Copenhagen
Carbon Neutral
by 2025

CLIMATE CAPITAL
COPENHAGEN

COPENHAGEN: FOR SUSTAINABLE CITIES

ARUP

The former fish market in the South Harbour is transformed into a Dutch inspired canal town / Credit: Rishi, Happy Living

COPENHAGEN: SOLUTIONS FOR SUSTAINABLE CITIES

This catalogue details eight sustainable city solutions from Copenhagen. In developing these solutions we were inspired by other cities around the world. We hope that the lessons we learnt will, in return, be of inspiration to you and your city.

Cover image: Harbourfront housing / Credit: Rishi, Happy Living

Lord Mayor Frank Jensen / Credit: Jacob Carlsen

« AN **INTRODUCTION** »

SUSTAINABILITY IS NO LONGER A CHOICE FOR MOST SOCIETIES: IT'S A MUST. ESPECIALLY IN OUR CITIES. HERE WE MUST ALL STRIVE TO BALANCE THE QUALITY OF PEOPLE'S LIVES WITH SOUND ECONOMIC AND ENVIRONMENTAL DEVELOPMENT.

It was thought that environmentally friendly development would limit economic growth. However, quite the reverse turns out to be true. Green growth can, indeed, boost economic development and the quality of life.

It's not just about green products and services, it also concerns the more efficient use of our limited resources. This in the long run is the only road to continued growth.

Cities, in particular, play an important role in securing sustainable development. More than half of the world's population now lives in cities. In fact, cities are responsible for most of the world's GDP and for about 75% of Co_2 emissions. Sustainable societies must therefore start with sustainable cities.

However, the business of introducing sustainability into the city poses very different issues than affecting it in the country as a whole. The patterns of production and consumption, growth and employment, as well as social patterns are often very different and require city specific solutions.

In our bid to introduce more sustainability into our city, Copenhagen has looked for smart and effective solutions in other cities. We hope that in return, many cities can be inspired by the lessons we have learned.

To advance the quest for greater more sustainable cities, we have explained some of our best solutions in this catalogue. We hope you enjoy reading these case studies and gain some useful information from them.

Here's to a shared and sustainable future!

FRANK JENSEN
Lord Mayor of
Copenhagen

HARBOUR TURNS BLUE

Summer life at one of Copenhagen's three Harbour Baths / Credit: Kontraframe

THE HARBOUR TURNS BLUE

« THE IDEA OF SWIMMING IN COPENHAGEN'S HARBOUR WOULD HAVE BEEN OUT OF THE QUESTION AT ONE TIME. THE WATER WAS BADLY POLLUTED FROM THE CITY'S OLD SEWAGE SYSTEM AND LOCAL INDUSTRY. THE WHOLE AREA WAS ALSO BECOMING INCREASINGLY NEGLECTED AND RUN DOWN.

WE ADDRESSED THE PROBLEM BY **INVESTING** IN THE **COMPLETE MODERNISATION** OF THE SEWAGE SYSTEM. THE WATER QUALITY IMPROVED SO MUCH, THE MUNICIPALITY OF COPENHAGEN WAS ABLE TO OPEN A **PUBLIC HARBOUR BATH** IN 2002, WHICH HAS CONTRIBUTED SIGNIFICANTLY TO THE **REVITALISATION** OF THE CITY CENTRE AREA. »

THE HARBOUR'S SEWAGE PROBLEM//

- Discharge of wastewater from sewers and industrial companies was having a major impact on water quality
- Storm water run-off entered the sewage system and 93 overflow channels fed the wastewater into the harbour.
- De-industrialisation had left Copenhagen Harbour a run down and under-utilised part of the city centre.
- Copenhagen's sewage system was in need of modernisation.

THE SOLUTION - A BLUE TRANSFORMATION//

THE HARBOUR WAS TRANSFORMED INTO A BLUE PUBLIC SPACE BY:

- MODERNISING THE SEWAGE SYSTEM
- ADOPTING A CLEANING PROGRAMME
- DIVERTING LOCAL RAINWATER
- COMMISSIONING A STRONG URBAN DESIGN TO CREATE A CITY CENTRE BLUE RECREATION SPACE.

OUR SOLUTION IN DETAIL//

MODERNISING THE SEWAGE SYSTEM –

- Rainwater reservoirs with connecting conduits were constructed which can store wastewater until there's space again in the sewage system.
- Physical, biological and chemical cleaning, gasification of sludge and incineration processes remove nutrient salts and minimise discharge of heavy metals.
- 55 overflow channels were closed and wastewater is only discharged to the harbour during particularly heavy rainfall.

DIVERT LOCAL RAINWATER –

A pro-active system of localised water channels deal with rainwater locally, diverting it during heavy rain. The rain and wastewater is then stored locally and more slowly released into the sewer when capacity allows it.

CREATION OF CITY CENTRE BLUE RECREATION SPACE –

Public Harbour baths were opened in the Islands Brygge area of the harbour in 2002. Two further bathing facilities have been opened since, including a new harbour beach, with a fourth facility being added in 2011.

DEVELOPMENT OF AN INNOVATIVE AUTOMATIC WARNING SYSTEM –

This calculates and monitors the bacteria level in the harbour and identifies whether it's safe to swim. An on-line forecast is available on the city's website and to city residents as an app on iPhones/Android phones.

PLANNING REGULATION –

- New developments must use separate systems for rainwater and stormwater. The utility provider also operates a reimbursement scheme, wherein a landowner connecting to the sewer system is repaid a connection charge if the rainwater is derived locally.

- In new urban districts a three-tiered sewage system is established. One tier for roof water, one for road water and one for black waste water. The system has already proved very effective against flooding.

GOOD URBAN DESIGN – Urban design is fully integrated into the wastewater management system from considering storage tank design to green roofs and pavements.

ROBUST AND INTEGRATED MANAGEMENT STRUCTURE –

Collaboration between partners, including researchers, academics, architects, planners, engineers, municipality and private sector organizations led to the creative solution of a beach park and harbour bath, though the initial goal was only to improve the sewage system.

LONG TERM THINKING –

The first Wastewater Management Plan was formulated in 1976. Following on from this, the public baths project was initiated in 2001. The gradual but significant improvement of water quality in the harbour has been the result of a long-term approach.

THE BENEFITS OF OUR CLEAN HARBOUR//

ECONOMIC

- The revitalisation of the harbour areas has led to business and market regeneration.
- Local increase in property prices
- Improved potential for investment: there's now plans for much improved local transport to the Harbour Bath and beach park
- Job creation
- Increased liveability means that more families stay in the city contributing to a positive economic growth.

