and solar panels),

- availability of energy data to illustrate energy consumption and help reduce it.

Measures for sustainability concerning mobility are seen in the focus on walking, the bicycling routes, the metro connection and that parking is only available in central areas. The mix of dwellings and businesses will further decrease the necessary movements by car.

Green facades and small open spaces for recreation are part of the design. These are linked with the focus on human size buildings in the Nordhavnen development. There is also a plan to implement requirements for re-using grey water and constructing green roofs.

4.10.8 Transferability of the Practice Example

The idea of merging the development of urban areas with transport facilities was inspired by the English New Town principle. Copenhagen, however, not only financed their metro by selling building plots but also financed the remaining infrastructure necessary for Ørestad and Nordhavnen. This approach is probably only applicable in very attractive areas, close to the city centre and also close to recreational areas (green area in Amager for Ørestad and the seaside for Nordhavnen). Otherwise, the plots cannot be sold for prices that are high enough. Additionally, there must be a growing number of citizens in order to prevent older areas from becoming less inhabited as people move into the new areas.

The planning principles for Nordhavnen should, however, for the most part be transferable to other developments. Small scale buildings and urban spaces, sustainable concepts in terms of low energy buildings, low energy transport, etc. should be integrated into new city developments from the first planning phase right through to the realization phase. Additionally, the citizens' participation in the projects right from the start has been important for the success of the developments.

Rune Boserup, project manager for the urban development for COBE

"The urban development in Nordhavnen works well because By og Havn is the main driver and the City is very much behind its project and backs it with the necessary decisions. The public authorities and the metro line development provide security for the investors."

4.11 THINK TANK »BUILDING RENOVATION« AND THINK TANK »CITY 2025«

The Copenhagen Climate Plan foresees a 3% renovation rate in the existing building stock per year. In order to increase the number of building renovations taking place to meet that goal, the Landowners Investment Fond and Realdania, a philanthropic association supporting projects with a focus on cities, buildings and the built environment initiated a think tank on »building renovation« in autumn 2011.

4.11.1 Creation and Objectives

The think tank aims at accelerating the process of renovating existing building by bringing together the key actors and agreeing on supporting strategies and instruments. The initiative was joined by a broad range of actors involved in the building sector including builders, educational organisations, politics, building owners, research and organizations representing the public. During the first project phase, spanning a one year period, the think tank has discussed the following questions:

- What are the barriers for building renovations?
- Why is the innovation rate and the increase of productivity in building renovation rather low?
- How to specifically boost the renovation market?
- Are the financing possibilities currently available sufficient?
- New roles in building construction: how to improve the cooperation and the contracts?

4.11.2 Procedure, Measures and Project Implementation

At the end of this first project phase, the members agreed on the following seven areas of focus, which are meant to be developed further in phase 2:

1. Holistic thinking in renovation
2. Statistical analysis of renovation activities
3. Mapping of renovation needs
4. Clarification on the impact of renovations
5. Improvement in the training of builders
6. Support for innovations
7. Knowledge exchange

For each focus area, a key person was identified who will propose follow-up activities within the sector.

4.11.3 Financing the Project

There are no details about the financing of the think tank available. It is assumed that the initiators sponsored at least the meetings. The Danish Energy Agency acted as secretary for the think tank.

Since there are no specific measures defined so far, there have been no large costs associated with the think tank thus far either. The seven areas of focus, however, lead to the conclusion that funding will be necessary in the areas of education and training, surveys, knowledge transfer and innovation.

4.11.4 Actors

In addition to the two initiators Realdania and the Landowners Investment Fond, the think tank includes the following members:

- Danish building industry represented by associations
- Confederation of building materials
- Crafts council
- Architects association
- Danish architect offices
- Engineers associations
- Credit institutions and banks
- Ministry for town (Ministeriet for By)
- Dwelling and rural property agency
- Danish Building Research Institute (SBi)
- Copenhagen Property
- Knowledge center for energy savings in buildings
- Danish Energy Agency

Prof. Claus Bech-Danielsen

"One of the barriers for building renovation is that it is not `sexy`. New buildings are."

4.11.5 Barriers and Challenges, Key Drivers and Framework Conditions

Besides all think tank members having to agree on the focus areas, there were no barriers identified for the first phase of the action. Barriers, including the possible financing of the actions will most likely come up in the second phase.

Most importantly the initiators, but presumably all members of the think tank, are the drivers of the action. Copenhagen's Climate Plan, developed by the city administration, supports the initiative from the regulatory side. If Copenhagen really plans to be CO_2 neutral by 2025, major energy savings must be achieved in the building stock.

4.11.6 Successes and Success Criteria

It can be deemed a success that all major stakeholders participated in the think tank and agreed on the areas chosen for further action. Since the follow-up measures are currently being developed, the impact cannot be analyzed in a quantitative way at this time. Based on the success so far, a second think tank was initiated with some of the same actors, this time dealing with »Cities 2025«.

A way to measure the think tank »Building Renovation« would be to compare the building renovation rate before the action and afterwards. However, we were unable to find any statistical value for the renovation rate in Copenhagen in 2012 or any other year. The city's climate plan foresees a renovation rate of 3%/a. There has been no feedback from the target groups, apart from the participating organizations, so far.

4.11.7 The Think Tanks and Sustainability

Building renovations contribute to all areas of sustainability. Renovations reduce energy consumption and increase the value of buildings as well as the liveability of the city. The concrete measures will have to be defined and their impact on the city's sustainability must then be assessed after they are put into action.

4.11.8 Transferability of the Practice Example

A think tank, or more generally a meeting platform for stakeholders, is a good first step in developing a concept, mainly for ensuring the participation of all interested or affected parties. In working together, acceptable approaches for all sides can be developed and the financing process for possible actions is taken into account right from the start. The approach was not invented for this project but can be easily transferred to other countries and interest areas. It is also used in Germany where, for example, Chancellor Merkel invites experts to so-called »Energie-Gipfel« (energy summits).

4.12 ROYAL DANISH PLAYHOUSE – A LOW ENERGY BUILDING WITH SEAWATER COOLING

The new Playhouse for the Danish Royal Theater on the Copenhagen waterfront was opened in 2008. The playhouse consists of a main stage with 650 seats, a second stage with 250 seats and a small studio stage with 100 seats plus rehearsal rooms, a recording studio, costume workshop, restaurant, café, library, offices, facilities for staff and artists and a large public square in front of the building. The building was part of an EU FP6 project

Figure 41: Left: View of the Royal Danish Playhouse, built on top of the water; Right: Foyer area inside (own photographies by Heike Erhorn-Kluttig)

called »Eco-Culture« and as such had ambitious goals in terms of energy efficiency. The approach developed to meet the defined goals includes thermally active structures with energy storage, seawater cooling with heat pumps and demand-controlled ventilation. Surplus energy generated during the theater performances (overheating based on high internal gains) is used later through the storage system and the building features an intelligent Building Energy Management System (BEMS).

4.12.1 Creation and Objectives

After the Ministry of Culture decided that the City of Copenhagen needed a bigger and more modern theater, the idea of using the building as an energetic lighthouse was born. Engineers from COWI, responsible for the building service technologies, developed an energy saving heating and cooling design and included the building in an EU FP6 project that featured two other cultural buildings besides the Playhouse: the new library in Amsterdam and the new opera house in Oslo.

The objectives of the project have been to demonstrate reductions in energy consumption and CO_2 related emissions related to cooling by 75-80% and related to heating by 35-50%. In terms of ventilation, the goals are also a reduction of 35-50% CO_2 emissions. Further aims included demonstrating that the use of renewable energy sources and intelligent controls can be integrated into high-profile buildings. The applied technologies used include energy storage, seawater cooling, heat pumps, demand-controlled hybrid ventilation, building integrated PV systems and advanced BEMS as well as green concrete with less CO_2 emission than conventional concrete. A final objective has been to disseminate the ECO-concepts used in the buildings to a very wide range of people in both Europe and beyond.

4.12.2 Procedure, Measures and Project Implementation

The design of the building and building service system by COWI architects and engineers included the following measures:

- A high quality thermal building envelope designed to reduce the necessary heating and cooling requirements.
- The climate belt: an energy storage system using thermo-active slabs on the façade areas. Water filled tubes are embedded in the concrete slabs and function as both a heating and cooling system with temperature levels close to room temperature. During winter, excess heat from lighting and the audience is stored in the thermo-active slabs.
- Seawater cooling and an optimized heat pump: the Playhouse uses compressors for heating and cooling of the building. During summer, seawater is used for cooling the building via a heat exchanger; the compressor is only needed as a supplement during unfavourable conditions. In addition, the heat pump can provide the required temperature in the distribution systems during times when the temperature of the seawater is too warm or too cold.
- Ventilation: The large foyers and offices, etc. are ventilated with natural ventilation, which saves energy. In the auditoriums, demand-controlled mechanical ventilation is used. During summer, the building is also cooled during the night by so-called free cooling (night ventilation by opening ventilation slots at the bottom and skylights at the top of the building).

- Environmentally friendly ('green') concrete: The embodied energy of the concrete as well as the CO_2 emissions generated during the production is reduced.

4.12.3 Financing the Project

The costs for the entire building have now totaled about DKK 750 million (EUR 100.5 million). The EU has contributed DKK 5 million (EUR 670,000). The initial investment costs were somewhat higher than it would have been have been the case with a regular building, but the payback times are less than 15 years.

The additional costs in association with the specific technologies are listed below:

- thermo-active slabs and sea water cooling: 770,000 EUR (payback time: 12.2 years)
- intelligent ventilation and BEMS: EUR 404,000 (payback time: 6.5 years)
- environmental friendly concrete: EUR 200,000 (no payback since no energy saving)

The theater benefits from low operational costs due to its reduced energy consumption. Since the money for the theater comes from the cultural ministry, it is in the end the state – or the public – that benefits from these savings. The yearly operational costs for the cooling system are EUR 20,000 and for the ventilation system the costs amount to EUR 14,100.

4.12.4 Actors

The playhouse was built by the ministry of culture and based on the design of the architects Lundgaard & Tranberg A/S. The engineering part was covered by COWI, the acoustics for the halls by Street & Mortensen. The general contractor was Pihl & Sohn. For the energy efficiency measures, co-funding was received from the European Union within the 6th Framework Programme. For this, COWI was the leading actor (coordinator). The smooth operation of the Playhouse is supervised by Søren Nylin, with aims of further increasing energy savings.

Søren Nylin, operational supervisor of the Royal Danish Playhouse

"The Theater uses half of the energy per m² compared to the Opera House (built at the same time), though also there we are working on an energy saving operation."

4.12.5 Barriers and Challenges, Key Drivers and Framework Conditions

The Playhouse was completed before the Danish building crisis and therefore did not experience this general barrier. A challenge is nearly always the control of such complex buildings. Though the monitoring results have proven the success of the design even within the first two years, the multiple control scenarios for the building combining usage modes and temperature conditions have been regarded as too complicated and could be reduced from 16 different scenarios to only five. However, the commissioning procedure took two years after the completion of the building.

A key driver was the involvement of the engineering company COWI which designed the building service systems, planned the use of seawater cooling, the climate belt, the demand controlled ventilation for the auditorium and the natural ventilation as well as the other energy saving measures. The EU project requested detailed monitoring of the energy consumed and the effectiveness of the technologies. Combined with the BEMS, this made additional optimization during the commissioning process possible.

4.12.6 Successes and Success Criteria

The envisaged energy and CO_2 emission savings were quite ambitious, especially for a high-level cultural building in which complicated and diverse usage patterns must be met with the building technologies. The energy savings achieved by the building itself amount to 71% of the cooling energy and 41% of the heating energy, when compared to a regular building design. This is, for example, a saving of 865 MWh/a in heating. According to the monitoring results, all goals have been met if compared with the usage time initially planned. The planned electricity use was exceeded because of the longer usage time, but the heating consumption target was more than met and thus the total energy consumption target was achieved.

Characteristic value	Calculated	Monitored (average of the first two years 2008/2009)
Total heating energy consumption	1,530 MWh/a	1,244 MWh/a
Total electricity consumption	1,131 MWh/a	1,366 MWh/a
Total energy consumption	2,661 MWh/a	2,610 MWh/a

An even more important aspect of this project, however,

is the frontrunner or lighthouse function of the building, which may inspire all Copenhagen citizens to save energy in their buildings. The building is visually appealing, and both users and staff are happy with the building. The large number of visitors shows that the building has become an integrated part of the city's cultural life.

The project has been a huge success for the engineering company COWI. Especially the combination of thermoactive slabs and heat pumps for heating and cooling using seawater or ground water sources as a reservoir have been adopted in new building projects. This has formed and continues to form the basis for several projects where sustainability and low energy consumption are being prioritized.

4.12.7 The Playhouse and Sustainability

The energy efficient Playhouse contributes to the ecological pillar of sustainability by saving roughly 75% energy and CO_2 emissions when compared to a regular design. The economic pillar is addressed through reducing the energy costs by approximately the same ratio and the social pillar has been fulfilled since the cultural building is being used as a lighthouse building to motivate the citizens to reduce their own energy consumption as well. The energetic success could, however, be more prominently presented in the building and on its website. On the other hand, tours through the building inform visitors about the measures and successes of the low energy building design.

4.12.8 Transferability of the Practice Example

As already mentioned, based on the success of the building, the engineers have been able to transfer the main technologies and the general approach of sustainability to other major projects. The impact on the building's visitors (citizens and tourists) and their awareness of energy efficiency is, unfortunately, not easily assessable. However the general idea of lighthouse projects (in this case for energy efficiency) like the Royal Danish Playhouse is that they create awareness and interest at the public and especially at other building owners and planners so that the approaches will be multiplied.

