Gemeente Amsterdam

A Vattenfall company

From: City of Amsterdam, NUON/Vattenfall
To: International Energy Agency
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Subject: Submission of application for "The International District Energy Climate Award"
Date: Friday, April 1, 2011

1.1. Name and location of the system.

District heating and cooling, Amsterdam.

1.2. Name of the owner and type of ownership.

District heating
Two parties are responsible for district heating in Amsterdam:

- NUON: Since 1 July 2009, NUON has been a subsidiary of the Vattenfall Group. The group's Business Unit Heat is responsible for all heating and cooling activities. NUON is responsible for the entire district heating chain in eastern and southern areas of Amsterdam.
- WPW (Westpoort Warmte): The City of Amsterdam and NUON have set up a joint venture known as WPW. The City is represented by AEB (Afval Energie Bedrijf), a service division of the City that generates energy from waste. The parties each hold 50% of the shares in WPW. The AEB is used as the heat source, while WPW is responsible for the district heating network in western and northern areas of Amsterdam.

District cooling:
One party, NUON Heat, is solely responsible for the construction and distribution of district cooling. The City of Amsterdam's involvement is limited to a facilitative role.

1.3. Name, address, phone number & e-mail of the person submitting the application.

The following organizations are jointly submitting this application:

- Municipality of Amsterdam; development corporation (OGA). Rob Kemmeren, 0031 - (0)6 - 525.74.181, r.kemmeren@oga.amsterdam.nl
- Municipality of Amsterdam, Energy and Waste Company (AEB). Daniel Lauwen, lauwen@afvalenergiebedrijf.nl; 0031 (0)6 - 5067 2230;
- NUON: NUON Heat, Martin Buijck, martin.buijck@nuon.com, 0031 - (0)6 - 5203.4587

MOTIVATIONAL LETTER

2.1 Description of system
Our district energy entry for district heating and cooling is for the award category (a) "A municipal scheme with more than 10,000 users." Our application regards the entire programme over the past 15 and the coming 15 years. It is an integrated urban scheme for supplying heating and cooling on both large and small scales.

2.2. Category
Our application regards all the award categories:
a) "New district energy scheme (less than 5 years in operation)": Examples are: Amsterdam North urban district, Zeeburg Island, Houthavens, Overamstel urban district.
b) "Expansion of existing scheme": Examples are: Amsterdam West and Amsterdam South-East urban districts, IJburg I.
c) "Modernization of existing scheme": Examples are: the construction of an integral pipe tunnel, the use of TwinPipes, connection of new energy sources.
d) "District cooling": Large-scale district cooling and small-scale storage of cold air.

2.3. Why and how the programme was implemented? What has been achieved?
A special feature of the programme is the constant growth and continuing innovation of the system. The success of the scheme is remarkable because Dutch energy policy has, until recently, been dominated by the availability of cheap natural gas.

<u>District heating</u>
Power plants are located at three locations around Amsterdam and together generate sufficient residual heat to supply heat to the entire city. In 1993, the city began to make use of residual heat. In 2005, the Amsterdam City Council passed a resolution to implement district heating except where not feasible due to location-specific considerations. The resolution was motivated by the following considerations: high energy savings and reductions in CO_2 emissions at low cost, improvement of air quality, energy transition, etc. Much has been achieved. In 2010, the system had 50,000 consumers. According to current plans, this will be expanded to 100,000 consumers in 2020.
The district heating system is being continuously improved. The ground below Amsterdam is well suited to the underground storage of heat and cold. A small-scale collective system has been developed to supply ecologically sustainable cooling to homes and apartments. District heating is used to supply heat to these homes, while underground storage is used to supply cooling. Cold air (or water) is captured in the winter, stored underground and used for cooling in the summer. This system replaces conventional air conditioning.

Other innovations regard the organization structure (a public-private utility), the exploitation of increasingly sustainable energy sources (Amsterdam's waste energy plant, waste heat from a biogas facility, etc.) and technical improvements to the network (integral pipe tunnel, TwinPipes).

<u>District cooling</u>
There are a number of deep lakes around Amsterdam which are located close to large office parks. The cold temperatures at the bottom of these deep lakes can be used for district cooling. In 2004, a first project was started in Amsterdam's Zuidas ("southern axis") urban development project. A few years later, a second project was started in the Zuidoostlob development area in Amsterdam South-East. Each of these projects has a capacity of 60 MW, together producing a total of 120 MW of ecologically sustainable cooling. The project is the only one of its kind in the Netherlands. An important innovation is the use of oxygen injection to combat the growth of cyanobacteria.

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SUMMARY FOR THE WEBSITE

Amsterdam District Heating and Cooling – Growth and Innovation

Amsterdam's district heating and cooling programme is characterized by continuing growth and innovation. The technology and organization are sufficiently developed to enable a major expansion of the system.

District heating

Amsterdam's district heating programme was begun in the early 1990's. In 2005, the Amsterdam City Council passed a resolution to implement district heating except where not feasible due to location-specific considerations. This means that, in principle, all new construction projects are connected to the district heating system. The reduction in CO_2 emissions amounts to 50% to 80%. The system is growing at a rate of around 4,000 consumers a year. In 2010, there were 50,000 consumers. The plan is to have 100,000 consumers in 2020. Further expansion is possible by connecting existing buildings. The City of Amsterdam and NUON are cooperating in a joint venture known as WPW (Westpoort Warmte) to further expand the district heating system.

Large-scale district cooling

In 2005, NUON introduced a large-scale collective district cooling system. The deep lakes around Amsterdam are used as the source of cold. This system reduces CO_2 emissions by 75% and avoids the use harmful cooling fluids. This system is only possible if the source (deep water) and the consumers (offices) are located close to each other. At the present time, two projects are in operation in Amsterdam's Zuidas and Amsterdam South-East.

Small-scale district cooling

Recently, a small-scale collective system was developed to also supply ecologically sustainable cooling to homes and apartments. District heating is used to supply heat to these homes, while underground storage is used to supply cooling. Cold air is captured in the winter, stored underground and used for cooling in the summer. This system replaces conventional air conditioning.

