

**The cooperation strategy between local government and water companies
to achieve water sustainability**

Aarhus Municipality Case Study - Denmark -

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Abstract:

This study aims to shed light on the Aarhus municipality in Denmark and its policy in water management, using smart solutions to maintain water sustainability and make the best use of it, in light of the increasing population and the daily exploitation of water. Therefore, the local government of Aarhus resort to make partnerships with either public or private companies in the field of water to achieve the goals and vision of the municipality, and to ensure pure and clean water in the best ways and lowest costs in pursuit of one of the sustainable development goals.

Keywords: local government, Aarhus municipality, Water Companies, Water Sustainability.

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Introduction:

Urban water networks to provide drinking water supply, wastewater collection and treatment, and storm water management are essential elements of human health and environmental protection in cities around the world, While the water sector faces increasing pressures in light of global changes, cities are facing difficulties in managing extended droughts, flash floods and rising sea levels.

One of the principles of sustainable development is to secure water for all sectors, conserve it in a sustainable way and protect it from pollution, but It is a difficult commitment given the growing population, rising demand for food and energy, and climate change.

Public water supplies often suffer heavy water losses when distributed to consumers, as sometimes more than half of the clean water produced and pumped doesn't reach end users due to leaks, malfunctions or illegal communications.

The exploitation of groundwater forms part of a long-term strategy, with sustainable groundwater supply as a political priority and with the necessary resources allocated.

To meet the aforementioned difficulties, programmes have been developed that increase the efficiency of domestic, agricultural and industrial water uses along with programmes to increase the efficiency of water utilities, where water management is required the provision of advanced scientific research solutions, technological developments and innovative designs. For this, municipalities are involved as a local authority and a key partner in implementing the agendas set by the government to achieve sustainable water management.

The Danish government considers municipalities to be pivotal partners in achieving the 2030 Agenda for the Sustainable Development Goals, because they are closer to citizens and businesses and are responsible for providing most public services. so, it carried out a municipal reform in 2007 in which financial autonomy is granted, and the powers and responsibilities of the municipality are expanded to enable it to achieve the Sustainable Development Goals including water sustainability, and the municipality of Aarhus is one of the leading municipalities in the area of using smart technologies for water management, through partnerships with water companies.

From the previous we can present the main questions of our study as follows:

How compatible is the partnership between Aarhus municipality and water companies in achieving sustainable development goals in the field of water?

1. Aarhus municipality reforms to keep up with water sustainability:

Denmark made a large-scale reform of its local authority structure with the aim of forming larger, highly efficient and financially sustainable municipalities. The number of municipalities has been reduced from 271 to 98, and 14 municipalities have been replaced by 5 regions. This reform saw the transfer of most of the province's environmental responsibilities to the municipal or national level (OECD, 2019, p. 100) .Where Section 82

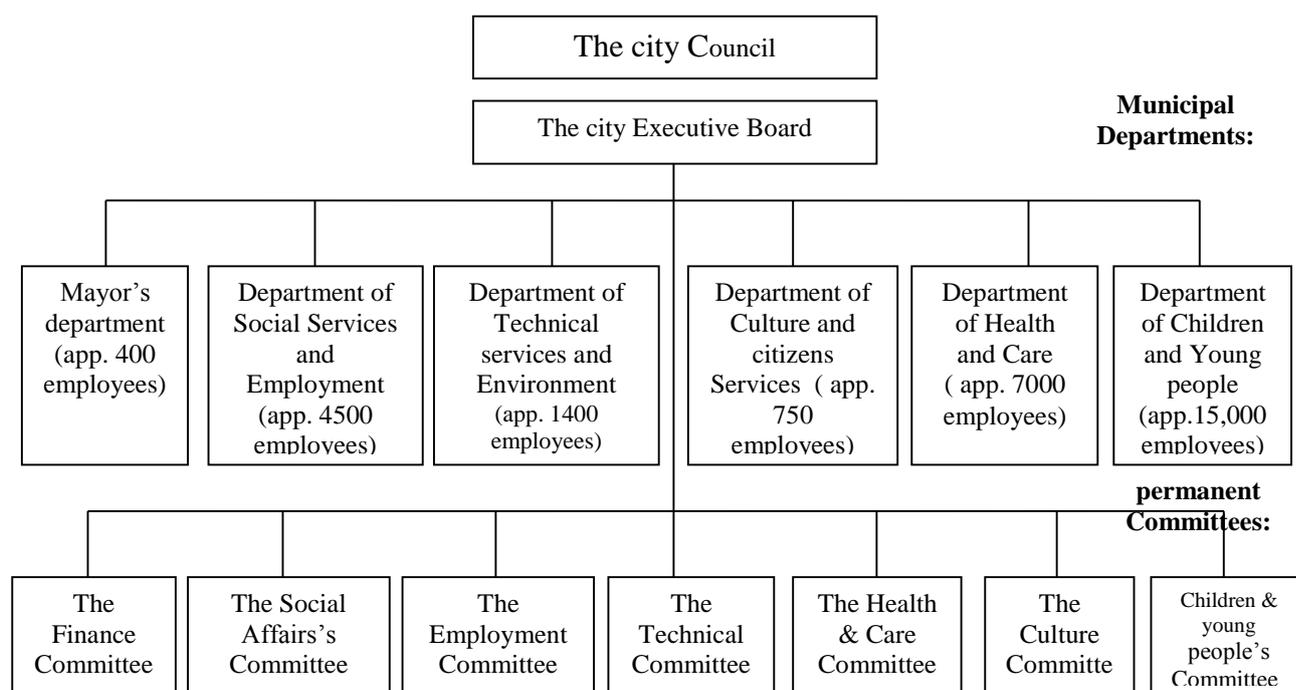
of the Danish Constitution refers to the right of municipalities to manage their own affairs independently under state supervision, and the rules on local government have included in the Local Government Act. The Act contains rules on administrative bodies, local councils, committees and the mayor. It also provides for certain rules relating to the financial management of municipalities, and municipalities may enter into agreements on cooperation (Ministry for Economic Affairs and the Interior, June 2014, pp. 14-15) .