4.13 PRODUCTION AND LOGISTIC NETWORKS IN COPENHAGEN AND GREATER COPENHAGEN AREA

Copenhagen has an ambitious goal: becoming carbon neutral by 2025. Another of the city's goals is to achieve an average annual growth in GNP of 5% until 2020 (City of Copenhagen, The Technical and Environmental Administration 2011). In order to reach this target, Copenhagen plans on strengthening its position as a centre for green growth and a living test lab for new green solutions. Cluster initiatives in various sectors like cleantech (Copenhagen Cleantech Cluster) or life science (MediconValley Alliance) attempt to connect stakeholders and actors from business, public research institutions and universities, public and private organizations and the investment sector. This is meant to promote cooperative working relationships between the stakeholders in order to create good framework conditions for business.

4.13.1 Copenhagen Cleantech Cluster

Important drivers for industrial development and growth for cleantech include history, policy and regulation. Cleantech is an umbrella term including energy-related sectors and environmental technologies. The history of cleantech growth in Denmark follows two tracks. One track is based on environmental issues and the other track on energy production and efficiency. Denmark was the first country in the world to pass a coherent Environmental Protection Act and after the oil crises in 1973, Denmark focused not on the construction of nuclear power plants but on alternative, renewable sources of energy supply (Copenhagen Capacity 2013). Both these areas of focus resulted in policies and strategies to protect the environment through environmentally friendly technologies and renewable sources for the energy supply. Denmark´s strong political focus on sustainable solutions and renewable energy sources makes Copenhagen a living test lab for exploring best practices for green solutions and pursuing growth strategies for international cleantech companies. Today, Copenhagen offers a strong cleantech platform – the Copenhagen Cleantech Cluster. The Cluster is home to companies, organisations, research institutions and universities with particular know-how within the energy and environmental sectors.

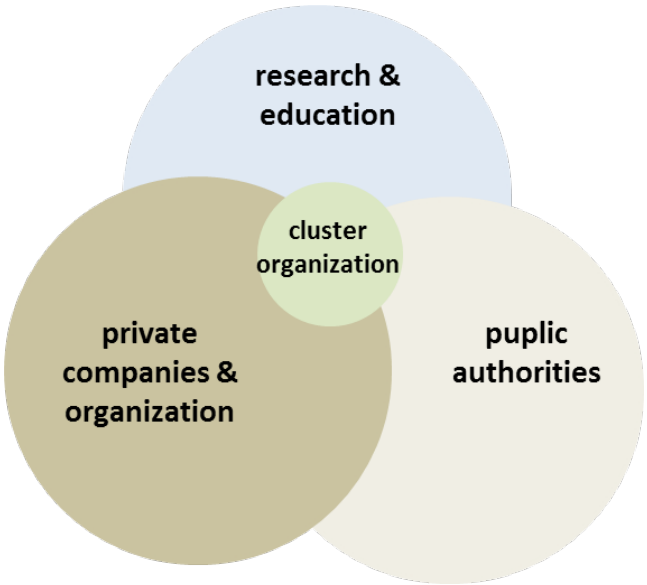


Figure 42: Copenhagen Cleantech Cluster Setting (own graphic, based on Copenhagen Cleantech Cluster 2012)

In April 2010, Copenhagen Cleantech Cluster was launched to ensure growth, innovation and cooperation between Danish cleantech firms (particularly in Copenhagen) and knowledge institutions. Copenhagen Cleantech Cluster is a member-based public, non-profit association, which brings together the most significant actors from within the Danish cleantech industry. The association was founded by 15 founding members. The organisation of the Copenhagen Cleantech Cluster is based on a triple helix model of cooperation. This triple helix model exists of three columns: university – industry – government. The model focuses on interactions between these columns (university, industry, government) and has been recognised as a key to innovation in knowledge-based societies.

The Copenhagen Cleantech Cluster's vision is to develop one of the world's leading cleantech initiatives, creating superior value for the involved companies and the research institutes and enabling these to differentiate themselves by connecting cleantech technologies and players across sectors and value chains. The cluster organization facilitates partnerships, engages in networking, and hosts events to create new business opportunities for the partners in the cluster.

The Copenhagen Cleantech Cluster includes the following eight cleantech-areas: sustainable materials, waste and recycling, water and wastewater, air and environment, green energy production, streamlining of energy consumption, energy infrastructure and energy storage. The technologies developed contribute to the production of renewable energy or sustainable materials, reduce the use of natural resources by exploiting the resources or energy more efficiently, reduce the harm caused by fossil fuels or reduce pollution problems. The engaged partners in the initiative can be divided into the following sectors: (1) industry, (2) research institutions, (3) public and private organizations. Based on an understanding of which activities and areas are involved in cleantech, the Copenhagen Cleantech Cluster conducted a study in the year 2011 which identified more

Facts:

There are more than 600 cleantech companies in the Greater Copenhagen area.
These Cleantech companies employ 77,500 people.
34,000 employees work directly with cleantech.
51% of the cleantech companies grew in 2011, 37% maintained their position.
51% increased their R&D budgets.
70% are also engaged in activities outside Denmark.

Figure 43: Facts of Copenhagen Cleantech Cluster in 2011 (Copenhagen Capacity 2012)

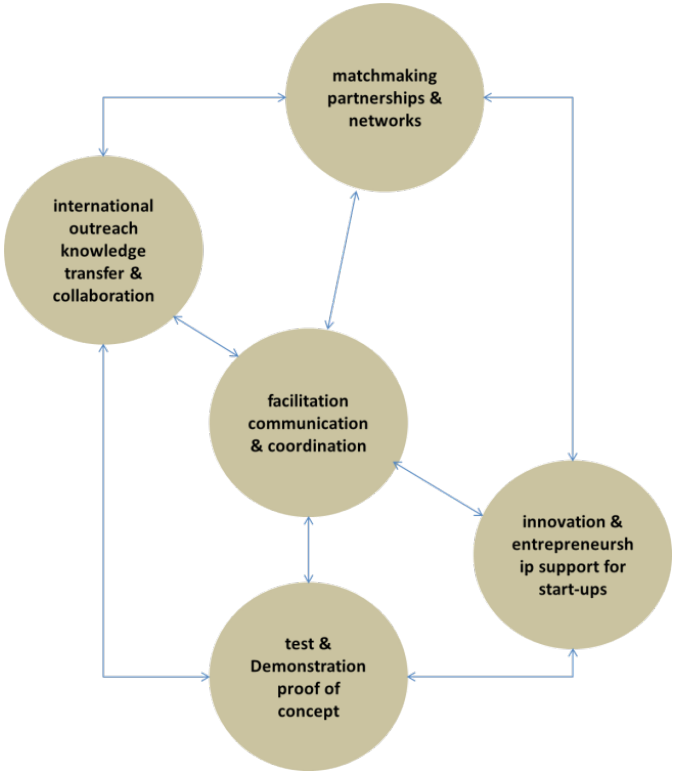


Figure 44: Overview of the Copenhagen Cleantech Cluster's services and focus areas (Copenhagen Cleantech Cluster 2012)

than 600 companies that work according to the definition of cleantech. An analysis of these companies shows that the largest proportion operates within the service sector, followed by retail and manufacturing companies.

As an organization, the Copenhagen Cleantech Cluster carries out projects within different areas including: test and demonstration, matching partnerships and networks, international contacts including knowledge transfer and collaboration and support for start-ups (Copenhagen Capacity 2012).

Copenhagen Cleantech Cluster received funding amounting to a total of DKK 142 million (around EUR 20 million) from the Capital Region of Denmark, Region Zealand (administrative region of Denmark) and the European Union Structural and Cohesion Funds from 2009 to 2014. The European Commission has launched a number of cluster related projects and initiatives aiming at the improvement of cluster policy within Europe and improving the efficiency of existing efforts in cluster management. Additionally, the members of the Cluster (companies) must pay a yearly membership fee (two categories: (1) DKK 300,000, around EUR 40,000; (2) DKK 10,000, around EUR 1,400) (Climate Consortium Denmark 2011).

The Copenhagen Cleantech Cluster has ambitious objectives. By 2014 the Cluster aims to achieve the following

objectives (Copenhagen Cleantech Cluster 2012):

- Creation of 1,000 new jobs.
- Attraction of 25 foreign companies to the cluster.
- Creation of 30 new research- and innovation collaborations between companies and research institutions, for example start-ups or joint research applications/projects.
- Establishment of collaborations with 15 international cleantech clusters.

In order to achieve these objectives and to create continuous growth for existing cleantech companies, or to support and assist new cleantech companies, the Copenhagen Cleantech Cluster provides different services for their various members. The services are shown in figure 44 on the right and explained below.

- Test & Demonstration: Copenhagen Cleantech Cluster supports the establishment of new test and demonstration facilities. Many companies have identified the lack of sufficient test & demonstration facilities as a major obstacle for their future growth.

- International Branding & Marketing: Copenhagen Cleantech Cluster is a part of the International Cleantech Network (ICN). Through targeted marketing and international cooperation, Copenhagen Cleantech Cluster wants to create opportunities for collaboration and knowledge transfer with other Cleantech Clusters and their members.

- Matchmaking & Sector Networks: Matchmaking is an important element of each Cluster or Network. To connect the different partners and members of the Cluster and to ensure that conditions are conducive to sharing knowledge is also important for the Copenhagen Cleantech Cluster.

- Innovation & Entrepreneurship: In this area, Copenhagen Cleantech Cluster's objective is to create the best conditions for new business ventures by supporting new ideas within existing companies as well as start-ups.

4.13.2 Medicon Valley Alliance

The idea of creating Medicon Valley slowly emerged during the early 1990's. This cluster connects universities, hospitals and companies in the Øresund Region, which includes the regions of Greater Copenhagen and Zealand in Denmark and Skåne in Sweden. Therefore, Medicon Valley is a bi-national life-sciences cluster with a large number of life science companies and research institutions located within eastern Denmark and southern Sweden. The almost century-long presence of a number of research-intensive and pharmaceutical companies, such as Novo Nordisk, H. Lundbeck, AstraZeneca and LEO Pharma, has also contributed to the development of the region as Medicon Valley. Today, there are universities, hospitals and life sciences companies, biotech, medtech and pharma involved in the cluster. Many of them are R&D based. The area includes twelve universities, 32 hospitals, more than 300 life science companies and a cluster organization called Medicon Valley Alliance.

The Medicon Valley Alliance (originally Medicon Valley Academy) was officially founded in 1997 as an EU Intereg II project with 23 regional actors. The primary initiators behind the cluster organization were the universities in Lund and Copenhagen. Both were supported by the major pharmaceutical companies in the region. In 2007, Medicon Valley Academy changed its name to Medicon Valley Alliance to signal its broader foundation in the region – not only in academia but also in the business and private domains of the region. Today, the cluster organization has more than 300 members.

The Medicon Valley Alliance is a Danish-Swedish network organisation which represents human life sciences in Medicon Valley. The network organization looks after the best interests of the life science community in Medicon Valley. The Medicon Valley Alliance is a non-profit member organization. The objectives of the organization are to increase economic growth and competitiveness as well as employment in Medicon Valley. Furthermore, the organization is committed to raising international awareness about Medicon Valley with the aim of attracting labour, investors, and partners.

The Medicon Valley Alliance supports their members through four types of services:

- Building Networks: The Alliance arranges events, seminars and meetings for its members. In this way, Medicon Valley Alliance operates as a platform for bringing its members together with other ongoing platforms as well as other local and international networks and their members.

- Organizing Events and Seminars: For its members, the Alliance arranges numerous events and seminars with the purpose of providing new knowledge and information about scientific, technical and management-related topics within the life sciences.

- Creating Overview: Through a regular magazine publication, the Alliance gives an overview of the latest developments in Medicon Valley and of the region's life science stakeholders.

- Conducting Analyses: Every year the Medicon Valley Alliance conducts analyses which provide information about challenges and trends in Medicon Valley.

4.13.3 Actors, Key Players and Financing

Both Clusters are comprised of an organization or association including various employees responsible for specific areas. Examples of these areas include: implementation and development of the cluster as an innovation platform, development of new projects to support the mission of the cluster and development of relationships with domestic and international stakeholders.

The Copenhagen Cleantech Cluster organization has two categories of membership: founding members and members. Founding members are members/companies who wish to take leadership and seek influence within the cluster. Such members can join Copenhagen Cleantech Cluster´s Board of Directors, get first priority in the strategic direction of new projects and access to all Copenhagen Cleantech Cluster activities. Companies which are only members can work together with Copenhagen Cleantech Cluster. Such companies get access to most Copenhagen Cleantech Cluster activities, and have the right to participate and vote at Copenhagen Cleantech Cluster ,s General Assembly and run for a position as a board member. Currently, the Copenhagen Cleantech Cluster has twelve founding members: Aalborg University, Albertslund Municipality, Bech-Bruun, Copenhagen Business School, The Danish Building and Property Agency, Copenhagen Municipality, Dong Energy A/S, HOFOR, IBM, Kalundborg Municipality, Rambøll, SEAS-NVE and Siemens Danmark A/S. In addition to the fees paid by the members, the Copenhagen Cleantech Cluster receives financial support from different parties. These parties include the European Union, Growth Forum Capital Region, Growth Forum Zealand, Danish Industry Foundation and Realdania. From each of these companies, one representative is a member of Copenhagen Cleantech Cluster´s Board of Directors (Copenhagen Cleantech Cluster 2013a).

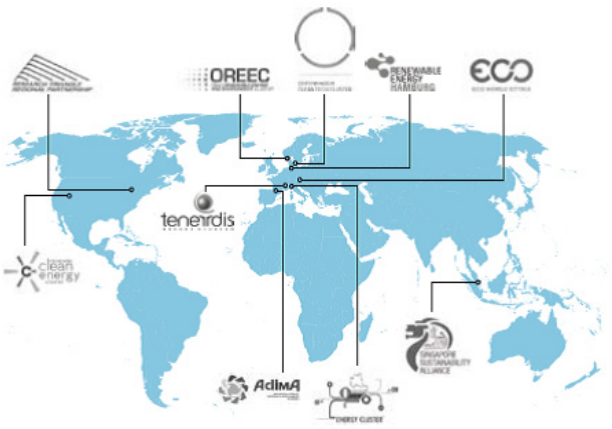
The Medicon Valley Alliance has a different funding model. The Alliance is primarily financed through membership fees and has three categories of members: regions and cities, universities and all other members. Each member in all three categories has to pay a basic fee of DKK 6,075 (around EUR 800) and an additional fee depending on the number of inhabitants, researcher or employees, respectively (MEDICON VALLEY ALLIANCE 2013). The Medicon Valley Alliance also has a Board of Directors. The members of the Board consists of a combination of Danish and Swedish representatives from private and public research organizations, academia and regional governments, as well as SME's and large international companies in the areas of biotech, pharma, and medtech.