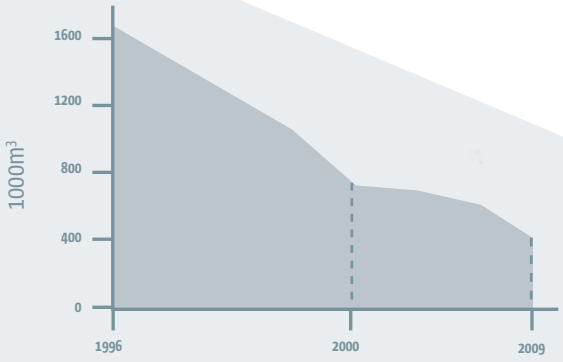
SOCIAL

- Residents and others can swim, sail and fish in the harbour waters at the heart of their city.
- Almost every resident now lives less than 10 minutes by foot to a green or blue recreation space or park.
- The baths have given residents a sense of pride, loyalty and ownership in the locality
- The Harbour development has enabled the wider regeneration of a badly run-down area and turned it into the most popular summer spot in the city.
- The Harbour baths are increasingly seen as an iconic landmark and so have raised the international standing and tourist attraction of the city.

Effect on real estate prices from transforming harbour areas from industry to residential.

ENVIRONMENTAL

- Reduced risk of urban flooding polluting the harbour through better stormwater management
- More and diverse flora and fauna is returning to the area.
- The water quality in the harbour continues to improve year after year
- Green roofs also relieve urban heat stress and improve insulation of buildings, and so help us to reach our carbon reduction targets.
- Residents used to drive 10km to a beach, now they can walk or cycle to the Harbour Baths.



Sewage and rain water discharged into the Port of Copenhagen

TURNING THE TIDE IN YOUR HARBOUR//

What sort of circumstances might other cities be facing that would make Copenhagen's experience of the harbour project relevant?

- A partly or fully de-industrialised harbour
- A sewage system in need of upgrade
- A climate that enables outdoor swimming a possibility.

Swimming 5 minutes away from the central city / Credit: Casper Dalhoff, BIG+JDS

MEETING THE RISING DEMAND FOR WATER

Green roofs on domestic buildings are an important part of climate adaptation / Credit: Gitte Lotinga

MEETING THE RISING DEMAND FOR WATER

« AS COPENHAGEN HAS GROWN, THE CITY FACES THE VERY REAL **RISK OF DEMAND FOR WATER OUTSTRIPPING GROUNDWATER SUPPLY**. FURTHERMORE, FLASH FLOODING IS A GROWING RISK DUE TO CLIMATE CHANGE. BUT BY ADOPTING **INNOVATIVE TECHNOLOGIES** AND POLICIES IT HAS BEEN POSSIBLE TO PROTECT THE GROUNDWATER RESOURCES AND **LIMIT LOSSES** FROM THE DRINKING WATER SUPPLY. »

CHALLENGE//

The main challenge is to maintain a high drinking water quality in the future based on ground water. Due to a lack of water sources within Copenhagen and local pesticide contamination of water sources immediately around the city, water has to be piped in over long distances. The city also faces rising groundwater levels, leakage of treated water from the water supply pipeline network and a low uptake of grey water use and re-use.

THE SOLUTION//

A COMBINATION OF SOLUTIONS HAS PROVED SUCCESSFUL, INCLUDING THE USE OF NEW TECHNOLOGIES TO MONITOR AND PREVENT LEAKS; PRICING MECHANISMS TO REDUCE WASTEFUL CONSUMPTION; AND ENGINEERING SOLUTIONS TO REDUCE OVERALL WATER DEMAND TO MANAGEABLE LEVELS AND BETTER MANAGEMENT OF STORMWATER.

OUR SOLUTION IN MORE DETAIL//

- **Created an evidence base:** detailed mapping of sediments below city, construction of models of a hydrological cycle around the city, and a detailed groundwater model and 3D mapping down to depths of 300m have enabled better management of water resources.

- **Used Information Technology to reduce waste:** A new SMART system management allows better regulation of water pressure.

- **Increased water efficiency –** an investment in the minimisation of water loss in the city's infrastructure through leak detection technology, regulation of water pressure and other mitigation measures. Water losses in pipelines are as high as 40 to 50% in some cities, whereas the figure for Copenhagen is now nearer 6 to 7%.

- **Managed rainwater more efficiently:** rainwater run-off is stored locally and more slowly let into the sewers when capacity allows it. Four types of system are employed:

  - EVAPORATION: e.g. green roofs,

  - RECYCLING: water storage and local reuse for garden watering, clothes washing, toilet flushing

  - PERCOLATION: slow seepage into ground e.g. permeable paving

  - DELAY: Balancing ponds, paved areas that store water and move it around before discharging into sewage system.

  - PURIFICATION: A variety of filtration and separation methods, e.g. sand trap and basins, oil separators, filters and advanced treatment.

- **Separate systems** for rainwater and rainwater runoff / storm water are required to be integrated into all new developments.

- **Financial incentives:** encourage businesses and citizens to reduce run-off into the city foul sewer network with up to 3,000 Euros available to residents for collecting and reusing rainwater, and consumer charges of 5 euros per cubic metre of water to reduce wasteful use of drinking water.

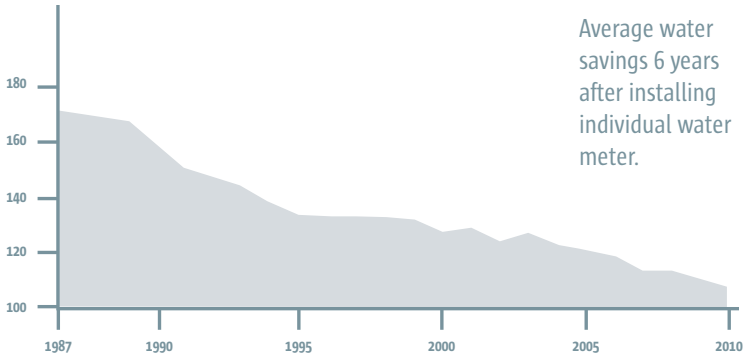
- **Awareness raising campaigns:** reduce individual consumption, with a target to cut consumption per capita from 110 litres per day to 100 litres per day. (From a high of 170 litres/day/person in 1987).

100

Target number of litres of water used per day, per Copenhagen citizen.

26%

Average water savings 6 years after installing individual water meter.



Water consumption in Copenhagen 1987-2010, litres/person/day

THE BENEFITS OF INNOVATION//

- ENVIRONMENTAL: water losses reduced to 6 to 7%; energy consumption from water services reduced and long-term need for energy intensive solutions like desalination avoided; no chemical treatment of drinking water, and a low demand for bottled water.

- SOCIAL: new recreational areas created from diversion of stormwater; strong engagement with citizens to take individual action in the best interest of the city as a whole.

- ECONOMIC: reduced long term costs through:
  - Lower energy use,
  - Less frequent need to fully replace existing pipe network
  - Better monitoring and repair
  - Lower risk of rainwater flooding

  local businesses achieve reduced production costs through greater water efficiency.

SAVING EVERY DROP IN YOUR CITY//

What sort of circumstances might other cities be facing that would make Copenhagen's experience of saving the city's water relevant?

- Shortage of clean water supplies
- High level of water loss from potable water system
- Risk of rainwater flooding.