1.1. Tasks and responsibilities of the municipality of Aarhus after the 2007 reform:

Aarhus is the second largest city in Denmark and the largest on the Jutland Peninsula, Aarhus is located in a large bay on the east coast of Jutland, and is the main city in western Denmark, due to being a regional center for research and education, as well as being home to the largest university in Scandinavia, a fast-growing and developed city in terms of its population and economy (Jensen, Nielsen, & Nielsen, 2016, p. 33) . It reached a population of 340,421 in 2018 (Sánchez Gassen, Penje, & Slätmo, 2018, p. 30), and it covers an area of 469 km² and it contains three main paths pass through the municipality, the largest of which is the Aarhus River.

The municipality is organized into 6 districts, each headed by a political leader, and the municipality of Aarhus and the municipalities of Copenhagen are the only ones in which the administrative boards are headed by elected officials, and political positions are distributed among political parties according to their electoral strength, so political and ideological disagreement sometimes prevents cooperation between sectors. In Aarhus, the mayor is entrusted with financial management (Jensen, Nielsen, & Nielsen, 2016, p. 34).

Figure 1: Organizational structure of the municipality of Aarhus after the municipal reform of 2007



Source: Alderman Bünyamin Simsek, (13th September 2019), AARHUS: Designing the Liveable City, p 4, in https://www.unece.org/fileadmin/DAM/hlm/Meetings/2019/09_12-13_Glasgow_Conference/GCCL_2_5_Willacy_reduced2.pdf

The Climate Adaptation Plan was developed at the level of the Department of Technical Affairs and Environment, where a steering group has been established comprising the heads of planning and nature offices, and the Technical and Environmental Department is organized into 7 sections. Where the collaboration between climate adaptation and climate mitigation of impacts form one of the four units managed by the Department of Nature and Environment. Green spaces and water are also managed in the Department of Nature and Environment, while the Municipality works to place urban use and land planning within the Planning and Buildings Section, and the road infrastructure is placed under the Traffic and Roads section. In this way, policies aimed at addressing climate adaptation and mitigation in Aarhus are being formulated (Bünyamin Simsek, 2019, p. 2).

Among the tasks of the municipality of Aarhus related to the ecosystem, we mention the following: (OECD, 2019, p. 101)

- Determination of most of the functions of public administration under Danish environmental legislation and duties relating to citizens;
- Preparation of action plans under the Environmental Objectives (Protected Areas) Act, wastewater management plans, water supply plans and municipal waste management plans;
- Maintenance of waterways to allow free passage of water;
- Preparation of regional and natural development plans and river basin management plans, as well as monitoring of nature, the environment and the management of contaminated soils;
- Administrative functions such as granting permits and inspections to the largest companies and facilities that are potential and most harmful to the environment, and the protection of the coastline;
- Mapping, planning and granting permits for the extraction of raw materials.