Technical improvements

Other innovations regard the organization structure (a public-private utility), the exploitation of increasingly sustainable energy sources (Amsterdam's waste energy plant, waste heat from a biogas facility, etc.) and technical improvements to the network (integral pipe tunnel, TwinPipes).

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Continuous growth and increased sustainability

District heating and cooling

Amsterdam has an ambitious programme for district heating and cooling which it started to implement in the early 1990s and is currently growing by around 4,000 connections each year. In 2010 there were 50,000 connections, and in 2020 this number will have reached 100,000, with further growth possible. District cooling will be implemented using deep lake water. The total capacity will be 120 MW. The photograph above shows buffers of the waste incineration plant with the slogan 'Waste is heat'.

Amsterdam

Amsterdam is the capital city of the Netherlands. Some key statistics regarding the city:

- 750,000 inhabitants
- 390,000 homes and apartments
- 8 million square metres of office space
- (Long term) construction plans for: 1 million m^2 of office space and 70,000 homes/apartments.

Amsterdam's energy strategy for 2040

The aim of the policy is to provide sustainable, reliable and ecologically sustainable energy to the entire city of Amsterdam. With regard to sustainability, the city administration aims to achieve a 40% reduction in CO_2 emissions in 2025 compared to 1990. To this end, a large-scale programme has been initiated, known as the 'Energy Strategy 2040'. The pillars of this policy consist of the following components: traffic (bicycles, electric vehicles), sustainable energy sources (wind, solar, burning of waste) and the built environment. The last component, the built environment, consists of two subcomponents:

- Energy saving through continuously improving insulation
- Sustainable generation through district heating and cooling and thermal energy storage. This means switching from gas heating (central heating, heating of tap water) to sustainable heating and replacement of electrical cooling (air conditioning, compression coolers) with sustainable cooling.

In Dutch cities, gas is the main energy source used for heating (accounting for 85%). The shares are:

- 415,000 REU use gas
- 55,000 REU use district heating

The aim is to expand district heating from the current figure of 55,000 REU to 100,000 in 2020 and subsequently to 200,000. This includes newly constructed buildings as well as some of the existing buildings. The share of gas will decrease, both in relative and absolute terms. In the long term, gas will be phased out in the entire city (more than 500,000 REU) by connecting all existing buildings to the district heating system. Copenhagen serves as an example of a city where this has been carried out successfully.

A residential equivalent unit (REU) is a unit that is used to compare the heating consumption of homes and apartments to that of commercial or industrial buildings (offices and corporate buildings). The following applies: a single home or apartment is (naturally) equal to one REU and 100 m2 of commercial or industrial floor space is regarded as representing one REU. Amsterdam thus has a total of 390,000 + 8 million m2 / 100 = 470,000 REU. There is no similar unit for the consumption of cooling, because there are too many differences in terms of temperature, capacity and purpose (cooling of rooms, cooling of industrial processes). Furthermore, much data about the consumption of cooling are not known.

Amsterdam is fortunate in having three sustainable heating/cooling technologies: district heating, district cooling and thermal energy storage. District heating makes use of the waste heat from nearby power plants, district cooling makes use of the cold in deep lakes, and a thermal storage system stores heat or cold underground and uses this for heating in the winter and cooling in the summer. Cold air storage is a form of thermal energy storage, which can be used for cooling in combination with district heating for heating. Cold air (or sometimes water) is captured in the winter, stored underground and used in the summer. In this case, cold is stored instead of heat. The energy strategy aims to facilitate expansion of all these systems.

Sustainable district cooling will be provided by the following systems:

- 2 collective district cooling projects
- 60 individual thermal storage projects, amounting to roughly 3,000 REU. The first cold-air storage facility (a type of thermal storage) will be realized in the short term in Amsterdam North.

No quantitative targets have been formulated regarding the growth of these systems.

District heating

There are power plants at three locations surrounding Amsterdam. Together these produce enough waste heat to supply the entire city. These locations are:

- Diemen – a gas-burning power plant belonging to NUON/Vattenfall. This power plant is connected to Amsterdam's district heating network.
- Hemweg 7 and 8, consisting of a gas-burning power plant and a coal-burning power plant, both belonging to NUON/Vattenfall. These power plants are *not* connected to Amsterdam's district heating network.
- The Waste and Energy Company (AEB), which is a waste-fired power plant (WFPP). AEB belongs to the City of Amsterdam. This power plant is connected to Amsterdam's district heating network.

In the near future, NUON will be building two new gas-burning power plants (Diemen 34 and Hemweg 9) which will operate in addition to the existing power plants. These are suitable for supplying heat. Amsterdam's two university hospitals have peak and back-up generators that are connected to the district heating network. The sources used for the network are shown in figure 1.

figure 1 Sources for the Amsterdam heat network

The district heating energy supplied by Diemen represents a 50% saving in energy and CO_2 emissions compared to traditional central heating boilers. The heat energy provided by AEB represents a saving in CO_2 emissions of 80%. This is due to the following:

- Half of the waste used to fire AEB's waste-fuelled power plant consists of biomass.
- Biogas from Amsterdam's sewage treatment plant is used. This sewage treatment plant is located next to AEB and produces 10 million cubic metres of biogas. This gas is used to fire a combined heat and power (CHP) plant, which

generates electricity and heat. This is then used to supply around 4,000 houses with 100% sustainable heat. It is possible to double the production of biogas.

The load curve over a year is shown in figure 2.

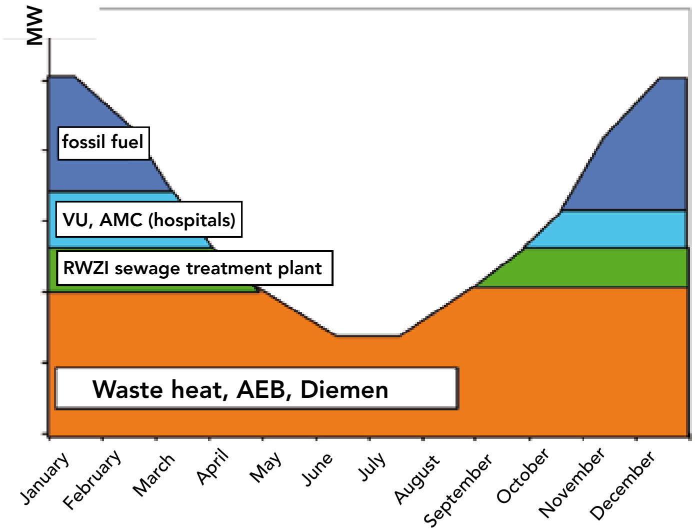


figure 2 Amsterdam heat load curve

Organization and network

There are two organizations that supply district heating in Amsterdam and both have their own networks.