One of the many joys of water / Credit: Thorkild Christensen

CYCLING: THE FAST WAY FORWARD

The fastest way of getting around in Copenhagen is by bike / Credit: Mikal Schlosser

CYCLING: THE FAST WAY FORWARD

« CYCLING HAS ALWAYS BEEN A DANISH TRADITION, BUT COPENHAGEN HAS GONE ONE STEP FURTHER AND MADE CYCLING **INTEGRAL TO URBAN PLANNING AND DESIGN**. IN FACT, IT HAS A TARGET TO INCREASE CYCLING'S 'TRAFFIC MODAL SHARE TO WORK AND EDUCATION' FROM **36% IN 2007 TO 50% BY 2015**. AS A RESULT, DESPITE DANES ENJOYING SOME OF THE HIGHEST AVERAGE LEVELS OF WEALTH IN THE WORLD, THE MAJORITY CHOOSE **LOW-EXPENSE, BUT QUICK AND CONVENIENT CYCLING**, AS THEIR PREFERRED WAY OF GETTING AROUND. »

TWO WHEELS VERSUS FOUR - THE CHALLENGE//

While Copenhagen is largely flat and enjoys a relatively dense, compact design, the climate is not necessarily the best for cycling. Winter temperatures fall as low as -15°C and there's a high annual rainfall approximately 600 mm.

The first bike lane was constructed as early as 1896 (the controversy then was that bike lanes conflicted with road space for horses!) but by the early 1980s transport infrastructure did not make cycling a priority and growing car usage threatened to deter bike users. The first integrated cycling lane plan was written in the early 1980s and has been developed ever since. Recent research continues to identify key target groups who could be converted to cycling/cycling more often, if cycling were made:

- MORE CONVENIENT
- FASTER
- SAFER

PEDAL POWER - OUR SOLUTION//

CYCLING INFRASTRUCTURE WAS MADE CENTRAL TO OUR URBAN PLANNING AND DESIGN AND WE INVESTED HEAVILY IN DEDICATED, UNINTERRUPTED CYCLE LANES AND EASY TRANSFER TO PUBLIC TRANSPORT SERVICES.

OUR SOLUTION IN MORE DETAIL//

- New designated cycle lanes were introduced along existing roads to separate cyclists from other road users and so maximise safety. By 2010 there were 369km of cycle lanes including two dedicated cycle bridges, providing safe pathways along desired routes into the centre of the city.
- Obstacles were removed from existing cycle lanes and routes were made more direct to key destinations, to reduce travel time.
- 'Greenwaves' prioritise cycles along the primary routes, so that cycles travelling at 20km/hr can travel non-stop into the city.

20 KM/H

Top speed in Copenhagen Greenwaves

109,586 TONNES

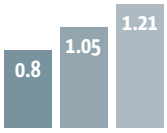
1995 - 2010
reduction in Co_2
emissions.

- To add convenience, bikes were integrated into the wider transport network, so passengers could easily transfer between cycling and public transport. Carriages on trains were upgraded to accommodate cycles, including travel at peak times.
- 42km of 'Greenways' were installed in suburban areas to provide safer, more direct neighbourhood routes away from main roads and through parks and recreational spaces.
- Cycle lane bike counters reinforce messages that cyclists matter and simultaneously provide real-time data to municipalities.
- A 'Cycling Embassy' teaches safe cycling to children who take this learning from the classroom to the city streets.
- Public information and traffic systems are used to make car, lorry and van drivers more aware of cyclists and reduce collisions.
- A new type of family bicycle has been developed to carry children safely along with a new public city bike that has been developed which is free of charge for locals and tourists.

GET YOUR CITY ON ITS BIKE//

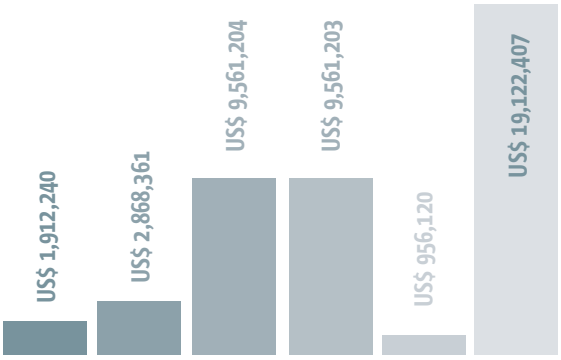
What sort of circumstances might other cities be facing that would make Copenhagen's experience of cycling relevant?

- Ability to control strategic road planning and determine which mode (cycle / bus / car) should have priority along key city routes.
- Compact, dense city design so that cycle commuting is within most people's range.
- Good weather is not necessary – Copenhagen's winters are very cold!



1995
2000
2009

Distance traveled each day in Copenhagen by bicycle, mio. km.



Air Pollution
Climate change
Noise
Accidents
Infrastructure wear
Congestion

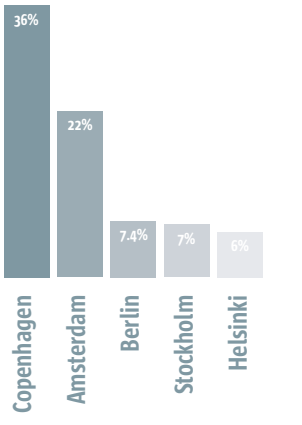
Estimated avoided external costs (US$) of shift from vehicle to bicycle. Data from City of Copenhagen accumulated 1995-2010.

43,025,607 US$

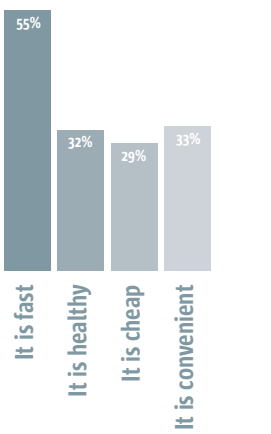
Total avoided external costs.

THE BENEFITS OF A CITY THAT CYCLES//

- ENVIRONMENTAL: reduced noise, air pollution and Co_2 emissions (90,000 tonne reduction annually).
- SOCIAL: healthier citizens reduce health care costs at an estimated rate of US$1 per km cycled.
  - 88% of people cycle because it is the fastest and most convenient way to get to work
- ECONOMIC: Cycling provides a low-cost form of transport and by reducing journey times and congestion, increases economic productivity.



Proportion of journeys to work by bicycle in European capitals.



Why people choose to bike in Copenhagen.

