

# Water supply

Meeting the rising demand for water



# Introduction

The City of Copenhagen benefits from 100 % coverage of pipe distributed tap water delivered 24 hours a day 365 days in a year. The water is of high quality, has a pleasant taste and can be drunk directly from the tap.

## Facts about the water supply of Copenhagen

- Approximately 1 mill. consumers
- Drinking water production 57 mill. m<sup>3</sup>/year
- 15 water works
- 57 well fields
- 540 abstraction wells

Public water supply in Copenhagen has a long history. Until 1853 a number of private companies were operating district based water supply, hereafter it became an obligation of the City to provide water. The foundation of today's water supply was established in 1859 with the first municipal water treatment plant and a comprehensive renovation of the distribution net. The water sources were a mix of spring water and river intake. The water supply developed rapidly as the town of Copenhagen expanded.

Today the water supply of Copenhagen is managed by HOFOR, a company entirely owned by the City of Copenhagen and seven other suburban municipalities. HOFOR provides water supply to the eight owner municipalities and partly to nine other surrounding municipalities.

The geology in Denmark provides, in general, excellent groundwater aquifers with easy accessible water of a high quality which requires a minimum of treatment. As a consequence, the drinking water supply in Denmark is entirely based on groundwater.

The choice of groundwater as a resource for drinking water, besides the obvious qualities in taste and freshness, has several derived consequences.

Groundwater is a limited resource, especially in areas with a large number of consumers as in Copenhagen. Therefore early intervention has been required to use this limited resource in an optimal manner. Various initiatives have cut per capita consumption down to 104 l/p/day, (2012) and leakage from the distribution net was 7 % in 2012. As pumping of water is by far the largest energy consumer in the water sector, these initiatives have contributed positively towards lowering CO<sub>2</sub> emissions.

Groundwater, as it is found around Copenhagen, is very simple to treat and therefore requires less energy than treatment of surface water or desalination. Actually, the requirements for surveillance of the quality of publicly distributed water are higher than those given to the industry of bottled water. The high quality and good taste of tap water leaves the less environmentally friendly bottled water with few and difficult sale arguments.

# Technical solution

## The political framework

The water supply in Denmark is regulated by law issued by the Ministry of Environment, who delegates the responsibility to the 98 municipalities in Denmark.

As an essential commodity the water sector is governed by long term planning. This is especially important when using a limited natural resource as unpolluted groundwater.

The groundwater in Denmark belongs to the public. A landowner does not own the groundwater beneath his/her property. The right to abstract and utilize the groundwater is granted by the local authorities where the well field is located. Abstraction permits given to water utilities can have duration of up to 30 years.

The Danish drinking water supply is based entirely on groundwater. It is the government's official position that drinking water should be based on natural clean groundwater which only has undergone a simple treatment of aeration and filtration. This has caused an extensive investigation, mapping and protection of groundwater resources partly financed by a consumer paid fee connected to the deliverance of water and partly paid by taxes.

Several political initiatives have helped reduce water consumption. These were implemented at least 15 years ago, and are still in place today.

In the nineties it was a political goal to move part of the taxes from direct income tax to fees related to actual consumption. From 1994 till 1998 a water fee was gradually increased until it reached an amount close to 1 EUR/m<sup>3</sup> and the fee has stayed at this level ever since. Around 10 % of this fee is earmarked to be used on groundwater protection. The fee added to the incentive of reducing water consumption.

Throughout the nineties it had become increasingly common to install individual meters, also in apartment buildings. This trend was supported by a law in 1999 making it mandatory having a meter in all buildings, and thereby having all billing based on metered consumption. For apartment buildings individual metering on apartment level was not a request. Despite the increased water price individual meters have been installed in only 10% of already existing apartment buildings, where all new apartment buildings have individual meters.

In 1999 the law regarding the water fee was tightened. The water utilities would have to pay the fee of approximately 1 EUR for any undocumented loss of water above 10 % of the water delivered from the

waterworks. This caused an increased focus on leakage detection on the water supplies distribution network.

## **Water supply plan for the City of Copenhagen**

In Denmark every municipality is obliged to have a water supply plan. The plans are typically renewed every 5 – 10 years. The water supply plan for Copenhagen is politically approved by the politicians of the City of Copenhagen. Besides from setting guidelines for the water supply and providing transparency for the citizens, the plan also functions as a coordination tool between the municipality and the water supply company.