A keyplayer for both Clusters is Copenhagen Capacity. Copenhagen Capacity is one of nine founding partners in the Copenhagen Cleantech Cluster and is responsible for the overall coordination and facilitation of Copenhagen Cleantech Cluster. Copenhagen Capacity also plays an important role for Medicon Valley. Copenhagen Capacity is one of two official inward investment agencies in the region and helps companies connect to potential partners and investment opportunities.

4.13.4 Sustainability

Both clusters have made a significant contribution to increasing the economic growth, the competitiveness and the employment in the regions. This includes assuring existing jobs as well as creating new job in the region. With a variety of services, the clusters support the companies in their activities and their networking.

The Copenhagen Cleantech Cluster is important for green growth in the City of Copenhagen and Denmark. In the period 2004-2009 cleantech enterprises in the Greater Copenhagen area grew by 55%. In the same time the manufacturing industry grew only by 8%. Cleantech enterprises contribute significantly to the economy. Additional the City of Copenhagen actively use new green technologies in



Network Partners:

- Renewable Energy Hamburg (Germany)
- Lombardy Energy Cluster (Italy)
- Tenerrdis (France)
- ACLIMA (Spain)
- Eco World Styria (Austria)
- OREEC (Norway)
- Singapore Sustainability Alliance (Singapore)
- Research Triangle Region Cleantech Cluster (North Carolina, US)
- Colorado Clean Energy Closter (Colorado, US)
- Copenhagen Cleantech Cluster (Denmark)

Figure 45: Overview of the ICN`s partners and their office's location (The ICN o. J.)

the city self and although to serve as a living lab indicating success. In this way Copenhagen will become innovation and growth and underpin development in cleantech industry which supplies products and consulting serves to reduce pollution and resource consumption. A downside of this development is an ongoing retreat of manufacturing industry of the city and maybe Denmark with a simultaneous focus on tertiary sector of economy.

4.13.5 Transferability of the Practice Example

There are different cleantech Clusters located throughout the world, with a focus on different thematic priorities. Some of these are members of the ICN. These single Clusters are examples for the transferability of networks.

Clusters, such as the Copenhagen Cleantech Cluster aimed at promoting a specific economic area, can be transferable under certain circumstances. One of the framework conditions necessary may be that the members of such a cluster understand the cluster to be a democratic partner network, making decisions together and having regular meetings. For a effeteness operation of a cluster existing not hard criteria. It is certainly helpful if the parties have a similar understanding of cooperation and communication. A condition for the performance or benefit of clusters is the confluence of the society and companies in the region. Within networks there should be an intensive exchange of material goods, but especially of information and knowledge. This does not mean that cooperation must take place at all levels. A unique feature of the Copenhagen Cleantech Cluster is the understanding of the city to serve as a living lab for green technologies and green solution and the engagement of the city government to use new developed technologies intensively in the city.

5

5 RESULTS OF THE CITY RESEARCH

5.1 ACTORS WITHIN THE CITY

On the basis of the practice examples in chapter 4, the actors identified as being important in each sector analyzed have been assembled to provide an overview of who may be important in regards to sustainable development in Copenhagen. However, this table does not provide a comprehensive picture of all important actors, as this would have been too complex and large a task to fulfill within the two week research stay.

Table 2: Actors within Copenhagen

	Partner	Internet	Category
Business Innovation and Governance	City of Copenhagen, Technical and Environmental Administration	www.tmf.kk.dk	
	- CBD		
	- Center for Environment/Climate Secretariat		
	- Center for U-Crban Development		
	City of Copenhagen, Finance Administration *- Citizen Service*	www.okf.kk.dk	
	- International Affairs and Sustainable City Development		
	University of Copenhagen *- Department of Political Science*	http://polsci.ku.dk/	
	Realdania	www.realdania.dk	
	Service Cluster Denmark	www.serviceplatform.dk/english/sider/default.aspx	
Energy	Middelgrunden	www.middelgrunden.dk/	
	CTR	www.ctr.dk/en/home.aspx	
	Byg og Havn	www.byoghavn.dk/	
	Dansk Fjernvarme	www.danskfjernvarme.dk/	
	Cenergia Energy Consultants	www.cenergia.dk/	
	City of Copenhagen - The Technical and Environmental Administration; CBD	www.tmf.kk.dk	
	Hotel Manager	n.n.	
Water	City of Copenhagen – The Technical and Environmental Administration	www.tmf.kk.dk	
	- Center for Parks and Nature		
	- Center for Environment		
	HOFOR	www.hofor.dk	
	Ramboll	www.ramboll.dk	

	Partner	Internet	Category
Water	University of Copenhagen - *Department of Geosciences and Natural Resource Management*	www.ku.dk	
	Technical University of Denmark - *Demartment of Civil Engineering*	www.byg.dtu.dk	
	Smith Innovation	www.smithinnovation.dk	
	DHI	www.dhigroup.com	
	Hotel Manager	n.n.	
Security	City of Copenhagen – The Technical and Environmental Administration - *Center for Park and Nature*	www.tmf.kk.dk	
	CBD	www.kk.dk/sktKjeldsKvarter	
	COBE architects	www.cobe.dk	
	Smith Innovation	www.smithinnovation.dk	
	By og Havn	www.byoghavn.dk	
	National Police	www.politi.dk	
	Central Fire Department	www.okf.kk.dk	
Mobility	City of Copenhagen – The Technical and Environmental Administration	www.tmf.kk.dk	
	- *Center for Traffic*		
	- *Center for Parking*		
	- *Center for Resources*		
	Clever.dk	www.clever.dk	
	Metroseleskabet I/S	www.m.dk/metroselskabet	
	Tuxi	www.tuxi.dk, www.tuxigroup.com	
	Danish Cyclists' Federation	www.cyklistforbundet.dk	
	Better Place	www.betterplace.com	
	Nissan	www.nissan.dk	
	Transportens Innovations Netvaerk	www.tinv.de	
	The Danish Electric Vehicle Association	www.danskelbilalliance.dk	
	Technical University of Copenhagen - *Department of Transport*	www.transport.dtu.dk	
	Danish Technological Institute	www.dti.dk	

	Partner	Internet	Category
Buildings	City of Copenhagen – The Technical and Environmental Administration	www.tmf.kk.dk	
	- City Architect/CBD		
	- Center for Environment		
	Byg og Havn	www.byoghavn.dk	
	Realdania	www.realdania.dk	
	Cenergia Energy Consultants	www.cenergia.dk	
	COBE Architects	www.cobe.dk	
	SBi/Aalborg University	www.sbi.dk	
	Kuben Management	www.kubenman.dk	
	Royal Danish Playhouse	www.kglteater.dk	
	Danmarks Almene Boliger	www.bl.dk	
	Ramboll	www.ramboll.dk	
	COWI	www.cowi.dk	
P & L	Copenhagen Cleantech Cluster	www.cphcleantech.com/	
	Ramboll	www.ramboll.com	
	DI Confederation of Danish Industry	www.di.dk	
	medicon valley alliance	www.mva.org	
	Novo Nordisk	www.novonordisk.com	
	Dansk-Tysk Handelskammer	www.handelskammer.de	
	Copenhagen CAPACITY	www.cocap.com	

Legend:	
	Politician/Administration
	Industry/Enterprise
	Interest Group/Citizen
	Science/Research

Source: m:ci

5.2 ANALYSIS OF PROJECTS AND PROCESSES, OBJECTIVES AND DECISIONS

The use of a distinctly **integrative approach** was identified as a unique characteristic within Copenhagen's activities relating to developing, designing and implementing policies as well as organizing and executing projects within a public and public private context across various sectors and fields of action. In a majority of the observed practice examples, and confirmed by almost all of the interview partners within the city administration – albeit often being relative informal agreements and procedures – projects encompassing numerous stakeholders, fairly large budgets as well as extensive time horizons can only be successfully implemented with and through the strong participation and the engagement of all involved partners. Evidently, jointly developing acceptable solutions via highly **communicative consensus oriented** management processes can only be realized if generous time budgets are incorporated into projects. However, it has become very clear throughout the entire on-site research phase that no matter what area the experts came from, this cost (time needed to engage in process) seems widely accepted as a necessary factor, which, in the end, is thought to improve the overall result and the success of projects of any kind.

The city of Copenhagen has an impressive resource at its disposal: a large **administrative body** including around 45,000 employees serving 550,000 inhabitants (for comparison: in Stuttgart, 18,000 employees work in the administration, while the city has around 590,000 inhabitants). On the one hand, this means that nearly 10% of the population works within the city administration, and so this group represents a large share of the citizens. On the other hand, the high number of employees, together with a high level of education and motivation amongst these individuals (at least concerning the persons contacted in this research), provides the potential to shape and push forward processes in Copenhagen. The m:ci team was impressed by the level of professionalism and creativity it encountered whenever having personal interaction with officials from the administration. Unlike the traditional image one often has of administrations responding in a rather reactive manner to triggers and requests from outside their own jurisdiction, the team was able to gain insight into many initiatives originating from within the administration itself. Some of the most prominent examples include:

- The Climate Adaption Plan (Technical and Environmental Administration, Center for Parks and Nature).
- The Bicycling Strategy 2025 (Technical and Environmental Administration, Center for Traffic).
- The Climate Plan 2025 (Technical and Environmental Administration, Center for Environment).

However, the administration cannot and does not shape the processes in Copenhagen on its own. Its employees actively involve **other actors** in the processes and are also contacted by actors outside the administration with ideas. The administration is responsible for the compilation of plans and other objectives for development, regulations on the city level, and the control of compliance with these regulations. Additionally, it also actively involves actors such as private consulting companies and research institutions in these processes. For example, the Climate Adaptation Plan was developed by the city administration and approved by the City Council. As advisers, it lists: COWI, Deloitte, Rambøll (private consulting companies), Danish Climate Centre, University of Copenhagen, and DHI (research institutions).

Uniquely, when it comes to ensuring solid **financing concepts** for such ambitious plans, Copenhagen has chosen a strategy which aims to distribute the burden of cost between private households and the municipality. For instance, with respect to the aforementioned Cloudburst Management Plan (chapter 4.6), the overall projected volume of DKK 3.8 billion over the course of the next 20 years is split into three categories. The municipality covers the smallest portion, at about 10%. Roughly 30% of the costs will be contributed by the private sector in the form of investments in relevant infrastructure to better serve the strategic goals of the plan. By far the largest share, however, will be generated by private households in the form of revenues from fees for adaptive measures. These fees are added to the price per m^3 of water (see chapter 4.4). In contrast to other countries worldwide, this study has shown that the Danish tax policy culture is characterized by the citizen's willingness to pay high tax rates in return for well-functioning infrastructure and public services.

Tasks such as heat supply via DH, gas supply, water supply, wastewater discharge, and the operation of municipal wind parks are the responsibility of a multi-municipal public enterprise called **HOFOR**. The city administration and HOFOR cooperate closely. In many cases, the administration develops objectives which HOFOR must achieve, while HOFOR influences these objectives through consultation and is responsible for choosing the means employed to achieve the objectives. For consultation and implementation, HOFOR also contracts out to private sector enterprises.

The **City Council** is responsible for legislative decision making within the city. It approves the yearly budgets allocated to administrative tasks as well as the various plans the administration prepares. Thus, the administration must convince the City Council of the relevance of the topics it is concerned with.

The City Council is elected by the citizens of Copenhagen. For more than 60 years, the governing party in Copenhagen has not changed. Therefore, Copenhageners are quite used to strong and stable alliances within their political environment. As in the rest of Denmark, public tax rates are fairly high in Copenhagen, especially compared to other European countries. As a result, the general public has high expectations when it comes to the quality, accessibility and especially the reliability of public services and infrastructure. In response, the city invests substantial resources in its own marketing efforts in order to foster its image as an agile, service-oriented, and – most important of all – green and livable city. Going above and beyond addressing the needs of its own population, Copenhagen thinks of itself as an urban **role model** for Europe, pioneering sustainable development solutions within various city sectors and areas. At the same time, Copenhagen (politicians and administration) hopes to help its private sector with the exportation of products and solutions, often using large development projects within the city as **test beds**, and thus reference projects, to be exported to other cities. A good example is the bicycling initiative: proven and improved over years within the city, Copenhagen exports its »**Copenhagenized**« concepts mainly through consultancy services for other cities, administrations and industries.

In order to understand the unique, creative and progressive pioneering environment within the city, it is worth mentioning an example of 'Copenhagen-style' agenda setting:

The vision of becoming the world's first CO_2 neutral capital by 2025 came from Rambøll, during the preparations for the World Climate Conference in 2009. The coordination of the Copenhagen Climate Plan has been the responsibility of the administration, while the City Council is responsible for approving it. Quantitative objectives for average per capita water consumption are defined by the city administration and HOFOR every few years. They are then included in the Water Supply Plan, which must be approved by City Council.

The quantitative objectives are communicated widely and are seen as an instrument with which to navigate and influence defined developments. If the objectives are not fully achieved, this is not necessarily judged as negative, provided the general trend progresses in the right direction.