1.2. Smart solutions to achieve the vision of the year 2100 in Aarhus municipality:

The Municipality of Aarhus aims to ensure clean water for nature and drinking water until 2100, starting from the seaport of Aarhus taking into account climate change. The vision covers the areas of groundwater, water supply, wastewater disposal, water resources management and land use, as well as the entire urban water cycle, including the watershed area, all of which require very high data management.

A- Achieving efficiency in design and operations :

Advanced Geographic Information Systems (GIS) network databases and hydraulic modeling software allow simulation of the performance of widespread underground pipe networks, Network management is improved by the increasing use of online surveillance, through home measurement and noise recording to detect leaks in distribution networks, as well as the measurement of combined sewer flows during rainfall, and the monitoring of wet weather by wastewater treatment plants aimed at temporarily increasing their capacity

to avoid sewage exceeding the permissible limit. The next step of integrated control focuses on scheduling ventilation in treatment plants by storing wastewater in the upper drainage system to ensure the initial use of renewable energy sources (wind and solar) during dry weather (Mikkelsen, 2018, p. 14).

B- Use of integrated control and alarm systems:

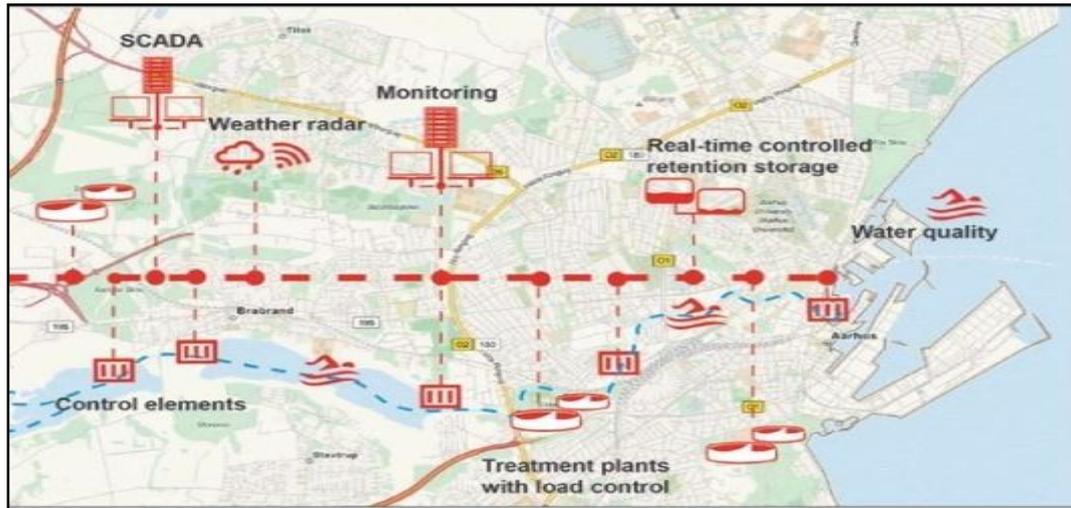
During the period 2007-2013; the requirements of the Vision of the year 2100 project were met in accordance with the WATER 4.0 approach through an integrated system of control and alarm in the operational real-time for urban areas, the system was automatically operational in 2013. This project includes the following tasks (Germany water partnership, 2019, p. 17): data acquisition, its processing and validation, model design, optimal strategy development, sending control instructions, controlling infrastructure elements, triggering operational alarms and alerting the public.

The WATER 4.0 approach places digitization and automation at the steel of water management's strategy with efficiency, flexibility and competitively. That include: "Networks between machines, processes, storage systems and resources", "Smart grids", "Internet of Things and Services". Planning, construction and operation are carried out by programs, allowing for a high degree of transparency for water users (agriculture, industry, households), with the provision of sustainable water infrastructure with the environment and the water circuit, thus covering current needs, while providing opportunities for sustainable creative activity in water management (Germany water partnership, 2019, p. 4) .

The project also focuses on aligning the infrastructure with high population growth, creating sufficient controllable storage capacity in real-time to avoid the combined flow of wastewater along with water pollution, integrating water in the urban regions, developing the port area into a recreation area with high-quality water, and adapting to climate change. All this has been done taking into account the limited possibilities related to structural procedures due to cost and space reasons.

Hazard areas and other key points of the Aarhus sewage system have been localized, and accordingly, sewage systems have been reviewed, three wastewater treatment plants and nine underground wastewater storage tanks have been connected, all of which combine sewage flooding with rainwater flows in real time. local weather radar has been installed to provide dynamic rainfall border conditions, Public participation has supported the acceptance of construction work (Germany water partnership, 2019, p. 17).