The latest plan for Copenhagen is from 2012. The main focus areas of the plan are: Reduction in water consumption, reliability in provision of water and water quality.

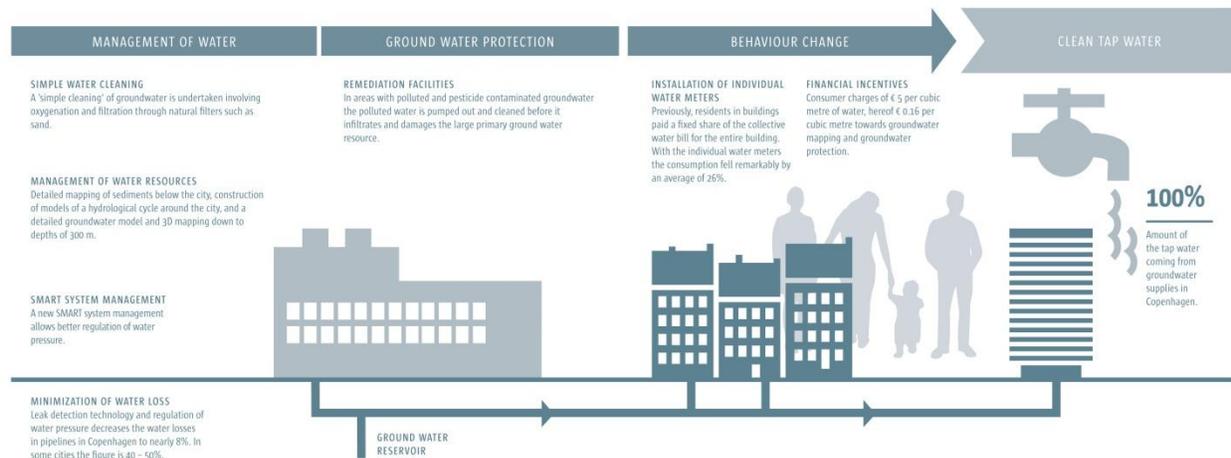
The water supply plan determines that the water supply, in general, shall be based on abstraction of groundwater, which after a simple treatment of aeration and filtration, comply with the national requirements for water quality.

Important goals are:

- In the water supply plan, goals are set for a percentage of water analyses which may be above any of the guideline values. Both in the former plan as well as the present, maximum accepted levels of exceedance of the guidelines is 2%.
- Before 2017 household consumption shall be reduced to 100 l/p/d. This is to be achieved through further development of water saving technologies and water conservation campaigns.
- To secure the supply, HOFOR shall continue to have abstraction permits and production facilities which allow production of at least 25 % more than is annually consumed.
- HOFOR shall continue to maintain the distribution network. The unaccounted consumption shall be as low as possible and not exceed 10 %.
- Reuse of water and use of low quality groundwater shall constitute 4% of the water consumption.

# The technical solution

## BETTER MANAGEMENT OF WATER RESOURCES



Copenhagen is located on the eastern coast of the island of Zealand and groundwater is abstracted from well fields up to 55 kilometers away from the city center. The underground of Zealand consists geologically of Quaternary deposits overlying Cretaceous chalk, limestone and Tertiary sand and clay. Copenhagen water supply is mainly based on abstraction of groundwater from the chalk aquifer. The groundwater quality from these deep aquifers is in general high. It takes 40-60 years for the water to penetrate down to the aquifer.

### Drinking water source

Water consumption increased dramatically through the sixties and up to the late eighties. In order to meet the demand, lake water intakes were established. One lake water intake was phased out in the early nineties, and the other as late as 2009.

The lake water was mixed with groundwater at the waterwork and pumped to Copenhagen through a several km long transmission pipe. Even though the lake water was only used occasionally, all the water delivered needed to be disinfected by chlorination with monochloramin due to the risk of bacteria in the long transportation pipe. As monochloramin affects the taste of the groundwater negatively, it has been an aim for years to avoid the use of surface water. A mutual backup agreement with the two largest neighboring water utilities cleared the road for a definite end to the use of surface water.