More than half of the people living in Copenhagen use their bike every day / Credit: Troels Heien, Monoline

TRANSPORT: THE GREEN LIGHT

The Copenhagen Metro has been awarded best in the world / Credit: Jakob Boserup

GIVING INTEGRATED PUBLIC TRANSPORT THE GREEN LIGHT

« LIKE MANY OTHER CITIES, ECONOMIC GROWTH IN COPENHAGEN HAS BROUGHT WITH IT INCREASED TRAFFIC CONGESTION. HOWEVER, BY INVESTING IN AN **EFFICIENT, RELIABLE AND HIGHLY INTEGRATED** PUBLIC TRANSPORT NETWORK, IT HAS BEEN POSSIBLE TO DELIVER SOME OF THE **HIGHEST LEVELS OF MOBILITY IN THE WORLD.** ALONGSIDE TRAFFIC, CONGESTION AND POLLUTION HAVE BEEN REDUCED TO LEVELS THAT ARE **EXTREMELY LOW** BY THE STANDARDS OF MAJOR INTERNATIONAL CITIES. THE NUMBER OF CAR TRIPS WITHIN THE CENTRAL PART OF COPENHAGEN FELL FROM 351,000 IN 1970 TO 284,900 IN 2010. »

THE CHALLENGE OF THE CAR//

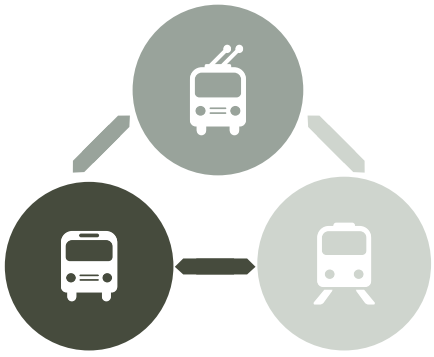
Without a decent alternative, people who can afford a car will drive it. Between 1970 and 2010 the number of daily car trips across the municipality border rose from 392,000 to 535,700 and across the whole of Denmark there has been an increase in cars from 408,000 to 2 million between 1961 and 2010. The Co_2 emissions from road transport rose along with the increased traffic to around 500,000 tonnes in 2005. Without concerted action Copenhagen could have faced the traffic congestion and pollution problems that have blighted many other cities.

Attempts to convince people to use public transport were hindered by:

- A massive improvement in travel time for car-traffic due to investments in road-infrastructure
- Unreliable and inconvenient public transport due to lack of investments in infrastructure
- Relocating work places away from the inner city to rural and suburban areas - often far from train stations and with high accessibility for cars
- Lack of integration between transport systems and operators
- Inflexibility of funding mechanisms to create new services

INTEGRATION - OUR SOLUTION//

OUR SOLUTION WAS TO DEVELOP PHYSICAL AND VIRTUAL (INFORMATION TECHNOLOGY) INTEGRATION BETWEEN BUS, TRAIN AND THE METRO SERVICES TO ENABLE PASSENGERS TO MOVE SEAMLESSLY BETWEEN DIFFERENT MODES.



An integrated transport system between bus, train & metro.

OUR SOLUTION IN MORE DETAIL//

- Integrated ticketing: one ticket is valid on bus, train and metro across all 3 public transport operators. Transfer between each mode is free.

- SMS ticketing: novel use of information technology enables passengers to simply text where they are and where they're going to, and receive a text reply which serves as their travel ticket. This speeds up journey times, reduces queuing and cuts operational costs. 60% of tickets for one journey are now bought by SMS and it is expected that paper based tickets will be entirely replaced within a few years.

- The formation of a special purpose company uniting the train, Metro, bus and telephone companies has enabled SMS to be easily adopted by customers, as fares are paid through telephone bills.

- Development of an online Journey Planner - an easy way to plan your journey from A to B across all the different transport modes.

- Bus stops are integrated into Metro stops and other public transport facilities to enable easy transfers.

- Bus priority signaling systems: using radio and GPS technology enables traffic controllers to keep lights green if buses are approaching and have brought improved accessibility and speed for buses.

- Fully integrated Real Time Information is provided to the public by traffic control, which can be viewed online or from mobile devices.

- Legislation was introduced to stop competitive public transport operators charging different prices.

- Significant cycle parking facilities have been introduced in each metro and train station and cycles are permitted to be taken on the trains themselves.

THE BENEFITS OF INTEGRATED TRANSPORT//

- ENVIRONMENTAL: by improving the integration of the system there has been an increase in the proportion of total trips made by public transport and a fall in private car usage. For every person using the Metro instead of travelling alone by car, carbon dioxide emissions drop by 83%.

- SOCIAL: the ability to change more easily between modes, and for cycling to be better adapted with the public transport system has enabled faster, safer, healthier and less stressful journeys. People use public transport and cycling because it is the fastest, cheapest and most convenient way to travel, contributing to Copenhagen's reputation as one of the most livable cities in the world.

- ECONOMIC: a successful integrated public transport system and reduced congestion make Copenhagen a good place to do business, with fast and reliable journey times for both passengers and freight.

INTEGRATED TRANSPORT IN YOUR CITY//

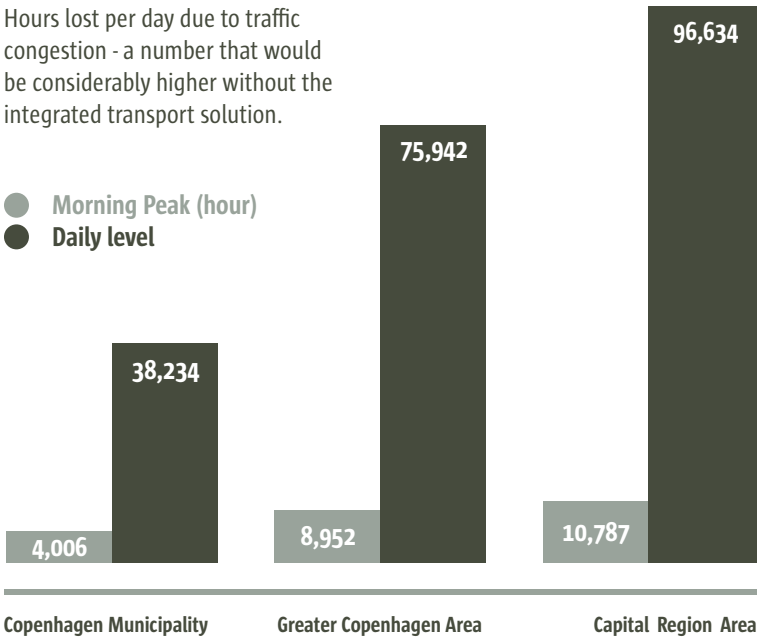
What sort of circumstances might other cities be facing that would make Copenhagen's experience of integrated transport relevant?

- High demand for travel
- Concern about traffic congestion
- Multiple public transport operators
- Mayoral ownership and/or strong regulatory control of key transport systems to enable their development

60%

The percentage of people paying for public transport in the city by SMS.

Hours lost per day due to traffic congestion - a number that would be considerably higher without the integrated transport solution.



Metro, train and bus meet at Flintholm Station / Credit: Metroselskabet/Lene Bente Skytthe

MAKING THE MOST OF WASTE

« BY PUTTING IN PLACE AN INTEGRATED PROGRAMME OVER MANY YEARS, COPENHAGEN NOW SENDS **LESS THAN 2%** OF WASTE TO LANDFILL. HALF OF THE WASTE IS RECYCLED AND MAXIMUM USE IS MADE OF WASTE TO GENERATE HEAT FOR THE CITY'S DISTRICT HEATING NETWORK. »

One bag of garbage provides 3.5 hours of electricity and 4 hours of heating for a household / Credit: Amagerforbrændingen

THE WASTE CHALLENGE//

Our waste management problems used to be similar to those of most other major cities:

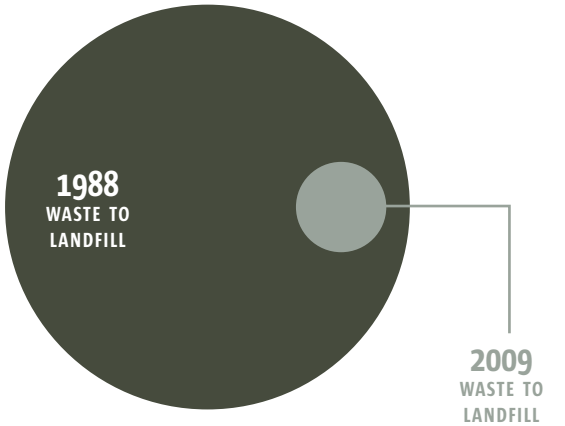
- In 1988, over 40% of the city's waste was sent to landfill.
- There was concern that incinerating waste within the city boundaries would create dangerous air pollution.