Figure 02: Design of the Real-Time Control System in the Municipality of Aarhus



Source: WATER 4.0, German water partnership, Germany, 2019, p 17, in https://germanwaterpartnership.de/wp-content/uploads/2019/05/GWP_Brochure_Water_4.0.pdf.

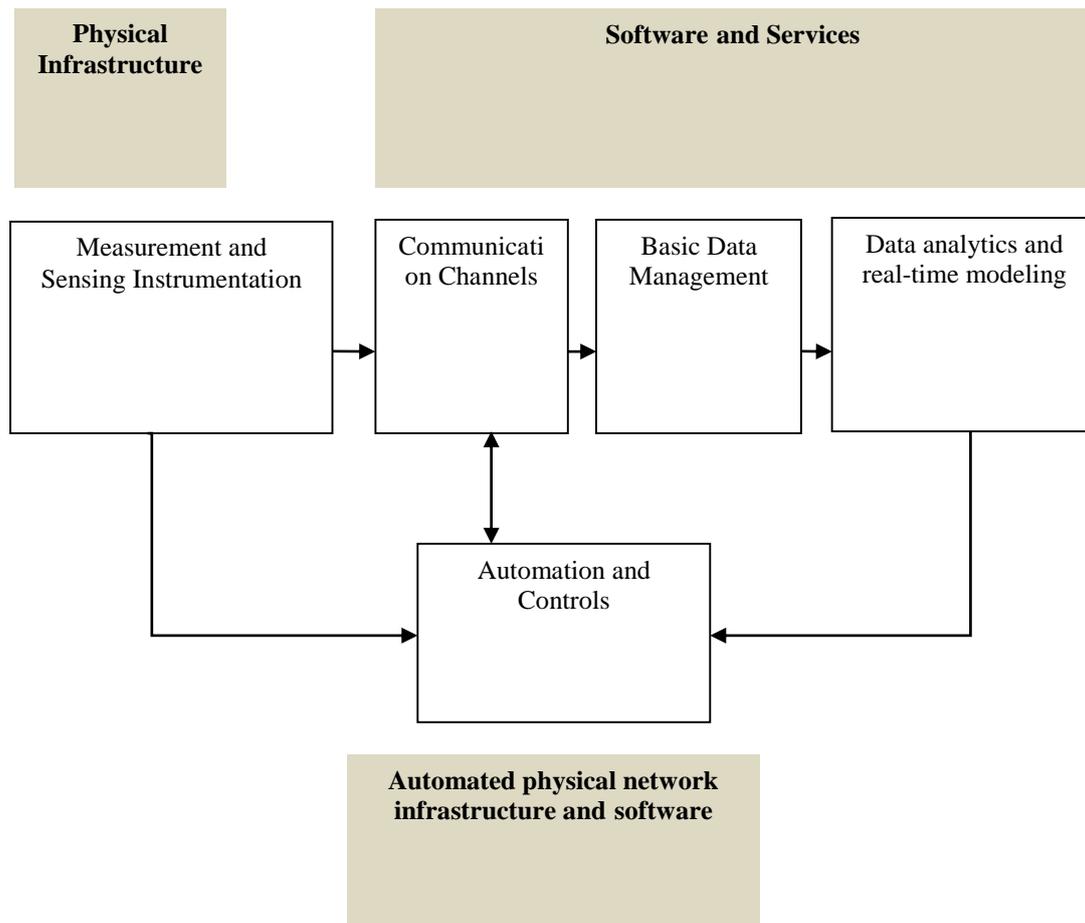
The alarm system predicts the deterioration of water quality, and uses real-time the data models from sewage systems and wastewater treatment plants as well as forecast rainfall data from local weather radar (Mikkelsen, 2018, pp. 14-15).

C- Using the Smart Meter Network:

The use of the comprehensive smart meter network requires physical infrastructure, as well as several programs and services that are explained in the following: (sensus, 2012, p. 23)

- Measuring and sensing instruments: which monitor flow (volume, pressure, temperature), quality (effluents, chemicals and pollutants, chlorine, pH degree), acoustics (leak detection), and the supply (water level in the tank);
- Communication channels: which include data communication infrastructure such as bidirectional radios and cellular networks;
- Basic data management: such as data reception and storage, access to and display of basic data (e.g., consumption data access interface), network visualization and GIS schematic tools, cyber security;
- Real-time Data Analytics and Modeling: it includes the leadership panel of senior management, predictive modeling, and data-driven decision making support (e.g. energy, leakage, assets, water supply and pricing, capital expenditure, and labor);
- Automation and controls: by establishing the automated network infrastructure (such as pumps and valves) and the programs to manage pressure, quality, flow, closure, etc.