People in Copenhagen can therefore enjoy tap water of an equal or better quality than bottled water. And the difference in price is enormous! One liter of cold tap water cost approximately 0,005 EUR while one liter of bottled water cost between 1 and 5 EUR, or the bottled water is 200 – 1,000 times as expensive. Bottled water does not have the prominent position in Danish supermarkets, as it can be seen in many other countries.

The City of Copenhagen has put an increased emphasis on the reuse of water or using gray water. Recycling of process water in industries is more and more common as well as using already polluted

groundwater for process water for example as cooling water. Often water saving activities end up being financially attractive for companies.

In regards to private housing, rainwater harvesting is the most common technique, where rainwater is used for flushing toilets and washing clothes. HOFOR financially supports the establishment of rainwater harvesting facilities.

The City of Copenhagen estimates that for 2011 around 2 % of the water use is covered by reused water. It is still the overall objective, for water supply of drinking water in Copenhagen to be based on pure groundwater with a simple treatment. But to minimize the import of water from outside of Copenhagen and the environmental impact the Water Supply Plan from 2012 present it is a goal for 2017 that reused water and low quality groundwater shall cover 4 % of water used for secondary purposes eq. non drinking water.

As the awareness of CO<sub>2</sub> emission has been increasingly prominent, the use of groundwater is still a much more attractive solution than for example desalination of seawater. Not until the majority of electricity is produced from wind power, solar panels etc. will desalination be environmentally interesting.

### **Groundwater management**

The threat to the use of pure groundwater in regards to both quantity and quality created already back in the 1970-80s an awareness of the importance of protection of the groundwater, which falls under the responsibility of the government and the municipalities. Denmark is classified into three types of groundwater-abstraction areas: particularly valuable, valuable and less valuable water abstraction areas. All catchment areas for HOFOR's larger regional well fields are categorized as being areas of particular value in terms of drinking water interest. Within these areas, the government is obliged to provide knowledge about geology and groundwater. The municipalities are responsible for elaborating water actions plans, which will ensure surface- and groundwater are at a state of good quality. One of the tools is regulating the land use.

As the landscape of Denmark is highly cultivated and more than 60 % is agricultural land, the emphasis has been on the use of pesticides and in certain areas of Denmark on nitrate. Larger utilities such as HOFOR has invested a lot of time, energy and money in groundwater protection, either by compensating neighboring farmers for avoiding the use of pesticides or by participating in forestation within the catchment areas.

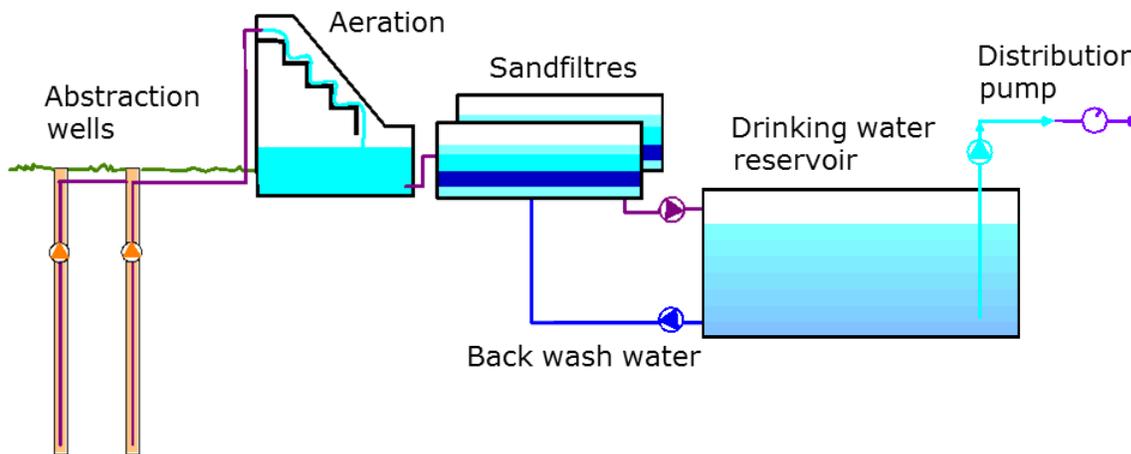
An important tool to estimate the catchment areas of the well fields is groundwater modeling. The Geological Survey of Denmark has established a national model covering the all of Denmark. This model has been used to create refined 'sub models' for several of the catchment areas to HOFOR's well fields. Besides from providing information for optimizing groundwater protection, the models can be used in the planning of groundwater abstraction. The 'sub models' are typically built by Danish consulting engineering companies, who nest and operate them for the municipalities and water utilities.