AN INTEGRATED SOLUTION//

OUR REMEDY UTILISED NATIONAL REGULATIONS TO BUILD AN INTEGRATED SOLUTION: A SUITE OF STRATEGIES, POLICIES AND INVESTMENTS THAT:

- INCREASE DIVERSION OF RESIDUAL WASTE FROM LANDFILL TOWARDS CO-PRODUCING HEAT AND POWER BASED ON INCINERATION
- IMPROVE RECYCLING SEPARATION

PROOF OF OUR SUCCESS//



In 2009 we sent only 1.8% of 827,000 tonnes of waste to landfill — 20 times less than in 1988.

OUR SOLUTION IN MORE DETAIL//

- Treating waste as a resource
  - setting a fixed price for recyclables collection
  - volume based charges for residual waste
  - experimentation with collection of plastic at a household level.
- National regulation means that waste sent to landfill incurs a tax of US$10/tonne, while waste sent to incineration incurs a tax of US$8.50/tonne.
- It is now illegal in Denmark to send combustible waste to landfill, when it could be incinerated.
- Focusing on changing public attitudes by supplying information on recycling and linking waste and climate change.
- Improving possibilities for reuse and recycling including easy and logical source separation
- Ensuring the generation of heat from waste is a central energy supply to the city's district heating scheme.
- A pilot plant for the treatment of 800kg/hour of unsorted household waste has been developed as part of the REnescience project. The plant was commissioned in December 2009 and separates the organic and inorganic fractions in the form of biogas or bioethanol. These bio fuels can be used for the production of power and heat in accordance with market demand. Metals and glass are separated from the inorganic fraction of the waste for recycling. REnescience is a cooperation between Dong Energy and the local waste incineration plant Amagerforbrænding.
- Maturing and upscaling of the REnescience technology, including design, construction and operation of larger waste refineries is being planned.
- A suggested liberalisation will set pricing free and introduce competition for waste.

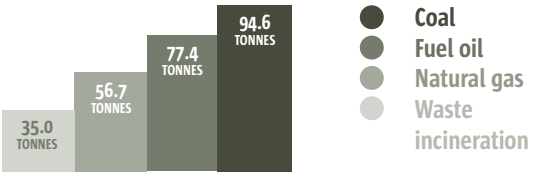
THE BENEFITS OF AN INTEGRATED WASTE MANAGEMENT APPROACH//

- ENVIRONMENTAL: Reduced Co_2 emissions through:
  - improved reuse and recycling
  - combined heat and power generation feeding the district heating network
  - centrally located waste facilities
  - advanced organic waste treatment.
- SOCIAL: The public now perceives waste as a resource to provide heat and power to homes and businesses and so they comply with the waste management system to process their waste in the most efficient and practical manner.
- ECONOMIC: waste is now treated as a resource, avoiding millions of euros of landfill taxes from the European Union, providing energy security and suppressing a rise in residential and business energy bills at a time of rising fossil fuel prices.

RECYCLING WASTE IN YOUR CITY//

What sort of circumstances might other cities be facing that would make Copenhagen's experience of recycling waste relevant?

- Significant waste volumes
- The ability to regulate or influence some or all parts of the waste management system: collection, separation, or treatment
- Capacity, or potential capacity, to use heat or electricity generated from waste.



Co_2 emissions from energy production, tonnes Co_2/GJ

THE FORCE OF PUBLIC SUPPORT FOR WIND POWER

« DESPITE UNEXCEPTIONAL WIND RESOURCES, **22% OF DENMARK'S TOTAL ELECTRICAL CONSUMPTION IS PRODUCED FROM WIND TURBINES,** THE HIGHEST RATE IN THE WORLD*. IN COPENHAGEN A **RENEWABLE ENERGY INFRASTRUCTURE** HAS BEEN INTRODUCED THROUGH A UNIQUE PARTNERSHIP BASED ON LOCAL OWNERSHIP. »

*BASED ON 2005 FIGURES.

The Copenhagen wind turbines at Middelgrunden are owned by citizens / Credit: Rishi, Happy Living

THE FORCE OF PUBLIC SUPPORT FOR WIND POWER

THE CHALLENGES TO WIND//

Like every city, Copenhagen faces challenges to wind power:

- Limited space to implement wind energy on a large scale within an urban environment.
- Wind turbines are expensive to build.
- Public resistance to the perceived visual and noise impact of wind turbines in the landscape.

18 HOURS

The time taken to construct two wind turbines.

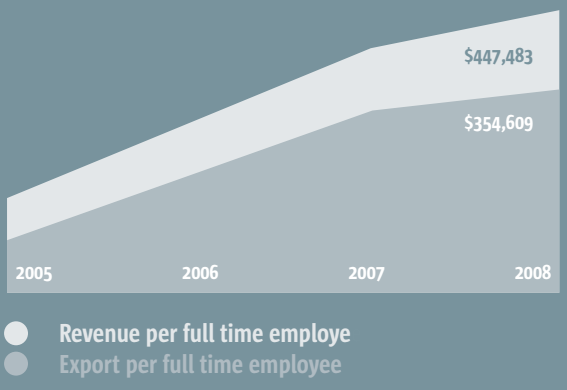
THE SOLUTION - LOCAL OWNERSHIP//

OUR SOLUTION WAS TO ENCOURAGE POPULAR SUPPORT FOR WIND-POWER BY CREATING A COMMUNITY-OWNED FACILITY, AND USING LOCAL SKILLS.

OUR SOLUTION IN DETAIL//

- COMMUNITY OWNERSHIP – the first wind farm at Middelgrunden, created a Wind Turbine Cooperative half-owned by the city owned utility company, with half the shares sold to 8,650 members of the local community. Each of the shares represents production of 1000 kWh/year and was sold for 4,250 DKK (US$809).
- PUBLIC AWARENESS CAMPAIGN – demonstration tours of on-shore wind turbines helped convince locals that there would be no noise impact from the project.
- HIGHLY EFFICIENT TECHNICAL CONSTRUCTION – specially designed foundations were developed to cope with the ice during severe winters. Optimisation of factors such as tidal movements, wave resistance, ice loads, fatigue strength and robust submarine cables were also incorporated.
- GRID REINFORCEMENT – the ability of the power grid to accept and balance increased levels of intermittent energy from wind turbines.
- LESSONS LEARNED from each successful wind farm are used to inform subsequent schemes, highlighting how replicable the model is.
- NATIONALLY SET TARGETS – the Danish Government set an aim to turn 50% of Danish electricity production into wind power by 2030, such targets drive renewable energy innovation.