- NUON supplies district heating to the eastern and southern areas of Amsterdam to the following districts (in chronological order of development): Amsterdam South-East, Zuidas, the Amsterdam South urban district, IJburg-1 as well as a number of CHP areas (e.g. Amsterdam's Eastern Docklands area and the GWL terrain urban eco district). NUON owns the Diemen 33 power plant and the network and supplies to consumers.
- WPW, a joint venture between the City of Amsterdam and NUON, supplies the following districts on the western side of Amsterdam: the Westpoort harbour area, Westelijke Tuinsteden and the Amsterdam North urban district. AEB is the source of heat, while WPW builds the network and supplies to consumers. All new projects in Amsterdam are carried out by WPW.

The existing (and contracted) networks are shown in figure 3. Yellow: NUON. Yellow/red: WPW, the joint venture between NUON and the City of Amsterdam.

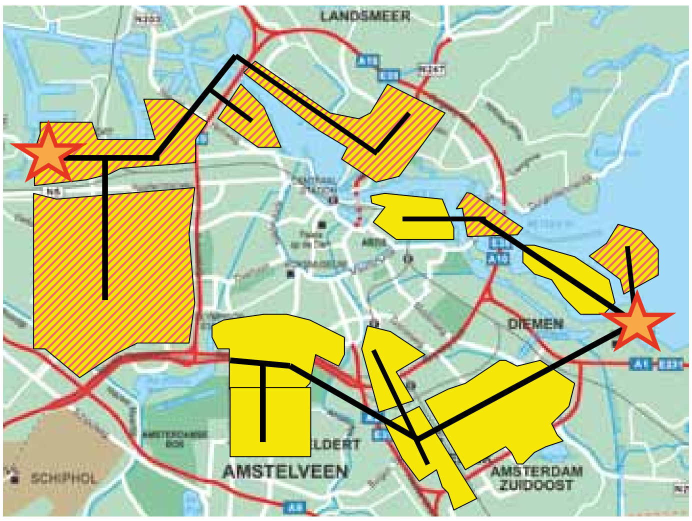


figure 3 The existing and contracted networks

In the long term, both parties wish to integrate the various district heating systems with each other. This involves two aspects:

- Physical: Links between the two parts will improve the energy performance of system as a whole. There are two possible ways of doing this: a 'small ring' on the southern side or a 'large ring' on the north side (see figure 4 and also under 'Improvements' below).
- Organizational: If the entire system is operated by a single organization, economies of scale can be achieved. In addition, public interests (third-party access, low prices and sustainability) and private interests (a financially sound business case) need to balanced. At the current time, different scenarios are being developed to investigate the best organizational structure and the best way of organizing ownership, liability, delivery, etc.

A single heating provider

The main scenario is described above. In this scenario, WPW is the heating provider for the entire city and is, in effect, a public-private utility. The heating will be produced by sources belonging to the parent companies, AEB belonging to the City of Amsterdam and the Diemercentrale power plant belonging to NUON.

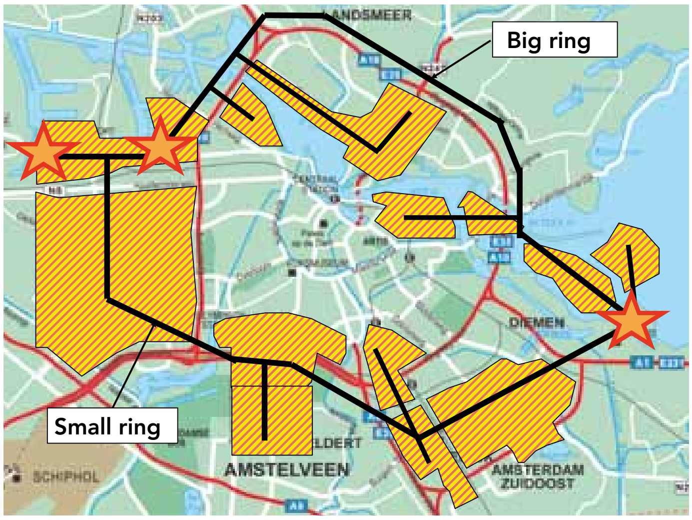


figure 4 Future scenario : single heat provider and closed network

Other scenarios are being investigated. Currently, a version is being studied which is similar to the organization of electricity distribution. The basic network will be owned by the government. The government appoints an organization (a 'market superintendent' or 'dispatcher') which purchases heat from the cheapest and/or most ecologically sustainable source. The options for a completely publicly-owned network are also being investigated.

50,000 consumers

NUON began constructing the district heating system in eastern Amsterdam in 1993. First Amsterdam South-East was connected, after which the system was extended into Amsterdam South. The next district to be connected was IJburg. The WPW joint venture began in Westpoort in 2000, followed by the Amsterdam New West (2005) and Amsterdam North (2008) urban districts and the other areas.

50,000 residential equivalent units are now connected to the system. The growth is around 4,000 REU per year. There are essential differences between the different areas. In Westpoort, for example, there are only large users and no residences at all. The opposite is true of IJburg and New West. In these districts it is mostly individual apartments and homes that are connected, and no large users. In terms of the entire city, the ratio is one to one.

The table below lists the projects grouped by owner and in (approximate) chronological order. The growth of the number of residential equivalent units is indicated. The table shows how NUON began and now has a dominant position. However, growth in recent years has been in WPW's areas.