Despite today's awareness of the importance of protecting the groundwater, past times lack of knowledge and regulations have caused pollution of groundwater at some locations to such an extent, that remediation of these sites are necessary. When designing remediation facilities, a groundwater model is a mandatory optimization tool.

The use of pesticides and their occurrence in water wells has caused debates between water utilities and farmers. Specifically for the water supply of Copenhagen, this has been even more complicated, because the City of Copenhagen abstracts water from rural areas many kilometers from the city center. Great efforts have been made by HOFOR to create alliances with local water supplies and thereby make the issue of pesticide use also a local one. Furthermore, the public debate has emphasized and strengthened the general opinion in Denmark, that drinking water shall be pure and unpolluted groundwater.

### Water treatment and monitoring

The abstraction of groundwater took place for years without any significant problems. The groundwater could be used for drinking water after a simple treatment of aeration and filtration before being distributed to consumers.



### *Simple water treatment as at HOFOR*

Denmark benefits from having only few natural occurring chemical parameters on critical levels in the groundwater, which is not removed by simple treatment. These are nitrate, nickel and arsenic with local exceptions in regards to other parameters. The geology at several of HOFOR's well fields cause a risk for release of nickel while the water table is lowered by pumping. Nickel can only be removed by carbon filtration. But as only around 25 % of the well fields, and most of those minor, delivers water with an elevated content of nickel, it is possible to dilute the content well below the guideline value of 20 µg/l.

As the groundwater aquifers mainly are limestone or chalk, the water is very hard, around 20 dH. HOFOR is presently investigating the possibilities of softening the water. It requires permission from the water authorities to remove the chalk from the water, and at present no water utility in Denmark has achieved such a permit.

In the eighties attention was drawn to contamination of shallow aquifers with pesticides or hazardous contamination from industrial production. This and other incidents caused an increase in the monitoring of groundwater quality. Contamination of some deeper aquifers was found due to this monitoring. Especially close to Copenhagen, where industrialization has been more intense, a number of well fields had to be closed down. The governing principle of use of pure groundwater has been maintained with very few exceptions. Instead of choosing a solution where further and more advanced treatment of the groundwater was applied, the polluted wells have been abandoned and alternative groundwater resources have been sought.

HOFOR is obliged by law to conduct an intensive surveillance of the water quality, throughout the production from the well fields, through the waterworks and at the distribution level. HOFOR's own laboratory is responsible for this extensive monitoring program. To ensure an all-time acceptable water quality, HOFOR has chosen to conduct a higher number of water quality analyses, than they by law are obliged to do.

In the water supply plan, goals are set for a percentage of water analyses which may be above any of the guideline values. Both in the former plan as well as the present, maximum accepted levels of exceedance of the guidelines is 2%.

HOFOR has obtained an ISO 22000 certification, which is the international standard concerning food safety. The principles of the Hazard Analysis and Critical Control Point (HACCP) in the ISO 22000, is operationalized in the practice by Documented Drinking water Safety, DDS). HOFOR has obtained a DDS certification, which reflects that drinking water is an important food item, and the hygienic standards on the production sites shall reflect this in operational practices throughout the water supply.