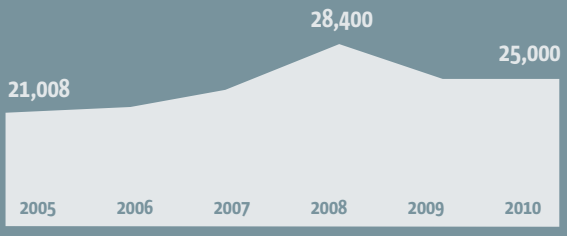
- Based on the Copenhagen Climate Plan, the city owned utility company plans to build more than 100 new wind turbines before 2025. Locally based cooperatives will be able to invest in the turbines.
- The main part of the new turbines will be based outside Copenhagen, either land based or sea based. However, a decision to build some of the turbines in Copenhagen has been politically approved.
- A recent survey among the citizens of Copenhagen indicates wide spread popular support for wind turbines in the city.



Revenue and export of the windmill-sector (US$)

THE BENEFITS OF WIND POWER//

- ENVIRONMENTAL: Significant contribution to achieving carbon reduction goals: for example, energy production at the Middelgrunden wind farm is estimated to be 89 million kWh of electricity annually. The project eliminates 258 tonnes of sulphur dioxide emissions, 231 tonnes of nitrogen oxide emissions, 76,000 tonnes of carbon dioxide emissions and 4,900 tonnes of dust and clink every year.
- SOCIAL: Community engagement in delivery of climate change objectives. Jobs were created. The wind industry employs more than 25,000 people in Denmark.
- ECONOMIC:
  – The City of Copenhagen made a profit out of the sale of its' first successful wind farm. Revenue has now been recycled back into city projects.
  – Green Economy – through creating strong local demand, the Danish wind turbine industry has grown into a multi-billion dollar industry, achieving growth rates of over 30% per year, with over 350 companies producing turbine towers, blades, generators, gear boxes and control systems. Almost half the world's wind turbines are now produced by Danish manufacturers.
  – Low running costs – Wind turbines have low running costs following initial investment and expenditure.



Employment in the windmill sector

THE RIGHT CLIMATE FOR WIND//

What sort of circumstances might other cities be facing that would make Copenhagen's experience of community-owned wind power relevant?

- Average wind speeds of at least 5 metres per second – usually seen as the minimum for wind power to be commercially viable.
- Mayoral power to create or support a community-owned solution.

Below: Reduced Co_2 emissions and produced windmill energy in Copenhagen 2001-2010

332,862
TONNES

Reduced Co_2 emissions

3,503,811
GJ

Production of wind energy in Copenhagen

432,569
APARTMENTS

Number of apartments the electricity can power for one year

Wind turbines are an integrated part of the Copenhagen skyline / Credit: Rishi, Happy Living

KEEPING THE CITY WARM EFFICIENTLY

98 per cent of households are connected to the district heating grid/ Credit: Becky

KEEPING THE CITY WARM EFFICIENTLY

« OUR DISTRICT HEATING SYSTEM IS AMONG THE **WORLD'S LARGEST AND MOST SUCCESSFUL.** IT SUPPLIES **98%** OF THE CITY AND 500,000 INHABITANTS WITH RELIABLE AND AFFORDABLE HEATING. DISTRICT HEATING IS ONE OF THE MOST CARBON EFFICIENT WAYS TO PRODUCE AND SUPPLY ENERGY LOCALLY, CUTTING OUT MUCH OF THE WASTE ASSOCIATED WITH CENTRALIZED POWER GENERATION. BY INTEGRATING RENEWABLE FUELS SUCH AS BIOMASS TO REPLACE FOSSIL FUELS IN THE SYSTEM, **FURTHER EMISSIONS REDUCTIONS** HAVE BEEN ACHIEVED. »

THE CHALLENGE OF RISING ENERGY PRICES//

The district heating system was first established in the mid 1920s, but it was more intensively developed as a way to protect citizens and the economy from the dramatic rise in fossil fuel prices in the 1970s - a time when the city faced:

- Over dependency on increasingly scarce and expensive fossil fuels
- Air quality concerns caused by coal burning within a city environment
- Low efficiency of energy distribution in existing district heating network

OUR SOLUTION//

THE SOLUTION WAS TO REDUCE THE CITY'S RELIANCE ON FOSSIL FUELS BY MAXIMISING ENERGY GENERATED FROM WASTE.

Technologies such as Combined Heat and Power (CHP) to capture and re-use heat energy that is otherwise lost in the electricity generation process. Our district heating network distributes this heat energy efficiently around the city. The integration of renewable fuels, such as biomass, further reduces the carbon intensity of the network.

98%

The percentage of Copenhagen served by the District Heating System.

OUR SOLUTION IN DETAIL//

Development of a district heating system that uses heat generated from waste-to-energy plants; along with CHP technology, initially fuelled by coal, natural gas, and oil.

Step-by-Step expansion of the network – district heating does not necessarily require an overhaul of existing energy systems. It can be implemented over a significant period of time. A steam network was originally established to supply hospitals and industry, and once a steam pipe was established, offices, institution and dwelling houses nearby were also connected.

Regular rehabilitation of the system over time to maintain an efficient network and provide the best value to residential and business customers.

De-carbonising the district heating system:

- Renewable energy supply: The use of mixed fuel, such as natural gas, oil, straw and wood pellets in CHP units allows the highly efficient use of the energy in the fuels (up to 94%), and so results in lower carbon dioxide emissions. Biomass is planned to replace coal and provide 100% renewable energy from the CHP plants, one plant has been converted to 100% biomass and the conversion of 3 additional plants is planned.
- Developing technology to burn straw with optimum fire protection.
- The goal of the city is in the short term to convert all remaining coal-fired CHP to biomass.
- As a long term strategy the City of Copenhagen is now testing the use of geothermal energy in the district heating network.
- Nitrogen oxide, sulphur dioxide and fly ash are removed from the flue gases before being released into the atmosphere and used to produce high quality by-products such as gypsum, concrete blocks and insulating material.
- Optimise the operational efficiencies of the network, such as seasonal reductions to the temperature of the heat supply - low temperature district heating.

There are also plans to have biogas as an operational part of the town gas grid as a result of extracting gas from sludge waste water treatment processes.

THE BENEFITS OF DISTRICT HEATING//

ENVIRONMENTAL:

- The District Heating system achieves lower carbon dioxide emissions than the individual gas (40% lower) and oil (50% lower) boilers it replaced.
- Overall carbon dioxide emissions resulting from the consumption of heat and electricity have dropped from 3,460,000 tonnes in 1995 to 2,541,000 tonnes in 2005.
- Cogeneration of heat and electricity use approximately 30% less fuel to produce the same amount of heat and power in separate heat and power plants.
- Around 40% of the waste incinerated from the city is turned into electricity and heat. Combined with an extensive programme of waste management, prevention, separation and recycling, only 1.8% of waste in Copenhagen is deposited in landfills.
- Conversion to biomass fuelled district heating is further decarbonising the energy supply.