Graph 1 shows the growth of the Amsterdam network over the past 15 and the coming 15 years. The graph shows linear growth from the beginning of the 1990s to 2010. The contracts for New West, North and Zeeburg Island guarantee that the trend can continue to 100,000 REU in 2020. After that, growth to 200,000 REU is likely, but this has not been agreed contractually. Growth

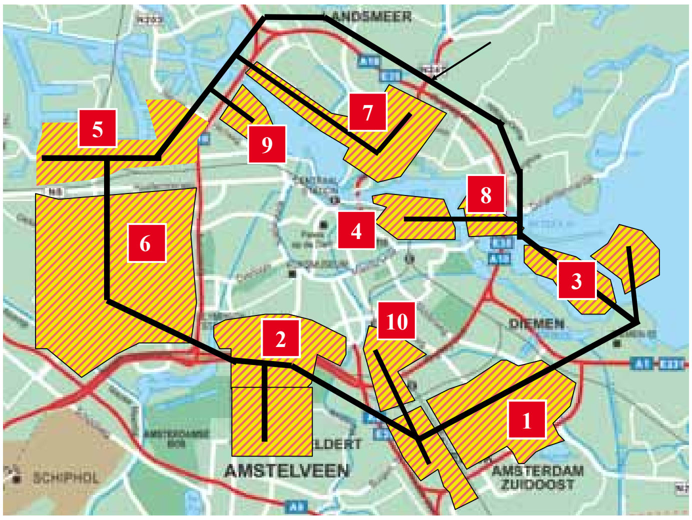
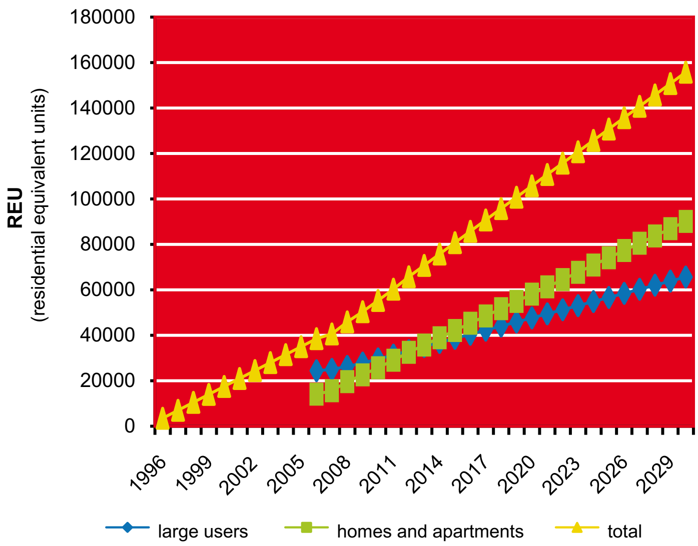


figure 5 The different urban districts (see table 1)

to 500,000 REU is possible if the entire city is connected to district heating. Copenhagen serves as an example, where 98.3% of the city is connected to district heating.

District cooling

Deep lakes are suitable for providing district cooling. Cold water has a higher density than warm water and therefore sinks to the bottom. This cold water (6 to 8 °C) is extracted using a closed system of pipes and transported to the urban area, where it is used for cooling buildings and data centres.



Graph 1 REUs connected to the networrk until 2030

The warmed water returned is discharged into the lake. The lake does not become warmer, because the amount of heat in the discharged water is small compared to other natural sources (summer sun, inflow of water from elsewhere, etc.). Furthermore, the water is cooled again in winter. A lake's capacity for storing cold is determined by the available cold at the bottom of the lake during the summer. The seasonal cycle is shown in figure 6.

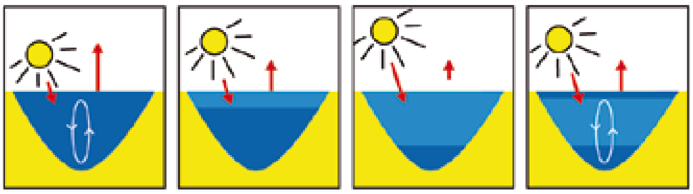


figure 6 The seasonal cycle of district cooling by lake

District cooling replaces compression cooling systems, resulting in a 75% saving in terms of energy and CO_2 emissions and reducing the usage of harmful cooling fluids.

District cooling in Amsterdam

There are a number of lakes around Amsterdam that were excavated long ago for sand. The lakes are more than 30

Table 1: Overview of number of NUON and WPW consumers and growth since 2006.

	Urban district	party	REU 2006	REU 2007	REU 2008	REU 2009	REU 2010	REU 2011	REU 2012
1	East	NUON	12,405	12,843	12,514	13,198	13,796	14,253	14,499
2	South	NUON	9,525	9,620	11,294	7,780	11,820	12,757	14,052
3	IJburg	NUON	2,581	3,572	6,241	7,256	7,860	8,260	8,460
4	Distributed CHP	NUON	10,490	10,610	9,893	9,882	9,882	9,882	9,882
	Subtotal	*NUON*	*35,001*	*36,645*	*39,942*	*38,116*	*43,358*	*45,152*	*46,893*
5	Westpoort	WPW	3,527	3,962	4,769	4,841	4,871	5,171	5,471
6	New West	WPW	0	0	1,122	3,204	6,204	8,104	9,604
7	North	WPW	0	0	80	226	350	950	1,750
8	Zeeburg Island	WPW	0	0	0	0	0	50	400
9	Houthavens	WPW	0	0	0	0	0	0	0
10	Overamstel	WPW	0	0	0	0	0	0	0
	Subtotal	*WPW*	*3,527*	*3,926*	*5,971*	*8,271*	*11,425*	*14,275*	*17,225*
	Total		**38,528**	**40,607**	**45,913**	**50,387**	**54,783**	**59,427**	**64,118**

Contracts have been signed for projects 9 and 10, but these are not being built yet.*

metres deep and are therefore suitable for district cooling. Two projects are now in actual operation. Both were initiated by NUON. These projects are:

- The Nieuwe Meer lake has been used for district cooling in the Zuidas since 2004 (60 MW). A permit for 75 MW (172 GWh) has been applied for.
- The Ouderkerkerplas lake has been used for cooling in Amsterdam South-East since 2009 (60 MW, 61 GWh).

At the present time, a total of 172 + 61 = 233 GWh of sustainable cooling can be supplied. The capacities of these sources are by no means fully utilized. The capacity of the Nieuwe Meer can certainly be doubled. Other lakes nearby can also be added to the system. In the future, it may also be possible to add a third project and link the existing projects together.