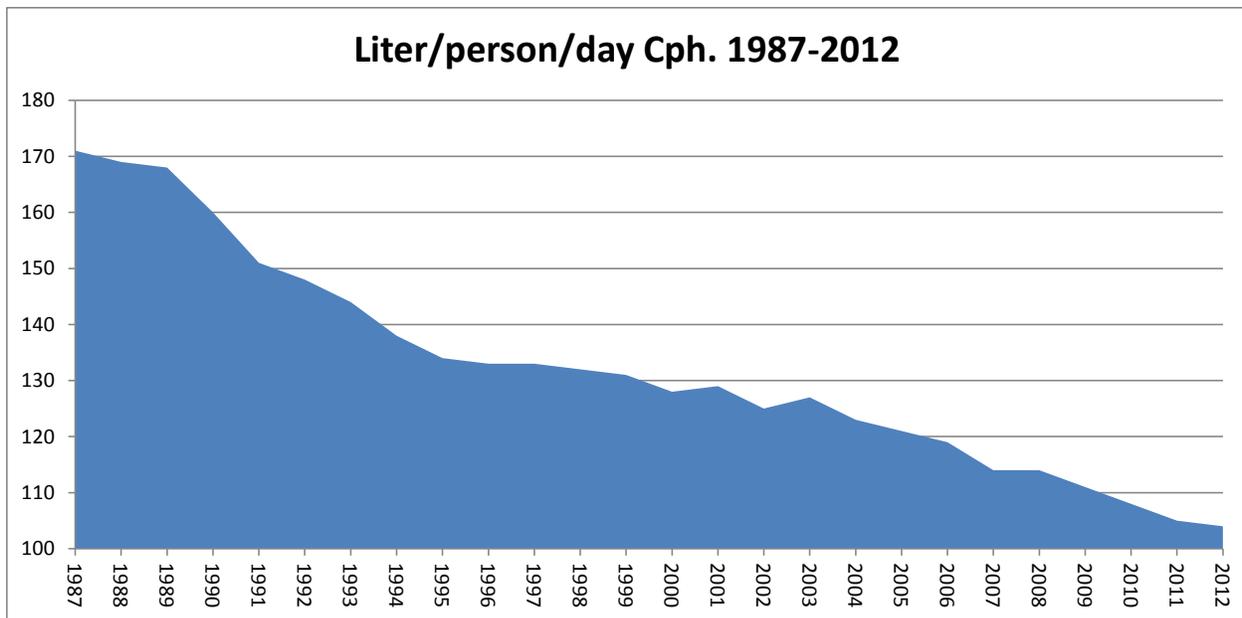
Intensive water surveillance and documented approaches have been a driver for HOFOR, as the tradition of no disinfection makes the water supply more vulnerable. Besides these preventive actions, a comprehensive contingency plan has been developed, in case an emergency occurs.

### **Water consumption**

Consumption of water was increasing up till the eighties, and at its highest, the water supply of Copenhagen produced more than 100 mio. m<sup>3</sup>/year, twice as much as today. Household consumption stabilized through the eighties, before it started falling at the end of the eighties. The graph shows the significant reduction in household consumption in Copenhagen from 1987. The per capita use of water is down to 104 l/p/d and in the water supply plan from 2012 the goal for 2017 is 100 l/p/d and for 2025 it is 90 l/p/d.

The most important drivers in reducing consumption have been increased water fees, metering of consumption and promotion of water saving utilizes such as low flushing toilets.

In 2012, household consumption covered around 66 % of the water use in Copenhagen, industry and other users around 27 %, while the last 7 % is unaccounted consumption. The water supply plan of 2012 has a target of a maximum of 10 % of unaccounted consumption.



#### *Household consumption l/p/d in Copenhagen*

The unaccounted consumption is caused by several factors: Inaccuracy in meters both at the consumer level and at the water utility itself, water used from fire hydrants, water used or lost to maintenance of the water utilities and leakage from the distribution network. It is generally accepted that the major cause to an elevated unaccounted consumption rate is leakage.

The distribution network in Copenhagen is in general old and provides water supply history in its great diversity of pipe materials. Some materials are less sustainable than others, this also becomes apparent during the systematic registration of leaks. Leaks in severe cases can be registered at the surface, but the majority is discovered by systematic acoustic leakage detection. All pipes in Copenhagen are tested over a cycle of three years.

The high age of the distribution network in Copenhagen has caused that the layout is based on different design principles than what is used today, where a distribution network is divided into a number of sections and a varied water pressure between clusters of sections. As leakage is directly related to water pressure it is of interest to lower the pressure as much as possible without interfering with service requirements. Further, a lower pressure saves energy used in the pumps lifting the water. In Copenhagen pressure sensors are installed at strategic locations to monitor, and through the Scada system, control and adjust the water pressure, (SMART system management).

#### **Awareness on water conservation**

Groundwater is a limited resource. It was realized that a continued growth in water consumption combined with a more common occurrence of pollutants, would cause over-exploitation of the groundwater resources. The water utilities embarked on creating awareness about the vulnerability of the groundwater resource.