5.3 KEY DRIVERS AND FRAMEWORK CONDITIONS

One of the areas of focus for the m:ci research teams was the identification of reasons for why certain processes worked or did not work in the cities analyzed. Therefore, during the analysis of the practice examples, key drivers and framework conditions were defined for each of the examples. These have been listed and categorized in a table, and this list has been reduced to include only those factors considered most important. Finally, each member of the city team evaluated the factors in the table, based on whether they are relevant for their practice example and whether the factor exerts a direct or indirect effect. The eleven drivers which applied to most practice examples are listed below in table 2, in the order of accumulated applications. For example, the demand for an attractive urban environment has a direct impact on seven of the analyzed practice examples and additionally an indirect

Table 3: Top Eleven Key Drivers in the Analyzed Practice Examples in Copenhagen

Key Driver	Direct	Indirect
Demand for attractive urban environment, Liveability Concept	7	4
Local scientific competence	3	8
Large, motivated and skilled administration	7	3
Citizens with ecological awareness and idealism	5	5
Climate Change	5	5
Focus on Internationalization of Copenhagen Solutions	4	5
Lighthouse projects	3	5
Availability of technologies	5	2
Mission statement, driving ideas, common sense	4	3
Test lab for new, innovative solutions (in small scale)	4	3
Active approach to promote and support communication/interaction/cooperation between different stakeholders/value chains	2	5

Source: m:ci

impact on four other practice examples. All in all, it affects eleven out of 16 analyzed practice examples.

The factor affecting most practice examples is the importance of **liveability** in Copenhagen. On the one hand, the citizens demand green spaces and clean water for recreation and are able and willing to pay more for plots offering these conveniences. On the other hand, the politicians and the administration use these characteristics of the city for marketing, with the objective of encouraging young and well educated people to live in/move to the city of Copenhagen.

The next three key drivers refer to specific **actor groups** in Copenhagen, which obviously influence the development of the city to a large extent. Scientific competency in Copenhagen has a more indirect than direct impact, being an important framework condition for many innovative achievements in the city, whereas the administration plays a direct, leading role in many projects (see chapter 5.2). Equally important are the citizens of Copenhagen, who have been characterized as having higher-than-average ecological awareness and who are proud of their city's green image. However, this perception has been relativized in some interviews which have indicated that, in many cases, economic considerations may be more important than ecological ones. An important lesson from Copenhagen is that, if managed well, **ecology and economy** can exist alongside one another. This is closely related to the driver »Focus on Internationalization of Copenhagen Solutions«, since this results in revenue generation through the exportation of innovative solutions (e.g. for the protection of the environment).

Climate Change is another important factor in Copenhagen. In contrast to other regions in the world, the focus here is not (yet) so much on water scarcity or rising sea-levels, but on heavy rain bursts and flooding of the city in summer. Thus, climate change also has negative consequences in Copenhagen and threatens the city with immense damages. However, through systematic planning, the city is making use of the need to react to this threat by implementing measures that further increase the quality of life in Copenhagen: the areas used for storing and discharging the rainwater also have recreational value. In recognition of its efforts, Copenhagen received the INDEX: Award (along with EUR 100,000) for its Climate Adaptation Plan in August of 2013 (Design to Improve Life 2013).

Innovative technologies are available in Copenhagen as a result of the scientific competence and well educated employees, and are implemented in **lighthouse projects** so they can be further developed and more easily exported. In addition to lighthouse projects (like the Middelgrunden wind farm), many smaller – but also innovative – solutions are tested in Copenhagen, such as the DPF system for rainwater treatment. In the interviews, the fact that Copenhagen sees itself as a **test lab for new solutions** was mentioned many times. This helps companies in Copenhagen, as they can implement their solutions as references, and it benefits the city administration because the employees can gain experience with new solutions which contribute to making Copenhagen a more green and livable city.

Last but not least, the Copenhagen-style of communication and cooperation is an important driving factor for the success of the city. By sharing a joint vision of development, citizens, private companies and the administration are constantly exchanging ideas in a constructive way. Therefore, there are few hierarchical obstacles, and communication occurs in a mutually respectful manner.

5.4 FIELDS OF SUSTAINABILITY

On the basis of the key drivers identified and taking into consideration the analyses of the practice examples, the m:ci research team has been able to make out some of the main fields of sustainability in Copenhagen. These fields characterize the approaches applied in Copenhagen and are the basis for the success of the city in terms of sustainable development.

Excellent education with a focus on creating awareness about environmental topics: Copenhagen has many excellent universities and therefore attracts and »produces« highly educated young people. Since industry focused on the production sector has become much less prominent in the city, it has had to rely on the tertiary sector, which requires well educated employees. These citizens are very receptive to awareness campaigns providing advice on how to live more sustainably. Many are also open to the implementation of new technologies that aid in the conservation of resources, such as wind parks and rainwater harvesting systems. One of the key findings is that the entire sustainability chain is not perceived as a negative trade-off as much as may be the case in many other European – and especially North American – cities. In many places, sustainability is often perceived as something which can only be achieved at the price of giving up many conveniences of daily life. However, based on the interviews conducted it appears that most Copenhageners are convinced that a more sustainable, hence more livable, city can be achieved without imposing too many heavy burdens (e.g. higher energy prices, higher taxes, etc.) on the citizens.

Flat hierarchies in city administration: hierarchies within the administrations in Copenhagen are obviously not very important, it was observed. As part of a very open communication culture – which may be a part of Nordic cultural heritage – people talk to each other on the same level. This communication style can be observed

within the public sector, but also in large parts of the private sector, which fully incorporate this less hierarchical management style.

Professional city marketing and transparency: this is a powerful administrative tool for the communication of successes both inside and outside the city. Inside the city, it motivates the citizens to participate in these successes and helps them to understand what the administration is doing with their money. From outside, it attracts tourists, students, workers, and investors. At the same time, it ensures transparency for all and creates the feeling of a necessity to act. It also defines developments and roadmaps as well as strategic stability. The advertising campaign used for the Climate Adaptation Plan in 2012 is an impressive example of this style of marketing and transparency.

Centralized technologies: examples include the DH network and the centralized water supply and treatment systems. Since they are operated in a centralized way, they utilize synergies and the newest, most efficient techniques, are very efficient in terms of costs, materials, and energy use.

Resource efficiency: the efficient utilization of resources is meant to guarantee the sustainable development of Copenhagen. Nevertheless, not all resources can be generated within the city limits; e.g. wood chips for generating energy must be purchased from abroad. The DH network is one example of an efficiency measure; another is the reduction of water consumption per capita, or the utilization of waste and sludge from wastewater treatment for the generation of energy.

Copenhagen as a living lab for new technologies and approaches: the administration encourages and facilitates the implementation of new technologies in the city, e.g. the DPF for rainwater or the Super Cycle Highways. These technologies and approaches can be optimized, and serve as references for later exportation. Copenhagen has the benefit of being able to assess new technologies and of implementing these early if they prove successful while it also profits from the generation of jobs if the products are successfully exported.

Green Growth: Copenhagen aims to create economic growth by supporting companies that specialize in the environmental sector. The city administration helps these companies with marketing and networking, and in turn benefits from the jobs created in this sector as well as from solutions that can be implemented in the city and that help to improve the city's image.

Strong tertiary sector: after the industry and the harbour decreased dramatically in the 1980's and 1990's due to relatively high production costs, Copenhagen experienced an economic crisis. As a result, it concentrated its economic growth on the tertiary sector; namely tourism, consulting, services, etc. The reduction in industrial production led to higher liveability, as the pollution decreased and less heavy vehicles needed to pass through the city. The harbor can now be used for swimming and large parts of it are being developed to create a new central part of the city (Nordhavnen).

Efficient mobility: many people use bicycles in the city. The public transport network is in excellent condition and bicycles can be transported on the s-trains, for instance. Within the city center, only few people use cars, as they are expensive due to high taxes, and practical alternatives to the highly congested streets are available. This also contributes to the excellent liveability of the city. Planned improvements to the bicycling network (e.g. Super Cycle Highways to the suburbs) and new metro lines (city circle line) will further reduce the congestion, especially if a congestion charge is reinstated.

Systematic, long term city planning: In 1947, the »Five Finger Plan« for long term city planning in Copenhagen was implemented. Green corridors were kept free of buildings, and s-train lines run along these »fingers«. Likewise, new developments such as Ørestad and Nordhavnen are planned and developed systematically and with long-term strategies. This plan is still a valid guideline for today's city planning and transport concepts. Additionally, these new areas are connected to the public transport network by metro before the development starts. The metro, in turn, is re-financed by the revenues from the plots, which rise in value because of the metro connection. Due to the involvement of citizens at an early stage in the planning processes, the solutions are of a higher quality and citizen concerns are unlikely.

Focus on greenhouse gas reductions: during the course of the preparations for the World Climate Conference in

Figure 46: Harbor Bath in Copenhagen (own photography by Marius Mohr)

2009, Copenhagen outlined the goal of becoming the first capital in the world to be CO_2 neutral, aiming for the year 2025. Different sectors such as mobility, heating, electricity production and consumption, as well as the private sector will have to contribute to achieve this ambitious objective, which is communicated actively.

Climate change adaptation: since 2008, Copenhagen's administration has been systematically developing plans for adapting Copenhagen to the consequences of climate change. The priorities lie on the adaptation to more frequent and heavier rain events, the urgency of which has been underscored by heavy cloudburst events in 2010 and 2011. In the long run, the rising sea level will also require adaptation in order to prevent severe damages.

Cooperation on a regional level: since the construction of the Øresund Bridge, the connection to Malmö in southern Sweden has improved significantly. Many people cross the bridge each day to commute to and from work. Economic clusters between Copenhagen and Malmö have been created, and both sides have profited from increased economic development. The Øresund region is expected to gain even more importance in the future.

Liveability in urban planning: the impact of planning for the quality of life of citizens and visitors alike is taken into account in all developments. The city would like to attract highly skilled and educated people and create conditions for them to stay in Copenhagen. Short distances to parks, water courses, and public transport facilities are part of this approach, as well as a strong focus on architectural quality and maintaining the city's visual identity.

Long-term concept for a more resilient Copenhagen: unlike most other metropolitan areas in the Western hemisphere, Copenhagen has proven to be decisive in implementing a long-term planning process in order to launch upgrading initiatives for all critical infrastructures. This is meant to provide more resilience against (mainly) the consequences of natural disasters with a strong focus on cloudbursts.

5.5 TRANSFERABILITY OF EXPERIENCES

Copenhagen sees itself as a role-model. Therefore, efforts are made to ensure solutions are transferable to other cities – first in Denmark, but also abroad. On the basis of the practice examples analyzed, it was observed that **framework conditions like culture, policies and regional conditions** are important preconditions for the transferability to other countries. The local approach used for the Middelgrunden wind farm cooperative, for example, is only transferable to cities with a culture of information sharing and open discussion for a better acceptance of new approaches and techniques. If this is given, it is an approach that can improve the development in cities significantly. Even more obvious, creating a bicycling city cannot be implemented without a bicycling culture, which takes decades to develop. Again, the achievements in terms of bicycling infrastructure in Copenhagen are outstanding and other big cities, including New York and Melbourne, are already attempting to transfer them.

Similarly, the centralized DH system is an exemplary step towards a sustainable city, as it uses resources very efficiently. The success of this approach is again dependent on a well-designed policy framework, which must be relatively **stable over long periods of time**. A strong actor able to invest in long lasting infrastructure is required. This is a parallel to the systematic approach for climate adaptation that has been agreed on in Copenhagen. Since the city infrastructure will be adapted over a period of 20 years, the results will only be visible in the long run. If a local government is forced to present successes for each election, and if the probability is high that a new local government will change the priorities for action, these long term developments cannot succeed.

The main driver for developing the Copenhagen Climate Plan was the hope that eventually other cities will incorporate the objective and/or the solutions regarding CO_2 reduction.

Regarding city development, Copenhagen was able to gain experience during **the development of the new district, Ørestad.** An important lesson learned, which was incorporated into the planning of the **Nordhavnen district**, is that small scale buildings and urban spaces, sustainable concepts with low energy buildings, and low energy transport should be integrated into new city developments right from the first planning phase through to the realization phase. Also, a concept within the security research sector commonly described as 'security and resilience by design approach', intended for incorporating these aspects into the entire planning and design phase of new large urban areas has already been adopted by the planners of the Nordhavnen district. A major advantage of this design approach, which will prove to be time and especially resource saving in the future, is the fact that once done properly, the built environment will not have to be readjusted, rebuilt, redesigned or upgraded at extreme costs at a later point. This should be transferable to most cities planning on developing new areas, and should be combined with citizen participation right from the start.

Cutting edge technologies either still in the development phase or being tested in lighthouse projects were also analyzed in this study. The DPF system is a process for the treatment of rainwater from roads. This concept will be transferable to densely populated areas with a demand for high water quality in urban streams or groundwater. In the Royal Danish Playhouse, technologies to greatly redu-

ce energy consumption have been applied and are already being transferred to other buildings. One example is the combination of thermo-active slabs and heat pumps for heating and cooling, using seawater or ground sources as reservoirs.

Organizational activities like the Copenhagen Cleantech Cluster and the reduction of water consumption seem to be easily transferable to many other cities. They do not require a large investment and are not in the focus of public awareness, but can strongly contribute to the sustainable development of cities, either by supporting private companies in developing ecologically friendly products and services, or by conserving resources.

Figure 47: Royal Danish Playhouse (own photography by Marius Mohr)

5.6 OUTLOOK

Relating to its energy and water supply, as well as sewerage disposal, Copenhagen utilizes **large scale centralized technologies**. On the one hand, this is very efficient in terms of both resources and costs and offers high reliability of service. On the other hand, this approach might obstruct the development of new and innovative solutions, which are more likely in decentralized systems where many different technologies can be applied. The latter systems are also more flexible and can thus react more quickly to changes in framework conditions. In Copenhagen, there is a tendency towards assigning public bodies and administrations with the task of organizing and implementing general systems and approaches addressing topics relevant for all inhabitants; such as, for example, heating energy supply. The feeling one gets is that Copenhagen is one big family and there is confidence in the fact that everybody – including the administration – will do their best for the sake of the community.