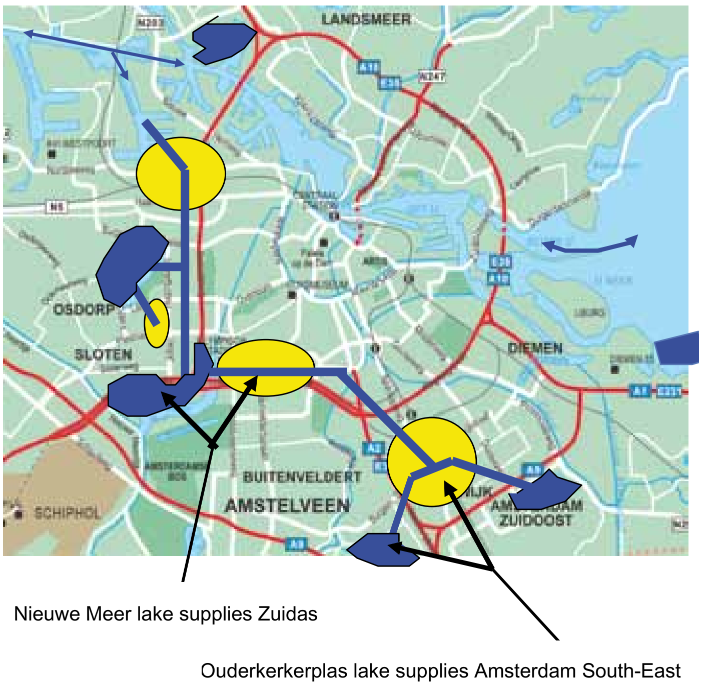


figure 7 Existing networks using the Nieuwe Meer and Ouderkerkerplas.

Cyanobacteria

In both lakes, cyanobacteria (also known as blue-green algae) cause major problems. Cyanobacteria cause the water to stink and are also slightly toxic. This causes much inconvenience to nearby residents and people using the lakes for recreation. In the Nieuwe Meer lake, cyanobacteria are combated by using a curtain of bubbles from a source placed at the bottom of the lake. This generates a vertical current, which pulls the cyanobacteria downwards. Deeper down in the lake there is less light, which reduces the growth of cyanobacteria.
A disadvantage is that this method affects the reservoir of cold water at the bottom of the lake and reduces the energy performance of the system. In the Ouderkerkerplas lake, experiments are being conducted with a new and innovative method of combating cyanobacteria: the injection of oxygen. The oxygen binds phosphates, causing the cyanobacteria to die off due to a lack of nutrients.

Reduction of CO_2 emissions

The current district heating system saves 50% to 80% of CO_2 emissions, which amounts to 1 to 2 tonnes of CO_2 per REU per year. The CO_2 savings for the gas-burning Diemercentrale power plant is 1 tonne per REU per year and the AEB waste-burning power plant saves 1.5 tonnes, while 100% sustainable heat saves 2 tonnes per REU per year. If the system grows from 50,000 REU to 100,000 REU, the total saving would amount to between 100,000 and 200,000 tonnes per year. A realistic expansion of the system to 200,000 REU would achieve a total saving of 200,000 to 400,000 tonnes per year. If the entire city is connected to the district heating network and the entire network uses more sustainable heat sources, the saving could even amount to 1 million tonnes.

District cooling saves 75% of CO_2 emissions compared to conventional compression cooling. Using sustainable means, 233 GWh worth of cooling is produced. If the equivalent amount of cooling were to be produced using a conventional compression cooling machine (COP = 2.5), 233/2.5 = 93 GWh of electricity would be needed. District cooling reduces this amount by 75% to 69.9 GWh. The average CO_2 emission for the electricity network in the Netherlands is 569 tonnes per GWh. The saving in emissions thus amounts to 69.9 GWh x 569 tonnes = 40,000 tonnes per year. This could be doubled if district cooling were to be implemented on a large scale.

Innovative sources for district heating

NUON and WPW are working continuously to increase the ecological sustainability of the sources. The objective is to phase out fossil fuels completely in the long term and replace them with sustainable sources. Three examples are described below. The first two examples have actually been implemented, while the third example illustrates the long-term vision.

- Expanding the use of biogas from Amsterdam's RWZI sewage treatment plant. Currently, 10 million cubic metres of gas are captured at the sewage treatment plant and used in a CHP plant. The waste heat is used for the district heating network. The quantity of gas taken from the sewage treatment plant can be doubled to 20 million tonnes in the short term. This would result in roughly 8,000 residential equivalents (REU) being completely climate neutral.
- Addition of new sources, such as Greenmills. Greenmills processes organic waste on a large scale. The waste is used to produce biofuels and 'green' electrical power. A biogas-burning CHP plant at Greenmills produces more waste heat than the company can use itself. This is completely CO_2-neutral heat, which can be used to meet basic load needs in the district heating system. Contracts will be signed this year for the supply of roughly 75 TJ, equivalent to roughly 3,000 REU.
- Research into alternative sources, such as geothermal energy. It will be possible to use geothermal energy in the long term. A first investigative survey showed that around 100 MW is available. Large-scale use only makes sense once the available waste heat is completely being used or the power plants no longer exist (after 2040).

During the coming decades, the demand for heat will be reduced due to the replacement of existing buildings and increasingly energy-efficient new buildings. It will then be possible to meet the demand for heating using completely sustainable means. Despite the reduced heating demand per home/apartment, the network will still be profitable, because there will be more consumers and it will be used more intensively. This is shown schematically in figure 8.