SOCIAL:

- 750 jobs were created in developing the grid infrastructure required for the district heating system.

ECONOMIC

- With high fuel efficiencies of up to 94% by simultaneously generating heat and power the power plants need much less fuel per kWh generated. In comparison, conventional power plants have an efficiency as low as 30-40%.
- District heating costs around 45% less than oil heating and approximately 56% less than natural gas for a home of 130m² and an average consumption of 18 MWh/year (based on 2009 figures). District heating is therefore considered price competitive for household consumers.
- District heating can be a competitive solution in new urban development areas, compared to alternatives like individual solar heating or individual heat pumps.

100%

Level of renewable energy now provided through biomass instead of coal at the Amager CHP plant.

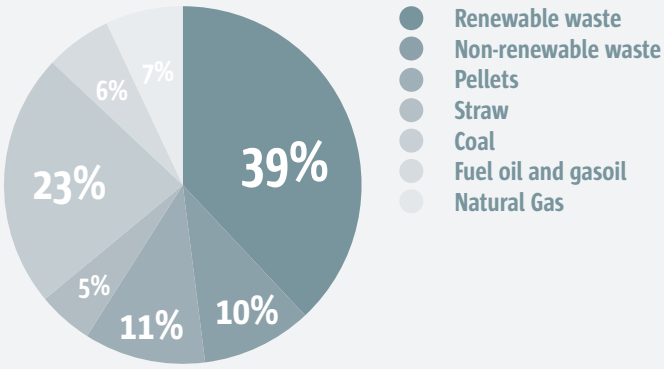
60,000 TONNES

Reduction of Co_2 emissions through waste incineration.

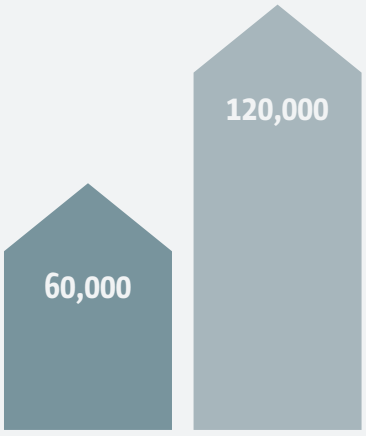
WHY SWITCH ONTO DISTRICT HEATING?//

What sort of circumstances might other cities be facing that would make Copenhagen's experience of district heating relevant?

- High heat demand in a concentrated area
- Ability to co-locate centralised (low carbon) generation capacity close to demand
- District heating network in need of modernization / optimisation, extension and / or decarbonisation.



Fuel sources for the district heating network



Supply of heat and electricity from the incineration of waste (number of households)

KEEPING COOL UNDER CO_2 PRESSURE

« THE INCREASED DEMAND FOR AIR CONDITIONING AND COOLING HAS LED TO HIGHER ELECTRICITY CONSUMPTION IN MANY CITIES. IN OUR EFFORT TO PROVIDE LOW CARBON COOLING, WE'VE BUILT THE **FIRST TWO DISTRICT COOLING NETWORKS.** THEY ARE BASED ON FREE COOLING FROM SEA WATER ABSTRACTION, ALONG WITH RUNNING SURPLUS HEAT FROM THE DISTRICT HEATING NETWORK, THROUGH ABSORPTION COOLING AND TRADITIONAL COMPRESSION CHILLERS. THE PROJECT IS EXPECTED TO **SAVE US 14,000 TONNES OF CARBON DIOXIDE PER YEAR.** »

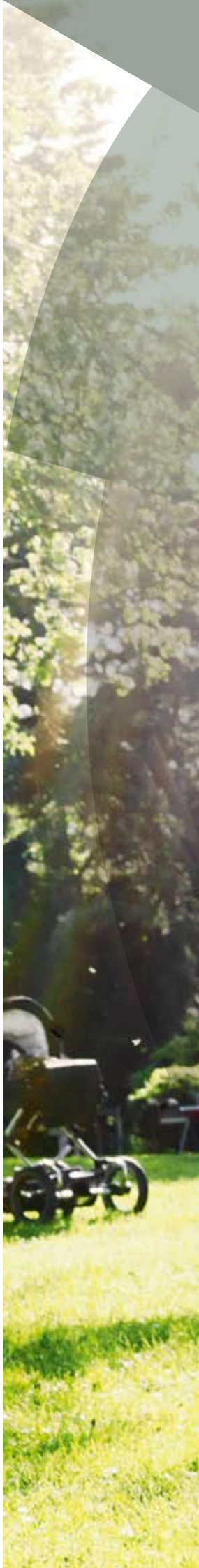
THE CHALLENGE WE FACED//

Peak summer temperatures in Copenhagen can hit as high as 35°C and are expected to rise by 2 to 3% by 2050 - with average daily temperatures also rising. And so the demand for traditional air conditioning is increasing. The problems are:

- Traditional air conditioning systems/compressor based chillers are expensive.
- Traditional cooling systems are noisy and utilise a lot of space.
- Dependency on electricity based cooling appliances could create unsustainable electricity demand and over reliance on fossil fuels.
- There is currently excess surplus heat within the district heating system during summer months when demand is low.

HOW WE MET THE CHALLENGE//

OUR SOLUTION WAS TO DEVELOP A 'DISTRICT COOLING' SYSTEM TO COMPLEMENT THE HIGHLY SUCCESSFUL DISTRICT HEATING SYSTEM. DISTRICT COOLING IS THE CENTRALISED PRODUCTION AND DISTRIBUTION OF CHILLED WATER. IT IS DISTRIBUTED VIA UNDERGROUND INSULATED PIPELINES TO COMMERCIAL AND INDUSTRIAL BUILDINGS TO COOL THE INDOOR AIR.



KEEPING COOL UNDER CO_2 PRESSURE

Credit: Rishi, Happy Living

OUR SOLUTION IN MORE DETAIL//

- **Identification of co-located buildings** - with cooling requirements to ensure there was an adequate demand for a district cooling network.

- **Building a new cooling station** – with a capacity of 15MW and utilizing a combination of existing resources: seawater from the Port of Copenhagen in periods where the seawater is sufficiently cold, and surplus heat from the district heating network during periods of low heat demand.

- **Cooling: our solution** – the use of excess heat from the district heating system during the summer months (this also helps balance the district heating system)

- **Integration of different principles of cooling** – the plant was designed around three different methods of cooling making it very flexible and highly energy-efficient, depending on the temperature of the seawater:
  - Free Cooling – Seawater temperature is below 5.5 degrees Celsius and cooling demand low (less than 2400 kW). All cooling demands are covered by free cooling heat exchangers.
  - Combined operation – Seawater temperature is between 5.5°C and 11.5°C. Heat exchangers are used for pre-cooling of the cooled water, before it is fully cooled by chillers to the desired temperature.
  - Chiller cooling – Seawater temperature is above 11.5°C. The seawater is too warm to be used for free cooling so absorption and compression chillers provide all cooling. Free cooling heat exchanges are bypassed completely.