In discussions with employees of the administration of Copenhagen, it was mentioned that, in the future, **more innovative technologies** will be tested in smaller scale (demonstration) projects, since a) motivated employees in administration are coming up with new ideas, and b) politicians are asking for innovative solutions they can present to the citizens in order to motivate them to participate in sustainable development. One example of this is the development of the Nordhavnen district, where a number of decentralized innovative technologies will be implemented (e.g. the re-utilization of grey water). Another field in which more innovative approaches will be implemented in future is energy efficient buildings. Here, technologies and innovations such as hybrid ventilation, PV integration, or the addition of roof top apartments to existing buildings will be implemented. Also, cooperation between entities within Denmark as well as within the EU and between public and private organizations is seen as a way to trigger new and innovative solutions. However, although new solutions are welcome, they will be integrated in the long-term planning perspective in Copenhagen.

To achieve the goal of becoming carbon neutral by 2025, Copenhagen is focusing on the production of energy, including wind power and biomass for DH. This is an example of the tendency towards centralized solutions in Copenhagen, mentioned above. Demand management, such as a reduction of the heat requirements of buildings through renovations, seems to be of less importance in Copenhagen. This may lead to there being **no improvement in energy efficiency** within the city, reducing the sustainability of the solutions. The reduction of water consumption in Copenhagen is an example of a successful demand side approach, although measures like renovating houses to reduce the heat requirements will be much more expensive. Since the centralized heating system keeps the costs of heating low, cost-benefit calculations in Copenhagen often come to the conclusion that the renovation of houses is not economically viable. Currently, there are discussions going on in the Danish government, as in all EU Member States, about how regulations can be changed to promote the renovation of buildings towards more energy efficiency.

Copenhagen will **continue to grow**, because it offers education, employment, and a high quality of life. Many people come from villages and small towns in Denmark. Young people are leaving rural areas; consequently many small settlements are becoming deserted. For agricultural production, not many people are needed in the countryside. This seems to be a global trend, and of course it causes many problems in the growing cities as well as in the deserted rural areas. Both sides will have to adapt to these developments.

On a global level, it may be more sustainable for people to live in **metropolitan regions**, as they have less need for transport, they use less space, and they have access to large scale, efficient infrastructure. To trigger this development, cities must be attractive for people to live in. As cities continue to grow, separate metropolitan regions are merging, such as Copenhagen and Malmö, forming conglomerates or regions. In these regions, actors within the different entities will have to harmonize planning and regulations and must cooperate to benefit from this development. An important framework condition for this scenario is the availability of space inside the cities, like the old harbour in Copenhagen, or former military zones.

A development typical for Middle European countries is the **shift from industrial production to the tertiary sector** (services, banks, tourism etc.), triggered by the industry leaving the region due to high production costs. As a reaction to the crises this caused in the 1980's, Copenhagen has focused strongly on green growth and clean tech. Some interviewees stated that it is easy to start a business in Copenhagen, but due to high taxation, keeping the company alive and growing is difficult. All in all, the focus on one sector might reduce the resilience of the city in terms of global developments and crises.

Figure 48: Nyhavn, visited by many tourists (own photography by Marius Mohr)

A kind of job-sharing between the city of Copenhagen and the surrounding region could be detected: while production facilities are often located outside the city, inside the city the focus is on sustainability services, knowledge, quality of life, and tourism. Inside the city, the companies find good conditions for starting up – for further growth, they can move to the region around the town where producing is less expensive.

It has been observed that, in Copenhagen, one of the first questions asked before taking action is »**does this increase the quality of life** – for individuals and for the community, in a sustainable manner?«. A discussion on how to define quality of life is an intense and ongoing process between the citizens.

Copenhagen provides a model for a city that focuses on quality of life as well as on **knowledge**. The universities attract young, well educated people, and the high quality of life convinces them to stay in the city after they finish their studies. They find jobs in consulting companies, research institutions, the tourism branch, the city administration or the national government. They receive high salaries and pay a high share of their wages to taxes and for plots and houses, however, they enjoy the services and the conveniences the city provides. The citizens are aware of their influence and are interested in participating; at the same time, the city administration is accustomed to involving both the citizens and private companies in planning processes.

The production industry is no longer allocated much space in Copenhagen; it pollutes the neighborhood, the facilities are not aesthetic, the goods must be transported, heavy trucks annoy the citizens, and the employees must commute to large production sites every day, generating traffic. Office buildings used by knowledge-based companies and institutions are much easier to integrate into residential areas, allowing employees to live closer to where they work and thus generating less traffic to be managed. This development has only occurred as the result of a major crisis following the exodus of the production industry – it was not the product of a conscious strategy, but rather a reaction to circumstances. In any case, it has led to a **fascinating model for a modern, middle-sized city**. It certainly helps that Copenhagen is one of very few large Nordic cities and that the Danes are perceived as friendly people and are role models in many aspects.

6

6 REFERENCES

Aachener Stiftung Kathy Beys (2013): Drei-Säulen-Modell. URL: http://www.nachhaltigkeit.info/artikel/1_3_a_drei_saeulen_modell_1531.htm, last checked 10/17/2013.

Aarhus Kommune (2013): We have plan. URL: http://www.aarhus.dk/sitecore/content/Subsites/Digitalisering/Home/English/The-Digital-Wave-Plan.aspx?sc_lang=da, last checked 10/17/2013.

Albrechtsen, Kåre (2013): New Model of Interaction between Ministry and Municipalities. Danish Ministry of the Environment, The Danish Wind Turbine Secretariat. URL: http://www.mim.dk/NR/rdonlyres/34B99602-8091-405B-9D4B-DCB0FE2C43FC/0/COP15_ET_TheDanishWindturbineSecretariat.pdf, last checked 10/17/2013.

Andersen, Flemming; Elleriis, Jan (2000): District heating based on geothermal heat. URL: http://dbdh.dk/images/uploads/pdf-ren-energy/dh-based-on-gerthermal-heat.pdf, last checked 10/17/2013.

Andersen, T.; Bredal, F.; Weinreich, M.; Jensen, N.; Riisgaard, M.; Kofold Nielsen, M. (2012): Collection of cycle concepts 2012. URL: http://issuu.com/cyclingembassy/docs/cycleconcepts2012/17?e=1862343/2867493, last checked 10/17/2013.

Bier, Christoph (1999): Network Access in the Deregulated European Electricity Market: Negotiated Third-Party Access vs. Single Buyer. URL: http://www.uni-saarland.de/fak1/fr12/csle/publications/9906tpa.pdf, last checked 10/17/2013.

BIG - Bjarke Ingels Group (2013): Amagerforbrændning. Bjarke Ingels Group BIG. URL: http://www.big.dk/#projects-arc, last checked 10/17/2013.

Bording, Lars (2013): Brief introduction to CLEVER.

By & Havn (Hg.) (2012): Nordhavnen: From Idea to Project : Inner Nordhavn August 2012. Udviklingsselskabet By & Havn. URL: http://books.google.de/books/about/Nordhavnen.html?id=zacsmwEACAAJ&redir_esc=y, last checked 10/17/2013.

Cahasan, Paul; Clark, Arielle Farina (2006): Copenhagen, Denmark – 5 Fingers Plan. URL: http://depts.washington.edu/open2100/Resources/1_OpenSpaceSystems/Open_Space_Systems/copenhagen.pdf, last checked 10/17/2013.

Cederkvist, Karin; Holm, Peter E.; Jensen, B. Marina (2010): Full-Scale Removal of Arsenate and Chromate from Water Using a Limestone and Ochreous Sludge Mixture as a Low-Cost Sorbent Material. In: Water Environment Research, Vol. 82, pp. 401-408, Water Environment Federation.

Centre for Urban Development (2011): URL: http://subsite.kk.dk/sitecore/content/Subsites/bdv/SubsiteFrontpage/SustainabilityTool.aspx, last checked 10/17/2013.

City Mayors (2004): Environment and economy are priorities for Copenhagen Mayor. URL: http://www.citymayors.com/interviews/copenhagen_mayor.html, last checked 10/17/2013.

City Mayors (2011): Danish and Swedish regions gave up power to create bi-national metropolis. URL: http://www.citymayors.com/economics/oeresund-region.html, last checked 10/17/2013.

City of Copenhagen (2008): A Metropolis for people. URL: http://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/LivingInCopenhagen/CityAndTraffic/CityOfCyclists/~/media/1D3CAE1817C94249BE8C686822B2C5A1.ashx, last checked 10/17/2013.

City of Copenhagen (2009): District heating in Copenhagen: an energy efficient, low carbon and cost effective energy system. URL: http://dbdh.dk/images/uploads/pdf-diverse/District_heating_in_Copenhagen.pdf, last checked 10/17/2013.

City of Copenhagen (2010): Copenhagen City of Cyclists Bicycle Account 2010. URL: http://www.cycling-embassy.dk/wp-content/uploads/2011/05/Bicycle-account-2010-Copenhagen.pdf, last checked 10/17/2013.

City of Copenhagen (2011a): Copenhagen climate adaptation plan. URL: https://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/LivingInCopenhagen/ClimateAndEnvironment/ClimateAdaptation/~/media/9FC0B33FB4A6403F987A07D5332261A0.ashx, last checked 10/17/2013.

City of Copenhagen (2011b): Copenhagen's green accounts 2010. URL: http://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/Press/~/media/2204303846A94E57AF42462F2B36E582.ashx, last checked 10/17/2013.

City of Copenhagen (2012a): Copenhagen 2025 Climate Plan. URL: http://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/Business/Growth_and_partnerships/~/media/F5A7EC91E7AC4B0891F37331642555C4.ashx, last checked 10/17/2013.

City of Copenhagen (2012b): Copenhagen's green accounts 2011. URL: http://www.e-pages.dk/tmf/8/, last checked 10/17/2013.

City of Copenhagen (2012c): Facts and numbers on Copenhagen. URL: http://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/Press/FactsOnCopenhagen/~/media/623689553FEC45B283A7053CE10C80BE.ashx, last checked 10/17/2013.

City of Copenhagen (2012d): The City of Copenhagen Cloudburst Management Plan 2012. URL: http://en.klimatilpasning.dk/media/665626/cph_-_cloudburst_management_plan.pdf, last checked 10/17/2013.

City of Copenhagen (2013): Official Website. URL: http://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage.aspx, last checked 10/17/2013.

City of Copenhagen (2013): Economic Management organization. URL: http://translate.googleusercontent.com/translate_c?depth=1&hl=de&ie=UTF8&prev=_t&rurl=translate.google.de&sl=da&tl=en&u=http://www.kk.dk/da/om-kommunen/forvaltninger/oekonomiforvaltningen/organisation&usg=ALkJrhhr1-iksMRQi-bzDR2PA5loqKbXqg, last checked 10/17/2013.

City of Copenhagen (2013): Main information. URL: http://www.kk.dk/da/borger, last checked 10/17/2013.

City of Copenhagen; Danish Ministry of the Environment (2008): The Danish action plan for promotion of eco-efficient technologies. URL: http://www.ecoinnovation.dk/NR/rdonlyres/9FEEE910-27A4-4BE7-8A01-DD17BE0C072E/0/KBH_havn_baggrundsartikel_1.pdf, last checked 10/17/2013.

City of Copenhagen, The Technical and Environmental Administration (2010): Copenhagen City of Cyclists. Bicycle Account 2010. URL: http://www.cycling-embassy.dk/wp-content/uploads/2011/05/Bicycle-account-2010-Copenhagen.pdf, last checked: 11/07/2013.

City of Copenhagen, The Technical and Environmental Administration (2011): Copenhagen Green Accounts 2011. URL: http://www.e-pages.dk/tmf/8/, last checked 10/17/2013.

Clauson-Kaas, Jes; Sorensen, Sonia; Johansen, Niels Bent; Nielsen Jan B. (2008): Run-off management in Copenhagen Harbour. URL: http://web.sbe.hw.ac.uk/staffprofiles/bdgsa/11th_International_Conference_on_Urban_Drainage_CD/ICUD08/pdfs/207.pdf, last checked 10/17/2013.

CLEVER A/S (2013): URL: www.clever.dk, last checked 11/07/2013.

Climate Consortium Denmark (2011): Copenhagen Cleantech Cluster. URL: http://www.stateofgreen.com/en/Profiles/Copenhagen-Cleantech-Cluster, last checked 10/17/2013.

COMET-Project (2004): Copenhagen region: Denmark's urban heart. URL: http://www.oeaw.ac.at/isr/comet/documents/Final_Results/COMET_deliv_no11_leafletCopenhagen.pdf, last checked 10/17/2013.

COMMIN (2008): DK Planning System. URL: http://commin.org/upload/Denmark/DK_Planning_System_in_English.pdf, last checked 10/17/2013.

Copenhagen Capacity (2012): Cleantech in East Denmark. URL: http://www.copcap.com/BusinessOpportunities/Cleantech/Facts, last checked 10/17/2013.

Copenhagen Capacity (2013): Copenhagen: where green ambitions become green growth. URL: http://www.copcap.com/BusinessOpportunities/Cleantech/Background, last checked 10/17/2013.

Copenhagen Cleantech Cluster (2012): Be a part of Copenhagen Cleantech Cluster. URL: http://www.cphcleantech.com/media/376340/ccc_profile.pdf, last checked 10/17/2013.

Copenhagen Cleantech Cluster (2013a): Board of directors. URL: http://www.cphcleantech.com/about/board-of-directors, last checked 10/17/2013.

Copenhagen Cleantech Cluster (2013b): Danish smart Cities: sustainable living in an urban world. URL: http://www.cphcleantech.com/media/2021654/smart%20city%20rapport_indhold_final_low.pdf, last checked 10/17/2013.

CEEO - Copenhagen Environment and Energy Office (2003): The Middelgrunden Offshore Wind Farm. URL: http://www.ontario-sea.org/Storage/29/2118_doc1.pdf, last checked 10/17/2013.

Copenhagen Visitor Centre (2013): Wonderful Copenhagen. URL: http://www.visitcopenhagen.com/search/editorial/global?keys=media%20facts%20about%20copenhagen%20facts%20about%20copenhagen%20Capital%20since%2014179, last checked 10/17/2013.