Improvements to the network

The network features five important improvements. The first three of these have already been implemented, while the fourth

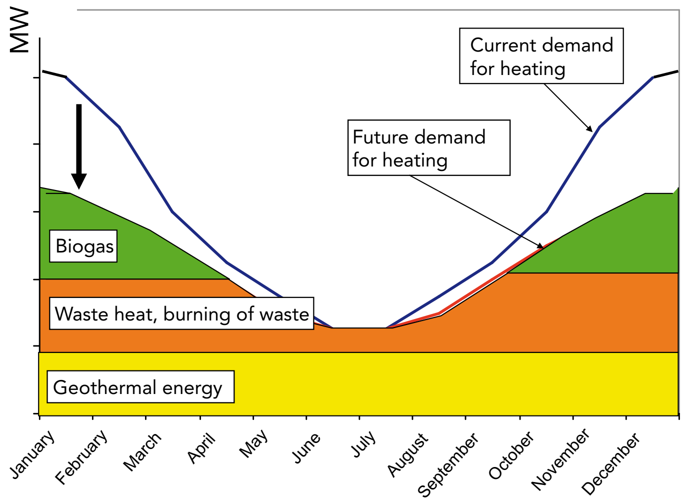


figure 8 Decreasing demand for heating after 30 years

and fifth are planned. The improvements are:

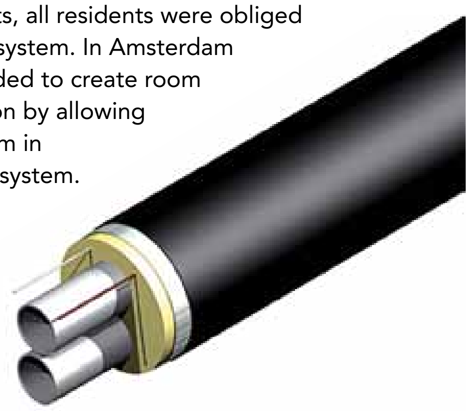
1. The building of the 'integral pipe tunnel' for the Zuidas area (figure 9). The complete pipe and cable infrastructure (electricity, water, fibre optic, gas, district heating and cooling, etc.) is arranged neatly in the tunnel. The implementation of this innovative project was only possible through intensive cooperation between all parties.
2. Additional buffer capacity. Buffer capacity increases the energy performance and financial yield of the entire network. The buffers are filled when the demand for heat is low and emptied when the demand for heat is high. .
3. The use of twin-pipes, in which both the supply and return pipes are within a single casing pipe (see the diagram below). This system is being used in the climate-neutral Houthavens district.
4. Linking of systems by means of a 'small ring'. This would improve the system significantly, because the most sustainable sources can then be used for supplying heat to the entire city. The disadvantage is that the existing pipes in the system have a small diameter, which means that the amount of heat that could be pumped through them is relatively limited. This small ring could be built in the short term.
5. Linking of systems by means of a 'large ring'. This would improve the system on a large scale because pipes with entirely new dimensions can be used. This means that almost all supplementary CHP plants would no longer be needed. The very high costs involved are a disadvantage. Implementation will only be possible in the long term, provided there is considerable growth in the number consumers.

figure 9 Integral pipe tunnel

Improvements

Improvements and innovations are introduced gradually over time and per project. The first projects in Amsterdam South-East and IJburg were class district heating projects: district heating was supplied from a traditional power plant. Subsequently, improvements were made to each project:

- New West: Two improvements were made in New West. Firstly, a joint venture was formed between NUON and the City of Amsterdam to improve the organization. Secondly, AEB was used as a sustainable source.
- Amsterdam North: Two improvements were made in Amsterdam North. Firstly in technical terms, in the form of an experiment regarding sustainable district cooling for homes and apartments. Cold-air storage is used for this purpose. The heat is supplied via the district heating system to around 200 homes and apartments through a substation. Cold air is captured in the winter, stored underground and used for cooling in the summer (see figure 10).
  Secondly, an organizational improvement was made in Amsterdam North through the allocation of 'degrees of freedom' with regard to the 'obligation to connect'. In previous projects, all residents were obliged to connect to the system. In Amsterdam North, it was decided to create room for experimentation by allowing degrees of freedom in connecting to the system.
- Houthavens: The Houthavens area is being developed according to the concept of 'climate-neutral construction'.



  The district may not produce any net CO_2 emissions for both heating and electricity. Any emissions that are produced must be compensated for. The buildings will be highly insulated. Heat will be supplied by the district heating system, which will also have a local buffer. Sustainable cooling is provided through the use of cold-air storage. Twin-pipes are used (supply and return pipes within a single casing pipe). As far as possible, roofs will be equipped with solar cells and wind energy generators. The combined use of a CHP plant in nearby Minervahaven office park and local heating supplied by the Cargill company is being investigated. The European Union has granted a 3.1 million euro subsidy for the application of the whole concept.
- OverAmstel: OverAmstel has a GRS (Gas Receiving Station). A GRS receives gas under high pressure (40 bar) from the national gassystem, lowers it to 8 bar for the municipal gassystem. While expanding, the gas produces a energy: a strong current which can be used for the production of electricity and cold which can be used for the cooling system. This energy is now wasted, but research is done to implement this innovative system.
- Existing buildings: The new large-scale improvement will take the form of the connection of existing buildings. At present,

this is only being done on a small scale. If suitable buildings are located near a main pipe, an appropriate offer is made to the owners. In this way, 30% of WPW's new connections in New West are existing buildings. In the near future, a more systematic and city-wide approach will be developed. The most important obstacles are not technical, but of an organizational and financial nature. Building owners, residents, WPW/NUON and the City of Amsterdam will have to reach agreement in broad lines with regard to the large-scale expansion of district heating in the existing city.

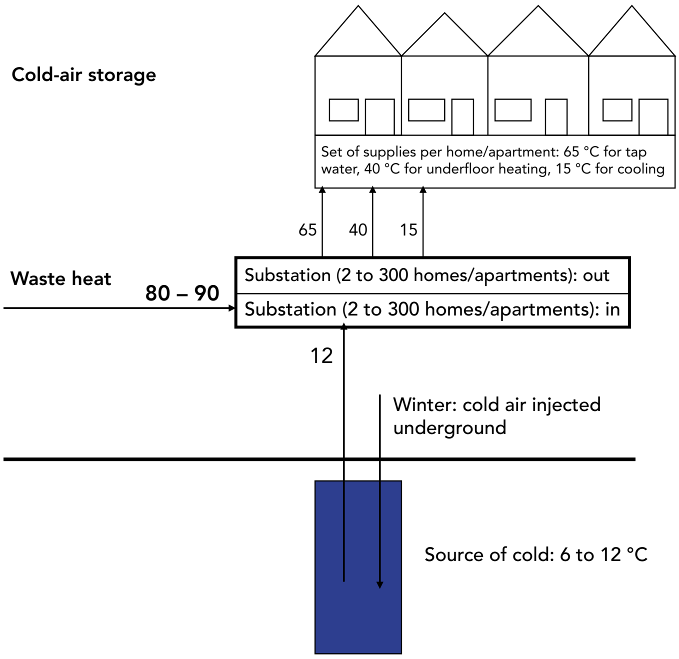


figure 10 Combining district heating and cooling

Innovative district cooling networks
The Netherlands does not have any large-scale district cooling networks. Therefore, the networks in Amsterdam are regarded as highly innovative. The projects themselves also involve several important innovations. The examples below are all under construction.