- **Created multiple connections to a network** – District Cooling works on the same principles as district heating. Chilled water is produced centrally and carried to the end customers through a system of pipes. Networks can be built adjoining district heating pipework, or can be laid where no existing network is in place.

- **Commercial development of network** - are based on profitable business cases.

THE BENEFITS OF OUR NEW COOLING SYSTEM//

- ENVIRONMENTAL:
  - Carbon dioxide reduction of 67%, compared to traditional cooling. The annual sulphur dioxide and nitrogen oxide savings are 62% and 69% respectively.
  - Potential to negate or, at least, reduce the urban heat island effect .
  - Demand for electricity is reduced because electrically operated chillers are replaced by free cooling and heat operated chillers and District Cooling.
  - Excess heat, noise and chemicals from or used in compressions chillers are avoided in individual buildings.

- SOCIAL:
  - Zero noise, in contrast to conventional cooling methods
  - Removes many of the health risks associated with cooling towers e.g. Legionnaire's disease.
  - Increased energy security from a centralised supply with improved resilience built in.
  - Back up provision available.

- ECONOMIC:
  - Reduction in expenditure for energy imports.
  - Cooling contracts with different organisations and institutions can be replicable, allowing easy transferability.
  - Free up commercial, retail and parking spaces as conventional cooling systems and fan coils on roofs are replaced by underground infrastructure.

THE CONDITIONS FOR CHANGING AIR CONDITIONING//

- **Client demand** - a customer base is a key requirement. Organisations with existing cooling systems of more than 150kW are likely to be interested in district cooling, as it becomes both financially feasible and attractive. A sufficient supply of customers in the vicinity of a plant is required to maximise the plant's total cooling capacity.
- **Suitable mix of buildings for developing network** – the district cooling network can be retrofitted in existing buildings (often overcoming issues of external units in the historic urban landscape), as well as being incorporated into new buildings.
- **Available Coolth** - a source of either surplus heat, e.g. from CHP or cooling provided by seawater.
- **Legal framework** – the District Cooling Act 2008 allows municipalities that fully or partly own district heating companies to create and run district cooling networks.

70%	80%	
Reduction of Co_2 emissions.	Reduction of electricity consumption.	Does not influence the architectural impression of the city.

Effects of district cooling compared to traditional cooling methods.

The district cooling system distributes chilled water to cool the indoor air of buildings

We hope you were as inspired by our sustainable solutions as we often are by other cities and their solutions.

The City of Copenhagen is pleased to provide more information about the solutions.

More information is available at: **www.kk.dk/english** including photo-downloads for the press.

Please mail remaining questions regarding the solutions, processes and their results to:
copenhagensolutions@okf.kk.dk


COME AND SEE US

COPENHAGEN CLEANTECH CLUSTER (CCC)

Copenhagen Cleantech Cluster (CCC) is the largest cluster organisation in Denmark and acts as the one-stop entry to Danish cleantech. Based on Denmark's long tradition in the field of cleantech technologies and renewable energy, CCC is among the leading and most renowned cleantech clusters in the world, creating superior value for companies, research institutions and public authorities by tying cleantech technologies and communities together across sectors, value chains and borders.

A unique group of partners are behind Copenhagen Cleantech Cluster, including a large number of companies like Vestas, Novozymes, Dong Energy and universities like Risø DTU, DTU, and the University of Copenhagen.

Further information: www.cphcleantech.com
Contact: info@cphcleantech.com
Tel: +45 3322 0222

ENERGYTOURS

Offers high-level delegations of commercial decision makers, technicians, politicians and journalists a unique opportunity to come and experience Danish cleantech and climate solutions. EnergyTours will create a program consisting of site visits and business meetings tailored to your current needs and challenges, helping you solve the problems of the future. Furthermore, EnergyTours offers to take care of all the logistics – from local transportation to accommodation and translation. Experience Danish technology live!

Web: www.energytours.dk
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Tel. +45 7210 0179

CLIMATE CONSORTIUM DENMARK

A public-private partnership set up in June 2008 to strengthen international awareness of Danish competencies and solutions in the areas of energy, climate adaptation and environment. As the official focal point for all business-related cleantech activities in Denmark, the Consortium works to promote solutions for sustainable growth locally and globally. The Consortium is owned by the Branding Denmark Fund, the Confederation of Danish Industry, the Danish Energy Association, the Danish Agriculture & Food Council and the Danish Wind Industry Association.

Web: www.climateconsortium.com
Email: info@climateconsortium.com
Tel.: +45 7210 0179

MINISTRY OF FOREIGN AFFAIRS OF DENMARK - THE TRADE COUNCIL

Through the Ministry of Foreign Affairs' Embassies, Consulates General and Trade Commissions, the Trade Council is present in all significant export markets throughout the world. The Trade Council's global network of 250 advisers with local expertise stands ready to serve Danish trade and industry. The Trade Council, advises Danish companies on export, internationalization, and innovation as well as foreign companies considering establishing in Denmark.

Web: www.eksportraadet.um.dk
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Tel.: +45 33 92 05 00

Foreningen af
Rådgivende Ingeniører
FRI

FRI (THE DANISH ASSOCIATION OF CONSULTING ENGINEERS)

A trade association of Danish consulting firms providing consulting services, planning and project management on a technical-scientific basis. In addition, member firms provide services in economic as well as non-technical fields with delivery of the relevant systems involved. Total turnover in the industry amounts to DKK 11 bn (€1,5 bn) in Denmark.

FRI's member firms provide independent consulting services on market terms. FRI represents the majority of businesses in the industry. FRI's member firms employ about 12,000 people in Denmark and over 9,000 abroad.

Web: www.frinet.dk/fri/english
Email: fri@frinet.dk
Tel.: +45 35 25 37 37

DWF
Danish Water Forum

DANISH WATER FORUM - YOUR GATEWAY TO WATER KNOWLEDGE!

Danish Water Forum is a network of Danish water organizations aiming at highlighting Danish water expertise and knowledge and facilitating concerted actions. The competencies and high standards of its members make DWF an excellent entry point to the Danish water sector and its services within all aspects of water industry, technology, science and management. DWF represents:

- Contractors and manufacturers
- Water companies and consultants
- Research institutions
- Government authorities and NGOs

DWF is open to all Danish organizations within water and related sectors such as environment, agriculture, and health.

Web: www.danishwaterforum.dk
Email: dwf@danishwaterforum.dk
Tel.: +45 4516 9038

D I
Confederation of Danish Industry

DANISH INDUSTRI

The confederation of Danish Industry (DI) is a private organisation currently funded, owned and managed entirely by 10.000 companies within manufacturing, trade and service industry. DI member companies constantly develop more efficient cleantech products and services and offers today environmental friendly solutions to most of the global climate challenges world wide. DI is strategic partner in various international cleantech partnerships including Copenhagen Cleantech Cluster.

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Copenhagen
Carbon Neutral
by 2025

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COPENHAGEN

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