CTR (2000): Environmentaly friendly district heating for greater Copenhagen. URL: http://www.ctr.dk/Images/Publikationer/Environmentally%20friendly%20district%20heating%20to%20greater%20cph.pdf, last checked 10/17/2013.

CTR (2004): The main disctrict heating network in Copenhagen. URL: http://freshaireva.us/wp-content/uploads/2012/04/Copenhagen-District-Heating.pdf, last checked 10/17/2013.

CTR (2009): Worldclass, climate-friendly heating. CTR. Online verfügbar unter http://www.ctr.dk/Images/%C3%85rsberetninger/Aarsberetning%202008%20-%20Engelsk.PDF, last checked 10/17/2013.

CTR (2012): Financial statements & annual report 2011. URL: http://www.ctr.dk/Images/%C3%85rsberetninger/Aarsberetning_2011_-_Engelsk.pdf, last checked 10/17/2013.

CTR (2013): CTR Medarbejdere. URL: http://www.ctr.dk/om-ctr/medarbejdere.aspx?#7.

CTR, VEKS, Københavns Energi (2009): Climate-friendly district heating for the future. CTR, VEKS, Københavns Energi. URL: http://www.eabalmorel.dk/files/download/Projects/VPH_Newsletter.pdf, last checked 10/17/2013.

DAC - Danish Architecture Centre (2012): Copenhagen: the world's best city for cyclists. URL: http://www.dac.dk/en/dac-cities/sustainable-cities/all-cases/transport/copenhagen-the-worlds-best-city-for-cyclists/?bbredirect=true, last checked 10/17/2013.

Danish Board of District Heating (2013): DH Characteristics. URL: http://www.dbdh.dk/artikel.asp?id=462&mid=24, last checked 10/17/2013.

Danishnet (2013): Kastellet Windmill in Copenhagen Fortress. URL: http://www.danishnet.com/info.php/pictures/copenhagen-126.html, last checked 10/17/2013.

Danmarks Naturfredningsforening (2013): Basic information. URL: http://www.dn.dk/, last checked 10/17/2013.

Danmarks Statistik (2012): Global cities: Copenhagen. URL: http://www.statbank.dk/HFU2 and http://martinprosperity.org/global-cities/Global-Cities_Copenhagen.pdf, last checked 10/17/2013.

Danmarks Statistik (2013): URL: http://www.dst.dk/da, last checked 10/17/2013.

DANVA – Danish Water and Waste Water Association (2011): Water in figures. URL: http://www.e-pages.dk/danva/100/19, last checked 10/17/2013.

Design to Improve Life (2013): Danish capital adapts successfully to climate change. URL: http://designtoimprovelife.dk/danish-capital-adapts-succesfully-to-changing-climate/, last checked 10/17/2013.

Diez, Willi (2012): Elektromobilität: Elektroautos mit deutlich niedrigeren Unterhaltskosten. Institut für Automobilwirtschaft (IFA) Hochschule für Wirtschaft und Umwelt, Nürtingen-Geislingen. URL: http://www.ifa-info.de/downloads/3241/Presseinformation%20Elektromobilit%C3%A4t%2020.11.12.pdf, last checked 10/17/2013.

DONG Energy A/S (2013): Clean and reliable energy. URL: http://www.dongenergy.com/en/Pages/index.aspx, last checked 10/17/2013.

DSB (2013): S-tog information. URL: http://www.dsb.dk/s-tog/, last checked 10/17/2013.

Dyrelund, Anders (2009): Heat Plan Denmark. Ramboll. URL: http://www.copenhagenenergysummit.org/Low%20Carbon%20Urban%20Heating,%20Heat%20Plan%20Denmark%20paper.pdf, last checked 10/17/2013.

Elsman, Peter (2009): Copenhagen District Heating System. City of Copemhagen. URL: http://www.copenhagenenergysummit.org/applications/Copenhagen,%20Denmark-District%20Energy%20Climate%20Award.pdf, last checked 10/17/2013.

ELTIS (2013): Shared (parking) space for bikes and cars in Copenhagen (Denmark). URL: http://www.eltis.org/index.php?id=13&lang1=en&study_id=3763, last checked 10/17/2013.

EMD International (2013): Background for »Lynetten Project«. EMD International. URL: http://www.emd.dk/WindPRO/WindPRO%20Project,%20Lynetten,%20Page%201, last checked 10/17/2013.

Energi Styrelsen (2010): Energy in Denmark 2009. URL: http://www.ens.dk/files/dokumenter/publikationer/downloads/energi_in_dk_2009.pdf, last checked 10/17/2013.

Energi Styrelsen (2011): Energy in Denmark 2010. URL: http://www.ens.dk/sites/ens.dk/files/dokumenter/publikationer/downloads/energy_in_denmark_2010_2.pdf, last checked 10/17/2013.

Energi Styrelsen (2012): Energy policy in Denmark. URL: http://www.ens.dk/sites/ens.dk/files/dokumenter/publikationer/downloads/energy_policy_in_denmark_-_web.pdf, last checked 10/17/2013.

Energi Styrelsen (2013): Main information. URL: http://www.ens.dk/, last checked 10/17/2013.

European Commission (2012): Waste water treatment. URL: http://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2012/07/Section-9-Waste-water-treatment_Copenhagen.pdf, last checked 10/17/2013.

European Commission (2013a): Adaptation to climate change. URL: http://ec.europa.eu/clima/policies/adaptation/index_en.htm, last checked 10/17/2013.

European Commission (2013b): Lighting the Cities – Accelerating the development of innovative Lighting in European Cities. URL: http://www.google.de/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=0CDsQFjAC&url=http%3A%2F%2Fec.europa.eu%2Finformation_society%2Fnewsroom%2Fcf%2Fdae%2Fdocument.cfm%3Fdoc_id%3D2303&ei=T75eUqeVG4nJtQbE1YDoDg&usg=AFQjCNEGTgGk4qjBl3K-5LUKCasyVZjjRg&bvm=bv.54176721,d.Yms, last checked 10/17/2013.

Eurostat (2013): Trends in crime and criminal justice, 2010. URL: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Crime_trends_in_detail, last checked 10/17/2013.

Falbe-Hansen, K.; Nissen, J. (2000): The Oresund Bridge completion. URL: http://www.arup.com/_assets/_download/download23.pdf, last checked 10/17/2013.

Global Site Plans (2012): Middelgrunden Wind Power Plant, Copenhagen: Major Player in the 40% Share of Annual Energy Consumption. URL: http://globalsiteplans.com/environmental-design/middelgrunden-wind-power-plant-copenhagen-major-player-in-the-40-share-of-annual-energy-consumption/, last checked 10/17/2013.

Government of Denmark (2012): How to manage cloudburst and rain water: Action plan for a climate-proof Denmark. URL: http://klimatilpasning.dk/media/590075/action_plan.pdf, last checked 10/17/2013.

Green Solar Cities (2012): Welcome to Green Solar Cities. URL: http://www.greensolarcities.com/, last checked 10/17/2013.

GreenMedia (2013): Climate Plan 2025 in Copenhagen, Denmark. URL: http://www.climateactionprogramme.org/news/copenhagen_denmark_aims_to_be_carbon_neutral_by_2025, last checked 10/17/2013.

Hvidovre Vindmøllelaugs (2013): Velkommen til Hvidovre Vindmøllelaugs nye hjemmeside! URL: http://www.hvidovrevindmollelaug.dk/, last checked 10/17/2013.

IDEA (2012): Denmark to be home to the world's largest biomass facilities. URL: http://www.districtenergy.org/blog/2012/10/05/denmark-to-be-home-to-the-worlds-largest-biomass-facilities/, last checked 10/17/2013.

Jensen, Marina B.; Cederkvist, Karin; Bjerager, Per E.R.; Holm, Peter E. (2011): Dual Porosity Filtration for treatment of storm water runoff - first proof of concept from Copenhagen pilot plant. In: Water Science & Technology, Vol. 64, pp. 1547-1557, IWA Publishing.

Jørgensen, Marc J. (2011): Copenhagen Carbon Neutral by 2025. URL: http://www.malekigroup.com/images/GBW2011/Podium1_MarcJorgensen.pdf, last checked 10/17/2013.

Kazmierczak, A.; Carter, J. (2010): Augustenborg, Malmö: Retrofitting SUDS in an urban regeneration area. URL: http://www.grabs-eu.org/membersArea/files/malmo.pdf, last checked 10/17/2013.

KL (2009): Read More: Political Organisation in the Municipalities. URL: http://www.kl.dk/eu/political-organisation-id59531/?n=0&section=4672, last checked 10/17/2013.

Københavns Kommune (2011): Plan For Forstat Drift. Københavns Kommune. URL: https://subsite.kk.dk/~/media/E46D0FC5D6B54F52817D2807300E8AB5.ashx, last checked 10/17/2013.

Københavns Kommune (2012a): Implementing of Agenda 21 plan for 2012 - 2015. URL: https://subsite.kk.dk/~/media/B0CB2E9DB32D4F648A15A7FBB9523EAE.ashx, last checked 10/17/2013.

Københavns Kommune (2012b): Vandforsyningsplan 2012. URL: http://kk.sites.itera.dk/apps/kk_pub2/pdf/874_XFk5rWrVAG.pdf, last checked 10/17/2013.

Københavns Kommune (2013): A growing, green city. URL: http://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/Press/FactsOnCopenhagen/~/media/128B58A82182470FBA569733F3C151A5.ashx, last checked 10/17/2013.

Københavns Kommune (2013): Giv et praj her eller fra din mobil. URL: http://givetpraj.kk.dk/, last checked 10/17/2013.

Københavns Kommune (2013): URL: http://www.kk.dk/da/om-kommunen/indsatsomraader-og-politikker/, last checked 10/17/2013.

Københavns Kommune (2013): Københavns Kommunes budget for 2013. URL: http://www.kk.dk/da/om-kommunen/regnskab-og-budget/budgetter/tidligere-budgetter/budget-2013, last checked 10/17/2013.

Københavns Kommune, Teknik- og Miljøforvaltningen Center for Miljø (2012): Vandforsyningsplan 2012. Københavns Kommune, Teknik- og Miljøforvaltningen Center for Miljø. URL: http://www.ke.dk/portal/page/portal/Grafik/pdf/Vandforsyningsplan%202012.pdf, last checked 10/17/2013.

Københavns Miljø- og Energikontor (2013): Dialog & Handling. URL: http://kmek.dk/, last checked 10/17/2013.

Kuben Management A/S (2013): Main information. URL: http://www.kubenman.dk/, last checked 10/17/2013.

Larsen, H.M. Jens; Soerensen, Hans Cristian; Christiansen, Erik; Naef, Stefan; Vølund, Per (2005): Experiences from Middelgrunden 40 MW Offshore Wind Farm. URL: http://www.middelgrunden.dk/middelgrunden/sites/default/files/public/file/Artikel%20Copenhagen%20Offshore%207%20Middelgrund.pdf, last checked 10/17/2013.

LGDK - Local Government Denmark (2009): The Danish Local Government System. URL: http://www.kl.dk/ImageVault/Images/id_38221/ImageVaultHandler.aspx, last checked 10/17/2013.

Lynetten Vindkraft I/S (2013): Velkommen. URL: http://www.lynettenvind.dk/, last checked 10/17/2013.

MEDICON VALLEY ALLIANCE (2013): URL: http://www.mva.org/, last checked 10/17/2013.

Middelgrunden (2001): Environmental Impact Assessment of the wind farm at the Middelgrunden Shoal. URL: http://www.middelgrunden.dk/middelgrunden/sites/default/files/public/file/Environmental%20Impact%20Assessment%20of%20the%20wind%20farm%20at%20the%20Middelgrunden%20Shoal.pdf, last checked 10/17/2013.

Middelgrundens Vindmøllelaug (2013): Offshore Wind Farm outside the Harbour of Copenhagen. URL: http://www.middelgrunden.dk/middelgrunden/?q=en, last checked 10/17/2013.

Ministry of Environment and Energy (2000): The Heat Supply Act. URL: http://soeg.ekn.dk/Afgorelser/Danish_Heat_Law_2000EN%5B1%5D.pdf, last checked 10/17/2013.

Ministry of Foreign Affairs of Denmark (2011): It's all about Denmark. URL: http://denmark.dk/en/~/media/Denmark/Documents/Quick%20facts/Its%20All%20About%20Denmark.pdf, last checked 10/17/2013.

Ministry of Foreign Affairs of Denmark (2013): Facts and statistics. URL: http://denmark.dk/en/quick-facts/facts/, last checked 10/17/2013.

NRPB; MLIT - National and Regional Planning Bureau NRPB, Ministry of Land, Infrastructure, Transport and Tourism MLIT (2013): Country profile: Denmark. URL: http://www.mlit.go.jp/kokudokeikaku/international/spw/general/denmark/index_e.html, last checked 10/17/2013.

Nederby Høj, Steffen (2013): Car suppliers position in Denmark. URL: http://www.tinv.dk/public/dokumenter/tinv/Konferencer%20og%20arrangementer/Afholdte%20arrangementer/A1/14-15%20marts%202013/2013_03_15%20Nissan%20%5BKompatibilitetstilstand%5D.pdf, last checked 10/17/2013.

Nord Pool Spot (2013): Power markets information. URL: http://www.nordpoolspot.com/, last checked 10/17/2013.

Norddeutscher Rundfunk (2013): Der lange Weg zur festen Querung. URL: http://www.ndr.de/regional/dossiers/fehmarnbeltbruecke/fehmarnbelt100.html, last checked 10/17/2013.

OECD (2012): Measuring the potential of local green growth: An analysis of Greater Copenhagen. URL: http://www.oecd.org/about/secretary-general/measuringthepotentialoflocalgreengrowthananalysisofgreatercopenhagen.htm, last checked 10/17/2013.

Øresund Region (2010): What is Øresund Region? URL: http://www.oresundsregionen.org/en/about-the-oeresund-region, last checked 10/17/2013.