- Combining district heating and cooling. The provision of heating and cooling to a building can be optimized through connections to both district heating and cooling.
- The materials used for the pipes. The metal pipes in the Nieuwe Meer lake showed a great deal of wear due to specific biological conditions. For this reason, the pipes have been replaced by a special type of plastic piping. This practical innovation is very important for further projects.
- Combating cyanobacteria in the water. In the Nieuwe Meer lake, the growth of cyanobacteria is being combated by mixing the different water layers in the lake using a curtain of bubbles. The disadvantage of this approach is that the size of the lowest and coldest layer is affected. In the Ouderkerkerplas lake, an experiment is being conducted with oxygen injection to avoid this drawback. The injected oxygen binds phosphates in the water. In turn, the cyanobacteria die off due to the lack of nutrients. This method has been used before often, but its application under typically Dutch conditions is new. An extensive scientific research programme is in place to determine the effects of the various measures. It is possible that the method could be used elsewhere, even if the water is being used as a source of cold.

Public-private utility company
A special aspect of the Amsterdam situation is the cooperation between the private energy company NUON/Vattenfall and the City of Amsterdam. In effect, this joint venture represents a public-private utility company. This cooperation offers many advantages. Two examples of this can be given. First, the expertise and know-how of WPW, the City of Amsterdam and NUON complement each other and facilitate the expansion of district heating. NUON provides technical expertise, regarding, for example, the financial planning of district heating projects, the construction of infrastructure, connections to the power plants, etc., while the City of Amsterdam contributes knowledge regarding urban development, the planning of housing and knowledge of the substrata below the city. Additionally, joint investment reduces the financial risks for both parties by 50%.

More liveable surroundings
District heating and cooling affect the liveability of an area in different ways. The most important aspects are:

- Less trouble and worries for consumers: District heating and cooling are robust technologies with little maintenance for the consumer. Improvements to the sustainability of the network are made outside the home, with no inconvenience to the consumer.
- Invisibility to the public at large: Measures to improve sustainability often create disquiet. Wind turbines change the landscape, nuclear power plants make people feel less safe and biofuels compete with food production. District heating and cooling do not have these disadvantages.
- Benefits for individual consumers, such as safety (no possibility of carbon monoxide poisoning or explosion risks) and less condensation when cooking.
- Improvement of air quality: District heating reduces NO_x levels by 1.5 µg/m^3. District cooling leads to a reduced use of harmful cooling fluids that contribute to the greenhouse effect and damage the ozone layer.
- Improvement of water quality: If the test regarding oxygen injection into the Ouderkerkerplas lake is successful, the recreational value of the lake will be increased.
- More efficient use of the electrical power grid: The demand

for cooling is increasing, which results in the peak demands for electricity becoming increasingly high. The use of sustainable cooling reduces the peak demand, which means that no changes have to be made to the electrical power grid.

Cheap gas

The greatest obstacle to the building of district heating and cooling networks in the Netherlands is the universal availability of cheap natural gas. An enormous reserve of natural gas was discovered in the northern Netherlands in 1959. In 1963, the Nederlandse Gasunie was founded, an organization tasked with the construction of a network of pipelines to supply gas throughout the Netherlands. Within ten years, three-quarters of all households were connected to the gas network, as well most companies and the power plants. This means that natural gas is an important competitor for two reasons:

- Technical: The properties of natural gas give it many advantages. It has a high caloric value, burns cleanly and the transport costs are low.
- Institutional: The gas sector dominates the existing energy market and politics. It offers all the economies of scale. There are extensive laws and regulations covering the sector. There is a great deal of capital available. There are large organizations and there is room for innovation and the implementation of new products (high-efficiency boilers, micro-CHP boilers, etc.). The district heating sector is (still) much smaller and does not offer the same economies of scale. There are few laws and regulations specifically applicable to the special characteristics of district heating projects. The pricing of district heating projects is based on the principle of not costing more than other sources. meaning that consumer prices may not be higher than in a similar situation in which a gas boiler is used.

The competition with gas was started by the continuous improvement of district heating projects. NUON and WPW operate on the cutting edge and are have experience in reducing costs. Secondly, institutional changes have been brought about by much political lobbying for, among things, a good district heating act. Finally, the City of Amsterdam has made use of its influence derived from the leasehold system (in which buildings are privately owned while the land they are built on remains municipal property) to facilitate the development of new projects.