Various campaigns addressing water saving techniques in regards to how people use water, such as not to let tap water run without reason or to take a shower instead of using the bathtub, have been run. Campaigning was done through advertising, either in the media or by household distributed campaigning material.

Water conservation campaigns have also focused on creating awareness in children. HOFOR is presently running a successful campaign among school children, as part of the goal of bringing water consumption down to magical 100 l/p/d in 2017. Besides from campaigns, schoolchildren in Copenhagen can learn about water and environment issues at a closed water plant set up for hands-on teaching on energy- and water supply.



## Organization

The water supply in Copenhagen was managed by the city until 2005, when it was separated from the city and became a private company; all stocks though are owned by the City of Copenhagen.

Other water utilities had already been through that process and in 2009 the Danish Parliament passed a Water Sector Reform Act. The reform was in line with the international trend of liberalizing and re-regulating the utility sectors in order to promote economic rationalization.

However, the water sector is regulated as being a non-profit business, having a balance between earnings and expenditure. This is to secure the main objective of water supply, which is to provide consumers with a reliable water supply, not generate a profit for the owners.

Copenhagen water supply has for many years provided water to a smaller or larger extent to 16 municipalities in the greater Copenhagen area. In 2012 the City of Copenhagen and 7 other municipalities merged their water and sewage companies into HOFOR, creating joint ownership with a total of 8 municipalities, now covering around one fifth of the population in Denmark.

The strategic planning as expressed in the water supply plan, in regards to the consumer service level and quality control in Copenhagen is under the responsibility of the City of Copenhagen and is approved by the city council. The City Council approves the water fees on an annual basis and approves the delivery terms. HOFOR is responsible for providing the water under the conditions given by the city. However, as HOFOR is abstracting water far out on the island of Zealand, the abstraction permits for well fields are granted from a number of local municipalities.

The water sector in Denmark is organized in Danva, the association which represent their interests, both in regards to the political establishment, other associations for example farmers and NGO's often with a nature preservative agenda. Danva has an important influence on the elaboration of laws, norms and standards. Likewise, they have been the initial driving force in benchmarking of the water sector in Denmark, which has been state-driven since the Water Sector Reform in 2009. HOFOR is active in Danva.

# Perspective

The water supply plan for Copenhagen outlines the goals for the coming years. The latest plan is from 2012 and some of the aim and goals are: Continued reduced water consumption, security in supply of water and in quality of water.

Before end of 2017 the household consumption of water shall be reduced to 100 l/p/day. This will be obtained through further development of water-saving technology, installation of low water use toilets and other water-saving sanitary installations combined with campaigns on water savings.

HOFOR will carry on renewal of the distribution network, and the unaccounted consumption should be as low as possible and below 10 %.

To secure the supply of water HOFOR's abstraction permits and production facilities should continue to cover a minimum of 125 % of the average water consumption. In line with securing the provision HOFOR will seek to establish further back up agreements with other water supplies on Zealand.

In regards to water quality, it is aimed that only 2% of all analyses conducted shows values exceeding the national guideline values, which for bacteriological analyses is no tolerance. Bacteriologic analyses are by far the most commonly conducted analysis. HOFOR has been part in introducing a new Danish developed technique, BactiQuant, which provides results within half an hour instead of 2 days, as for the traditional methods. Presently HOFOR is testing online monitoring of water quality at selected locations on the distribution net in parallel with traditional conducted analysis.

HOFOR is investigating the option of installing UV treatment at certain vital locations, to secure the quality of the drinking water. However, this will not imply a reduction in the frequency of water quality analysis.

Aiming to reduce the hardness of the water, is HOFOR in the process of achieving permits for establishing water softening by the method "lime softening". One of the minor water works will be selected for pilot testing in one to one. Softening of the water will reduce the water hardness from more than 20 dH till 10 dH. This will prolong the lifetime of various equipment in private homes as well as in the industry, reduces the need for soap for washing clothes and reduces the need for chemicals when cleaning.