Region Hovedstaden (2012): The Capital Region of Denmark. URL: http://www.regionh.dk/English2/.

Saskatoon Community Wind (2013): Middelgrunden Offshore Wind farm, Copenhagen, Denmark. URL: http://www.saskatooncommunitywind.ca/#!middelgrunden/c1bnx, last checked 10/17/2013.

Skovbro, Anne (2007): Urban planning in Copenhagen – Towards a Sustainable Future. URL: http://siteresources.worldbank.org/, last checked 10/17/2013.

Solar City Copenhagen (2013): Introduction to Solar City Copenhagen. URL: http://www.solarcitycopenhagen.dk/, last checked 10/17/2013.

Sørensen, H.C.; Hansen, L. K.; Molgaard Larsen, J. (2002): Middelgrunden 40 MW Offshore Wind Farm- Lessons Learned. URL: http://media.clemson.edu/public/restoration/wind/eu_offshore_wind/middlegrundendenwindlessonsspok02.pdf, last checked 10/17/2013.

Sørensen, S.; Petersen, B.; Kofod, N.; Jacobsen P. (2006): Historical overview of the Copenhagen sewerage system. URL: http://www.sewerhistory.org/articles/whregion/copenhagen/0010007.pdf, last checked 10/17/2013.

Statens Byggeforskningsinstitut (2012): Pressemeddelelse om Claus Bech-Danielsens udnævnelse. URL: http://www.sbi.dk/om-sbi/afdelinger/by-bolig-og-ejendom/claus-bech-danielsen/claus-bech-danielsen, last checked 10/17/2013.

The Agency for Spatial and Environmental (2009): The Danish Planning System. URL: http://www.byplanlab.dk/plan09/www.plan09.dk/NR/rdonlyres/4729DE2C-710B-44E8-BCE9-54CF20641695/0/DanishPlanning_120209.pdf, last checked 10/17/2013.

The Copenhagen Post (2012): Copenhagen releases 2013 budget. URL: http://cphpost.dk/news/local/copenhagen-releases-2013-budget, last checked 10/17/2013.

The ICN – The International Cleantech Network (o. J.): Bridging world-leading cleantech clusters. In: Copenhagen Cleantech Journal, S. 19. URL: http://www.cphcleantech.com/media/1782786/ccj_issue_2.pdf, last checked 10/17/2013.

The city of Copenhagen, Technical and Environmental Administration (2011): More people to walk more: the pedestrian strategy of Copenhagen. URL: https://subsite.kk.dk/PolitikOgIndflydelse/Byudvikling/Byplanlaegning/Udviklingsplaner/MetropolForMennesker/~/media/F04EF9F466274055861F106F44AEA079.ashx, last checked 10/17/2013.

Trafikstyrelsen, Center for Grøn Transport (2010): KORT OM – elbiler og plug-in hybridbiler. URL: http://www.trafikstyrelsen.dk/DA/Databases/~/media/Dokumenter/06%20Center%20for%20groen%20transport/Publikationer/Kort%20om%20elbiler%20og%20plug-in%20oktober%202010.ashx, last checked 10/17/2013.

TUXI (2013): Bybiler i kollektiv transport. URL: http://tuxi.dk/, last checked 10/17/2013.

USA TODAY (2011): Copenhagen - Overview. URL: http://usatoday30.usatoday.com/marketplace/ibi/copenhagen.htm, last checked 10/17/2013.

7

7 Appendix

A1: Interviews conducted during the research stay in Copenhagen

Practice Example / Topic	Name	Institution	Function	Date
General information concerning sustainable city development in Copenhagen	Carsten Vesterager Petersen			Round Table Event March 18, 2013; March 22, 2013 Morgenstadt Lab
	Ina Corydon	City of Copenhagen	Deputy, CEO	Mach 21, 2013
	Claus Bjørn Billehøj	City of Copenhagen, Finance Administration	Other actor	March 19, 2013
	Jørgen Edstrøm	HOFOR	CEO	March 21, 2013
	Peter Jeppe Tolstrup	Parc and Nature		March 22, 2013 Morgenstadt Lab
	Töger Nis Thomsen			March 22, 2013 Morgenstadt Lab
	Thomas Chapelle			March 22, 2013 Morgenstadt Lab
	Prof. Carsten Rode	DTU		March 27, 2013
	Prof. Henrik Madsen	DTU		March 27, 2013
	Prof. Sven Svendson	DTU		March 27, 2013
	Alfred Heller	DTU		March 27, 2013
	Hongwei Li	DTU		March 27, 2013
	Ivan Tengbjerg Herrmann	DTU		March 27, 2013
	Prof. Carsten Rode	DTU		March 27, 2013
Tools for Sustainability	Dan Borberg Mogensen	City of Copenhagen, The Technical and Enviromental Administration, Centre for Urban Design	Responsible for project	March 25, 2013
	Claus Ravn	Realdania	Executor	March 18, 2013
	Jens Villiam Hoff	University of Copenhagen	External expert	March 19, 2013
Network Initiatives for Green Growth	Lotte Kjærgaard	Green Business Network, Municipality of Copenhagen	Other actor	March 20, 2013
	Jørgen Abildgaard	City of Copenhagen, The Technical and Enviromental Administration, Center for Environment	Responsible for project	March 20, 2013
	Mette Abrahamsen	Service Cluster Denmark	External expert	March 25, 2013
	Marianna Lubanski	Copenhagen Capacity*	External expert	March 21, 2013
District Heating Copenhagen	Jan Elleriis	CTR centralcommunernes Transmissionsselskab, Metropolitan Copenhagen Heating Tranmission company	Responsible for project	March 20, 2013
	Erik Christiansen	Middelgrunden District indmollelaug	External expert	March 19, 2013
	Birger Lauersen	Dansk Fernvarme, Danish District Heating Association	Other actor	March 21, 2013

Practice Example/Topic	Name	Institution	Function	Date
Middelgrundens Wind Farm	Erik Christiansen	Middelgrunden Vindmollelaug	Responsible for project	March 19, 2013
Reducing Water Consumption in the City	Charlotte Storm	HOFOR	Executor	March 25, 2013
	Emma Matzen	Hotel Copenhagen Crown	User	March 26, 2013
Adaption to Climate Change	Lykke Leonardsen	City of Copenhagen, Technical and Environmental Administration, Centre for Parks und Nature	Initiator	March 21, 2013
	Jan Rasmussen	City of Copenhagen, Technical and Environmental Administration, Centre for Parks und Nature	Responsible for project	Round Table Event March 18, 2013
	Jan Burgdorf Nielsen	City of Copenhagen, Technical and Environmental Administration, Centre for Parks und Nature	Executor	March 25, 2013
	Christian Nyerup Nielsen	Rambøll	Project member	March 19, 2013
	Mikkel A. Thomassen	Smith Innovation / Klimaspring	External expert	March 27, 2013
	Prof. Marina Bergen Jensen	University of Copenhagen	External expert	March 26, 2013
Treatment of Road-Runoff	Prof. Marina Bergen Jensen	University of Copenhagen	Initiator	March 26, 2013
	Mette Lis Andersen	Realdania	Financier	March 18, 2013
Cloudburst Management Plan 2012 and Crisis Management	Stefan Werner	City of Copenhagen, Technical and Environmental Administration, Centre for Parks und Nature	Executor	March 27, 2013
	Nils Ole Blierup	CPH Fire Brigade		March 22, 2013
	Mogens Lauridsen	National Police		March 20, 2013
World's Most Bicycle Friendly City	Andreas Røhl	City of Copenhagen, The Technical and Environmental Administration, Center for Traffic	Responsible for project	March 20, 2013
	Tina Saaby Madsen	City of Copenhagen, The Technical and Enviromental Administration, Centre for Urban Design	Project member	Round Table Event March 18, 2013 March 27, 2013
	Brian Hansen	City of Copenhagen, The Technical and Environmental Administration, Center for Traffic	Project member	March 20, 2013
	Jens Loft Rasmussen	Danish Cyclists' Federation	Project member	March 21, 2013

Practice Example/Topic	Name	Institution	Function	Date
World's Most Bicycle Friendly City	Nina Kampmann	Metro Company: Metroselskabet I/S	Project member	March 25, 2013
	Claus Bjørn Billehø	City of Copenhagen, Finance Administration	Other actor	March 19, 2013
Electro Mobility	Anders Kragelund	Tuxi.dk	Responsible for project	March 20, 2013
	Carl Nielsen	Tuxi.dk	Responsible for project	March 20, 2013
	Richard Hoang-Gia Laugesen	City of Copenhagen, The Technical and Environmental Administration, Center for Traffic	Responsible for project	March 25, 2013
	Stine Holms	City of Copenhagen, The Technical and Environmental Administration, Center for Traffic	Responsible for project	March 19, 2013
Green Solar Cities	Jakob Klint	Kuben Management	Responsible for project	March 20, 2013
	Peder Vejsig Pedersen	Cenergia Energy Consultants	Responsible for project	March 25, 2013
Ørestad / Nordhavnen	Rita Justesen	By og Havn	Responsible for project	March 21, 2013
	Hans Christian Karsten	City of Copenhagen, Technical and Environmental Administration, Center for Environment	Project member	Round Table Event March 18, 2013
	Mette Margrethe Elf	City of Copenhagen, The Technical and Enviromental Administration, Center for Environment	Project member	March 20, 2013
	Rune Boserup	COBE Architects	Project member	March 20, 2013
Think Tank "Building Renovation" and Think Tank "City 2025"	Prof. Claus Bech-Daniels	SBi/Aalborg University	Project member	March 22, 2013
Royal Danish Playhouse	Søren Nylin	Royal Danish Playhouse	Operational supervisor of the Royal Danish Playhouse	March 21, 2013
Production & Logistic Network	Marianna Lubanski	Copenhagen Capacity	Responsible for project	March 21, 2013
	Stig Jørgensen	Medicon Valley Alliance	Responsible for project	March 19, 2013
	Lykke Schmidt	Novo Nordisk	Executor	March 19, 2013
	Morten Løber	Danish Industry	External expert	March 20, 2013
	Søren Holm Johansen	Rambøll	Other actor	March 25, 2013

A2: Collected Indicators for the City of Copenhagen

Recommended areas	Name of indicator (unit)	Description	Unit/Type of Value	Figure	Comment	Source
general data	Inhabitants in City			549,050	Year 2012	http://www.statbank.dk/BEF44
	Inhabitants in year 2002			501,158	Year 2006	
	Inhabitants in year 2007			503,699		http://www.statbank.dk/BEF44
	Inhabitants greater metropolitan region			1,800,000	Year 2008	http://www.copenhagendenmark.co.uk/2008/04/copenhagen-population/
	Size city		km²	88.25		
	Size greater metropolitan region		km²	3,030		
	Increase of population (city)		annual%	1.7		
	Population density (city)		inhab./km²	6,222		
	Population growth per year (over last 10 years)					
spatial data	residential	percentage of total area	%			
	industrial	percentage of total area	%			
	traffic infrastructure	percentage of total area	%			
	green areas/parks	percentage of total area	%			
	Protected area (% of city area)	percentage of total area	%			
	water bodies	percentage of total area	%			
social data	Persons per Household					
	living space per Person		m²			
	House ownership (%)					
	Average distance to work					
	Immigration rate (annual)					
	Average Age					
	Average life expectancy at birth					
	Average days of illness		days/year			
	Inhabitants per 1 doctor					
	Suicide rate					
	Birth rate					
	Share of employment primary sector					
	Share of employment secondary sector					
	Share of employment tertiary sector					
	Mobile phones per 1,000 residents			1,250	Denmark, 2010	
	Internet connection per 1,000 inhab.			888	Denmark, 2010	
	Share of public spendings for Education		%GDP	8.7	Year 2009	
	Share of public spendings for Health (%GDP)		%	9,70	Year 2010	

Recommended areas	Name of indicator (unit)	Description	Unit/Type of Value	Figure	Comment	Source
Social data	Gini-Index Country / City		%	26.9	Denmark, 2010	
	HDI Country (Human Development Index)			0.895	Denmark, 2011	
	GDI Country (Gender Development Index)			0.941		
Environmental data	Total energy demand		MWh/a			
	Energy demand private households		MWh/a			
	Energy demand industry		MWh/a			
	Energy demand transport sector		MWh/a			
	Energy demand for public transport (as part of transport)		MWh/a			
	Total electricity demand		MWh/a	2.64 Mio.	2010	Copenhagen`s Green Accounts, 2012
	Electricity demand by private sector		MWh/a	702,000	2010	Copenhagen`s Green Accounts, 2012
	Electricity demand by industry sector		MWh/a	211,000	2010	Copenhagen`s Green Accounts, 2012
	Electricity demand by transport sector		MWh/a	80,000	2010	Copenhagen`s Green Accounts, 2012
	Electricity demand for street lightning (as part of public energy demand)		MWh/a			
	Total heating demand		MWh/a	3 Mio.	2010	Copenhagen`s Green Accounts, 2012
	Gas					
	wind					
	hydro					
	CHP			1,524	2009/ 2010	http://dbdh.dk/images/uploads/pdf-diverse/District_heating_in_Copenhagen.pdf
	PV					
	Share of electricity demand produced within the city		%			
	Share of electricity demand produced by renewables		%			
	Level of ICT solutions installed in the energy supply system		1 (very high) - 6 (very low)			
	Average price for fuel in the transport sector		€ct/liter	182	Jan 2013	Copenhagen Portal, 2013
	Number of electricity suppliers with customers in the city			1	2012	Københavns Energi
	Number of Distribution System Operator (DSO)					
	CO_2-emissions generated by the energy sector		tons CO_2/a			
	Renewable energy targets existing		yes/no	yes		CPH 2025, 2012
	Renewable energy development plan existing		yes/no	yes		CPH 2025, 2012
	Subsidies given for the energy sector		Mio €/a	52,005,627	2010+2011	Copenhagen Green Accounts, 2012