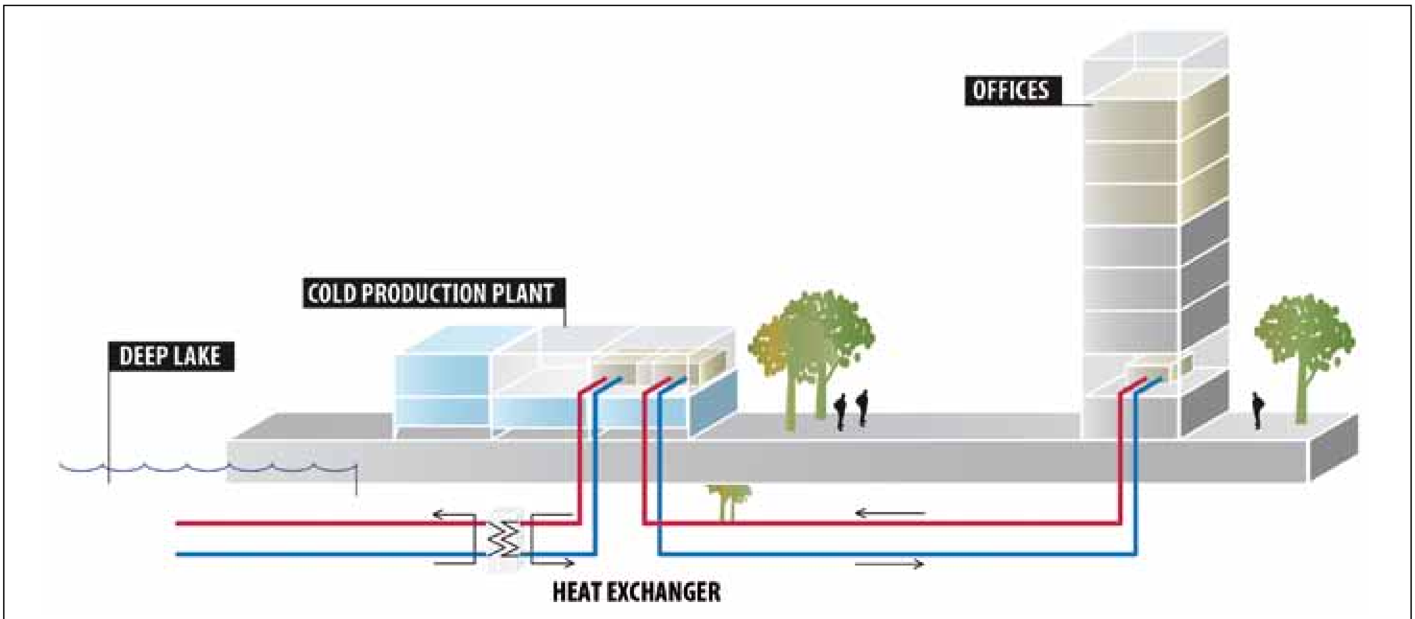
Negative image

A second problem is the negative image associated with district heating. District heating is regarded as an antiquated and centralized technology belonging to the past. The large and sturdy pipes suggest a technology from the previous century and do not fit the image of the computer age. There is much objection to the monopolistic character of district heating. Many consumers view the need to cook using electricity (because there is no gas connection in the home) as a disadvantage.

Cooking classes

The negative image of district heating is combated as much as possible through publicity campaigns and creating awareness of its current performance in terms of growth, sustainability and innovation. There are two target groups:

- Decision makers: These are made aware of the advantages of district heating for the public, including sustainability, possibilities for energy transition, improvement of air quality, etc.
- Consumers: Consumers are made aware of individual advantages such as safety, little maintenance, comfort, less condensation during cooking, etc. Participation by the City of Amsterdam will increase trust among the public. Additionally, it is explained that the monopolistic nature is not a problem, because the *Warmtewet* (heating act) provides the necessary legal protection for consumers in terms of prices and reliability of supply. When examined closely, other forms of energy (gas, electricity) turn out to be just as monopolistic as district heating. Finally, to get



District cooling is produced with the help of cold water from the deep layers of a lake. This water is pumped to heat exchangers in a cooling station. The water goes through the heat exchanger, with the cold water cooling the water in the pipes of the cooling system. The slightly warmed-up lake water is then immediately pumped back to the warmer upper layer of the lake. The water that has been cooled in the water system goes to the customer. This water then releases its cooling energy to the customer's internal cooling system which is used to cool rooms, computers and servers. The station thus eliminates customers' need for a cooling system of their own.

consumers used to cooking with electricity, special cooking classes are given. In the Amsterdam New West district, all district heating consumers were even provided with special sets of pots and pans.

Growth model

A so-called 'growth model' is being used. The programme consists of several independent projects, all of which are (almost) profitable. If an individual project is not profitable, subsidies are requested from the (national) government.

Investment in district heating

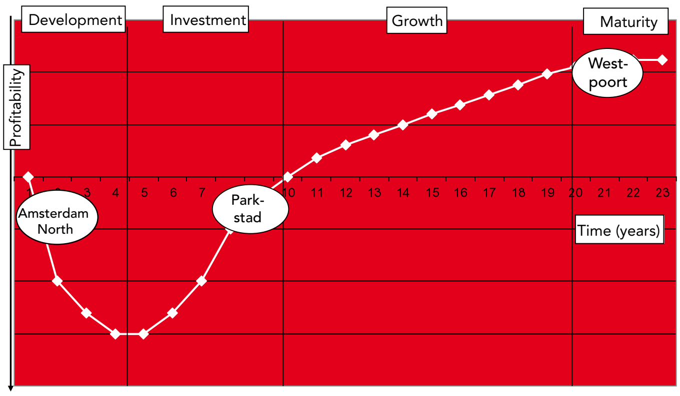
A heating project is characterized by losses and high investments at the start, while profits are made and investments are low later on. A project has roughly four stages: development, investment, growth and maturity. Investments are made during the first three stages of the project. Any growth in the number of consumers requires further investment. If the Earnings Before Interest and Taxes (EBIT) are charted over the different stages, a graph in the shape of an upside down hockey stick results. From stage 3, the EBIT is positive).

In graph 2, three existing WPW projects are shown schematically over time.

- Westpoort: a mature project. This project generates a constant cash flow that can be used to finance other projects.
- Parkstad: a project in the investment phase. If the revenues grow a little more, the project can finance its own investments from the project.
- Amsterdam North: a project in development. This project must make large investments, which must be financed by the other projects and the companies in the joint venture.

Individual projects

Individual projects are partly financed through loans and partly



Graph 2 Three WPW projects in different stages

from the company's own capital. Mature projects produce higher revenues over time and form the foundation for new projects. A key figure is that an investment of 7,000 euros is required per home or apartment. Therefore, to expand from 50,000 to 100,000 REU, an investment of 350 million euros is required. Further expansion to 200,000 REU in subsequent years would require an additional investment of 700 million euros. In order to connect the entire city to district heating (as has been done in Copenhagen) an investment of several billion euros would be required.

Investment in district cooling

The two district cooling projects each involve an investment of around 40 million euros, for a grand total of 80 million euros. These projects have a low yield and a long depreciation time. NUON has indicated that it cannot start any new projects in the near future. Instead, the company first wants to focus on the (financial) improvement of the current two projects. A new (financial) boost could support the expansion of district cooling.