Copenhagen is an old city, and still expanding. Large areas of the harbor front have become vacant and a new neighborhood, Nordhavnen, is going to be established, housing 40.000 people and as many jobs. The vision for Nordhavnen is to build a CO2 friendly neighborhood, and as the supply infrastructure will be established from scratch, this enables the choice of environmentally innovative solutions, making Nordhavnen a showcase of reuse water supply concepts.

# Process

1859: Establishment of the first municipal water treatment plant. The plant produced 2.5 mio. m<sup>3</sup>/year serving a population of approximately 155.000. The individual water consumption was 46 l/p/d. The water source was a mixture of surface water from surrounding lakes and groundwater.

1964: All 7 larger regional waterworks and well fields are established. The total annual water production was approximately 77 mio. m<sup>3</sup>.

1987: Household water consumption starts declining from 170 l/p/day.

1999: Mandatory metering of water consumption in all buildings.

1999: The water utilities would have to pay a fee for any undocumented loss of water above 10 % of the water delivered from the waterworks.

2005: The water supply for Copenhagen is separated from the city and turned into a company. However all stocks being owned by the City of Copenhagen.

2009: The water sector law was introduced. The main topic in the law is a requirement for water utilities to change from being a public owned to be privatized under the supervision of the public authorities

2012. Total water production is down to approximately 50 mio. m<sup>3</sup>/year, servicing 1 mio. people in the City of Copenhagen and 17 municipalities in Greater Copenhagen area. Individual household consumption has been reduced to 105 l/p/d.

2012: The water supply of Copenhagen merges with 7 other water supplies around Copenhagen.

# Sustainability

The water supply in Denmark is based on pure groundwater, and it is by regulation prevented, that any severe mining of the groundwater resources can take place. This requires that all parties involved cooperate on maintaining a sustainable water supply.

## Environmental

The EU Water Framework Directive is implemented in Denmark. This affects the manner in which well fields are managed. The interaction between surface water and groundwater is monitored and requirements are given to the water utilities to ensure that sufficient water runs in streams and rivers despite an impact from groundwater abstraction.

Bottled water is significantly less consumed in Denmark than in most other European countries. In 2011 the average consumption of bottled water in Denmark was 23 liters while for the EU in general it was 104 liters. If the citizens of Copenhagen consumed as much bottled water as the average person in Europe, and assuming that the water is sold in one liter containers, Copenhagen would be left with an additional 45,000,000 plastic bottles a year.

## Social

The City of Copenhagen follows and incorporates the public opinion among the citizens about all issues related to the life in the City. This is for example expressed in regularly conducted surveys among citizens.

Surveys among the citizens of Copenhagen regarding environmental challenges show that securing a reliable provision of drinking water is rated second after air pollution. The surveys, which are conducted once a year, support the efforts the City of Copenhagen conducts in regards to maintaining sufficient high quality groundwater. The surveys also support the continued effort made in reducing the water consumption among both citizens, public institutions of the City of Copenhagen and companies.

## Economic

When business opportunities are being investigated, a reliable infrastructure becomes a key parameter. The water supply in Copenhagen is reliable; companies can trust that there will always be safe and high quality water available.

# How to get started

Copenhagen would like to share knowledge. Depending of the nature of the topic you would like to know more about, you can contact us or our partners.

**City of Copenhagen:** Regarding over all water supply planning and surveillance of water utilities.

**HOFOR:** Regarding issues about reduction in water consumption, surveillance of water quality, and management of well fields and water works as well as frameworks to reduce water leakage in the distribution system.

**Ministry of Environment:** Regarding programs concerning groundwater protection and legal framework regarding water utilities.

## Contacts:

### Copenhagen Cleantech Cluster

Mail: [info@cphcleantech.com](mailto:info@cphcleantech.com)

Web: [www.cphcleantech.com](http://www.cphcleantech.com)

### City of Copenhagen

Mail: [copenhagensolutions@okf.kk.dk](mailto:copenhagensolutions@okf.kk.dk)

Web: [www.kk.dk](http://www.kk.dk)

### HOFOR

Mail: [hofor@hofor.dk](mailto:hofor@hofor.dk)

Web: [www.hofor.dk](http://www.hofor.dk)

### Ministry of Environment

Mail: [nst@nst.dk](mailto:nst@nst.dk)

Web: [www.naturstyrelsen.dk](http://www.naturstyrelsen.dk)