Recommended areas	Name of indicator (unit)	Description	Unit/Type of Value	Figure	Comment	Source
Environmental data	Ownership share of the city on the local utility		%			
	NO2		µg/m³	19.21	2007	
	PM10		µg/m³	23.40	2007	
	Amount of waste		1,000 t	827.1		
	% Recycling		%	23.61		
	CO_2 emissions overall		1,000 t	2,500		
	CO_2 emissions per cap.		t	5.38	2007	
	Water price		US$/liter	402.7	2009	
	Water use per cap.		l/day			
	Ecological footprint of city		gha/cap	8.3	Denmark, 2008	
Governance	Tax revenue Total					
	Loan programs			1	Incubators administer pre-seed capital through a programme initiated by the ministry of Science and Technology	http://www.copcap.com/content/us/doing_business/facts/venture_capital_market/government_initiated_capital_sources
	City has the right to define and change laws that regulate important infrastructures in the m:ci sectors			yes		http://denmark.dk/en/society/government-and-politics/
	Nr of parties in city council / parliament			7		http://en.wikipedia.org/wiki/Copenhagen_Municipality
	Public confidence in government		%	87		http://www.oecdbetterlifeindex.org/countries/denmark/
	Voter participation in last elections		%	87.5		http://www.electionresources.org/dk/folketing.php?election=2011&region=01
	Transparency of city budgeting			3		http://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/Press/FactsOnCopenhagen/Statistics/Income.aspx
	number of districts (decentral)			15		http://en.wikipedia.org/wiki/Copenhagen_Municipality
	Quality of masterplan			4		http://www.dac.dk/en/dac-cities/sustainable-cities-2/all-cases/master-plan/copenhagen-sustainability-at-district-plan-level/
	Content of masterplan regarding Morgenstadt			6		http://subsite.kk.dk/sitecore/content/subsites/bdv/subsitefrontpage.aspx
	characteristic e-government			4		http://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage.aspx
	rent index		€/m²	11.43	In the citiy centre	mbeo.com/cost-of-living/city_result.jsp?country=Denmark&city=Copenhagen&displayCurrency=EUR
	GDP per capita		US$	43.640	2009	
	GDP total					
	Growth rate		%	1.1	2011	
	Debt per capita		% of GDP	46.5	2011	
	Tax revenues (in 1000)		% of GDP	35.5	2011	

Recommended areas	Name of indicator (unit)	Description	Unit/Type of Value	Figure	Comment	Source
Governance	Public expenditures per year on city administration (without firefighters, police, schools, hospitals)					
	Rate of unemployment		%	6	2011	
ICT	Municipal ICT investments					
	Total annual expenses for ICT/inhabitant		US$	10,214		http://www.thecrystal.org/_download/ICT-for-City-Management.pdf
	eGovernment implementation status	The indicators focuses on the quality of self-services provided for citizens and businesses by the city administration as well as on integrated e-service delivery.		2		http://www.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/LivingInCopenhagen/CitizenService.aspx
	Use and Transparency of municipal data	The indicator focuses on digital provision of municipal data in a machine readable format (XML, rdf) for developing smart applications on the basis of public / basic data.		3		cer%20og%20arrangementer/Afholdte%20arrangementer/ITS%20gods%20060312/08%20-%20TI%20Siemens%2006032012.pdf und http://www.siemens.com/sustainability/en/environmental-portfolio/products-solutions/mobility/intelligent-traffic-management.htm
	Implementation status of Smart traffic solutions	This indicator measures the use of ict for constant (individualized car) traffic analysis and control in order to prevent traffic jams, provide parking lots and minimize pollution.		3		cer%20og%20arrangementer/Afholdte%20arrangementer/ITS%20gods%20060312/08%20-%20TI%20Siemens%2006032012.pdf und http://www.siemens.com/sustainability/en/environmental-portfolio/products-solutions/mobility/intelligent-traffic-management.htm Steria Road traffic management http://www.steria.com/uk/your-business/transport/road-traffic-management/ Copenhagen Intelligent Transport System http://www.stateofgreen.com/en/Profiles/Ramboll/Products/ITS---Intelligent-Transport-Systems
	Implementation status of Smart metering / Smart Grid solutions	This indicator measures the use of ict solutions for the management of a community-based energy provition and consumption as well as for the control of electic devices in households, fabrics, public buildings and other. The indicator provides evidence on whether ICT is used for energy savings and CO2 reduction by fostering small networks of local energy providers and by balancing energy consumption.		3		Young Engineers : http://ida.dk/netvaerk/fagtekniskenetvaerk/Documents/Challenge%20%207-%20smart%20grit%20district.pdf http://www.kooperation-international.de/fileadmin/public/cluster/Kopenhagen/Copenhagen.pdf EcoGrid Summary Report http://energinet.dk/SiteCollectionDocuments/Engelske%20dokumenter/Forskning/EcoGrid_dk%20Phase1%20Summary%20Report.pdf Smart Grid brochure http://www.e-pages.dk/energinet/217/1/?query=smart%20grid

Recommended areas	Name of indicator (unit)	Description	Unit/Type of Value	Figure	Comment	Source
ICT	eHealth Implementation status	The indicator discriminates the implementation grade of typical modern eHealth technologies, such as Telemedicine, Electronic Health records, Integrated Patient management Systems and other. In Stage 3, these technologies are fully implemented and used in daily routine.		3	eHealth in Denmark is based on a national strategy and a common innovation strategy. Danish national eHealth portal sundhed.dk was developed by IBM and based on IBM Websphere.	National eHealth strategy 2010. http://www.nationellehalsa.se/Uploads/National%20eHealth%202010.pdf Danish eHealth portal http://www.kith.no/upload/3592/stefan_ohlsson.pdf https://www.sundhed.dk/
Mobility	Number of commuters					
	Cycling modal-share			36	value for 2008-2010	http://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/LivingInCopenhagen/CityAndTraffic/CityOfCyclists/~/media/A6581E08C2EF4275BD3CA1DB951215C3.ashx, p8
	Pedestrian modal-share			7	value for 2008-2010	http://kk.sites.itera.dk/apps/kk_pub2/pdf/983_jkP0ekKMyD.pdf, p44
	Passenger transport performance per year					
	Length of cycling lanes			416	value for 2010, varies with definition	http://www.kk.dk/sitecore/content/subsites/cityofcopenhagen/subsitefrontpage/livingincopenhagen/cityandtraffic/cityofcyclists/cyclestatistics.aspx
	Length of bus network					
	Length of urban rail network (metro, tram etc.)			190	value for 2012, Copenhagen Metro & S-train network	http://www.statistikbanken.dk/statbank5a/SelectVarVal/Define.asp?Maintable=BANE41&PLanguage=1
	Number of airports			3	Copenhagen Kastrup, Roskilde and Skovlund	http://www.gcmap.com/search?Q=country:DK
	Number of ports					
	Number of registered cars			124,512	value for 2012	http://www.statbank.dk/statbank5a/selectvarval/define.asp?PLanguage=1&subword=tabsel&MainTable=BIL707&PXSId=111099&tablestyle=&ST=SD&buttons=0
	Number of registered two-wheelers			9,456	motorcycles and 45 mopeds, value for 2012	http://www.statbank.dk/statbank5a/selectvarval/define.asp?PLanguage=1&subword=tabsel&MainTable=BIL707&PXSId=111099&tablestyle=&ST=SD&buttons=0
	Number of car-sharing vehicles offered in the city					
	GHG emissions from transport		CO_2–CH_4 tons			
	CO_2 emissions			1,857,000	tons, value for 2011	http://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/LivingInCopenhagen/ClimateAndEnvironment/CopenhagensGreenAccounts/EnergyAndCO2.aspx
	Pollutant concentration of NOx (average / year]					

Recommended areas	Name of indicator (unit)	Description	Unit/Type of Value	Figure	Comment	Source
Mobility	Pollutant concentration of Particulate matter (PM10) (average/year)					
	Number of traffic accidents			230	value for 2009	http://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/LivingInCopenhagen/CityAndTraffic/~/media/BF3A66B079AB4ACAA6CA167ECF151EB3.ashx, p7
	...of which <18					
	...of which elderly >65 years					
	...of which pedestrians			53	value for 2010, fatalities and serious injuries	http://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/LivingInCopenhagen/ClimateAndEnvironment/CopenhagensGreenAccounts/Traffic/Injured.aspx
	...of which cyclists			121	value for 2008, serious injuries (116) and deaths (5)	http://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/LivingInCopenhagen/CityAndTraffic/CityOfCyclists/~/media/5BCCC20D62914D8197122DC07718A54A.ashx, p7
	Number of traffic deaths					
	Cars per 1,000 residents			228	value for 2009	http://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/LivingInCopenhagen/CityAndTraffic/~/media/BF3A66B079AB4ACAA6CA167ECF151EB3.ashx, p5
P&L	Share of freight vehicles (heavy trucks) in total road traffic		%			
	Share of freight vehicles (small trucks) in total road traffic		%			
	Share of road categories according to capacity / number of lanes / driving speed: Category 2	Calculation: Length of roads in each category [km] related to total lenth of road system [km]; City specific classifications can be described under comment				
	Share of road categories according to capacity / number of lanes / driving speed: Category 3	Calculation: Length of roads in each category [km] related to total lenth of road system [km]; City specific classifications can be described under comment				
	Share of road categories according to capacity / number of lanes / driving speed: Category 4 (narrowest streets in city)	Calculation: Length of roads in each category [km] related to total lenth of road system [km]; City specific classifications can be described under comment				
	No. of freight train stations in urban area					
	No. of port facilities in urban area					

Recommended areas	Name of indicator (unit)	Description	Unit/Type of Value	Figure	Comment	Source
P&L	Average distance to port facilities from city centre					
	Average distance to freight train stations from city centre					
	Average distance to airports from city centre					
	Classification of manufacturing companies in the city (by no. of employees)					
Security	Number of registered crimes		Absolute figures	14,479	2003, number of crimes reported per 100,000 inhabitants	http://www.kk.dk/FaktaOmKommunen/KoebenhavnITalOgOrd/StatistikOmKoebenhavnOgKoebenhavnere/UdgaedePublikationer/BlandedePublikationer/~/media/8A0E89102D244DAC9E1C93F7E7C57B5B.ashx
	Victims		Absolute figures	2,069	2003 crimes of violence	http://www.kk.dk/FaktaOmKommunen/KoebenhavnITalOgOrd/StatistikOmKoebenhavnOgKoebenhavnere/UdgaedePublikationer/BlandedePublikationer/~/media/8A0E89102D244DAC9E1C93F7E7C57B5B.ashx
	Crime detection rates		Absolute figures			
	Organized crime		Absolute figures			
	high-rise buildings (construction type: steel skeleton construction, ferroconcrete skeleton construction)		Absolute figures			
	residential buildings		Absolute figures	280,000	2004	http://www.kk.dk/FaktaOmKommunen/KoebenhavnITalOgOrd/StatistikOmKoebenhavnOgKoebenhavnere/UdgaedePublikationer/BlandedePublikationer/~/media/8A0E89102D244DAC9E1C93F7E7C57B5B.ashx
	bridges					
	tunnels					
	public transportation					
	public areas for mass events (sports, concerts)					
	Storm	Low, medium, high				
	Torrential rains	Low, medium, high				
	Hail	Low, medium, high				
	Thunderstorms	Low, medium, high				
	Flood	Low, medium, high				
	Earthquakes	Low, medium, high				
	Tsunamis	Low, medium, high				
	Fire incidents		Absolute figures			
	Casualty events (medical emergencies)		Absolute figures			
	Traffic accidents		Absolute figures			
	General emergencies		Absolute figures			
	Police officers					
	Fire fighters					
	Ambulance personnel					
	Availability of IT-Security Organisations			Yes		

Recommended areas	Name of indicator (unit)	Description	Unit/Type of Value	Figure	Comment	Source
Buildings	Total Number of buildings			47,253		
	Total Number of households			291,167		http://www.statistik.baden-wuert-temberg.de/SRDB/Tabelle.asp?H=ProdGew&U=05&T=99045041&E=GE&K=311&R=GE311000
	Floor space ratio (FSR; in DE: GFZ)			0.16		
	Gross floor area			36,089,721		
	GFA residential	quality of buildings		7,160,172	Total	
Water	Population connected to potable water supply	Percentage of total population	%	100		Email v. utility
	Population connected to public or private wastewater systems		%	100		Email v. utility
	Average annual precipitation			636		http://www.klimadiagramme.de/Europa/kopenhagen.html
	Total amount of water supplied	water supply		29.3	2011	http://www.ke.dk/portal/page/portal/Erhverv/Vand/Vand_forbrug?page=152
	Domestic water consumption/demand: domestic use	Percentage of total population		66		http://www.helsinki.fi/envirohist/seaandcities/articles/CopRig.pdf
	Tariff for water supply	Average values for city area		5,233.923	39.03 DKK/m³	http://www.ke.dk/portal/page/portal/Erhverv/Vand/priser_paa_vand_2012?page=915
	Length of water distribution network		km	1,100		Email v. utility
	Length of sewer system		km	1,100		http://www.sewerhistory.org/articles/whregion/copenhagen/0010007.pdf
Water	Tariff for sewage	Average values per person and year		1.05	Tariff drainage transport 7.8 DKK	http://www.ke.dk/portal/page/portal/Erhverv/Vand/priser_paa_vand_2012?page=915
	Tariff for storm water	Average values per person and year		0		http://www.globalwaterintel.com/archive/11/9/market-insight/water-tariffs-continue-upward-momentum.html
	Energy recovery from wastewater	Chemical and heat energy				
	Amount of sludge produced from wastewater treatment	Total amount of sludge		30,879	treatment plants (dried solid capacity: 2.35 t/h) other plant capacity around 0.5 (rough estimation - 2nd source)	http://www.stateofgreen.com/en/Profiles/Ramboll/Solutions/Sludge-for-energy-in-Copenhagen-(Lynettef%C3%A6llesskabet) AND http://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2012/07/Section-9-Waste-water-

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