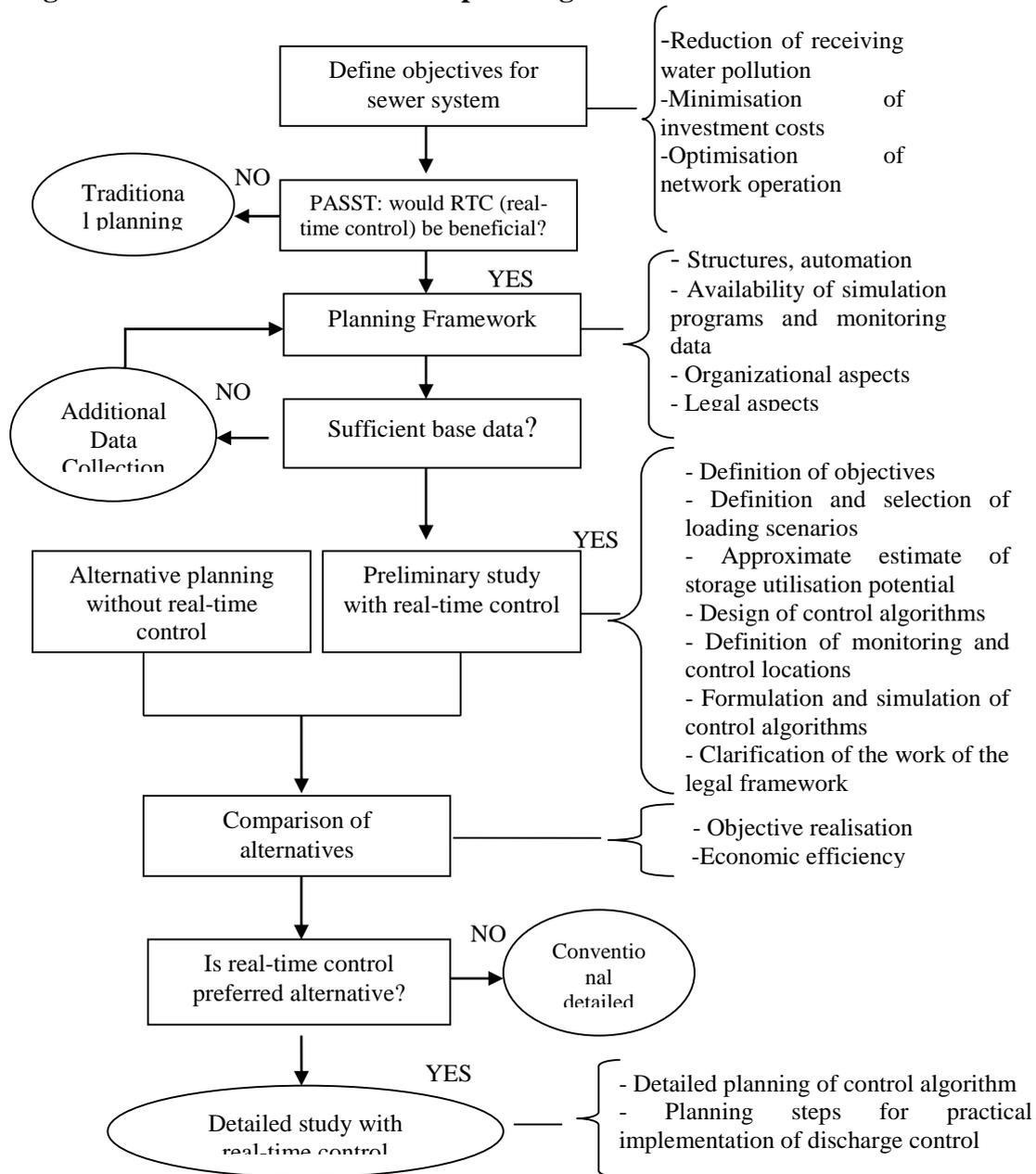
Figure 03: Diagram of an actual Infrastructure for the Smart Meter Network



Source: Water 20/20, bringing smart water networks into focus, (2012), p 23, in <https://sensus.com/wp-content/uploads/Sensus-Smart-Water-20-20-8.5-X-11-White-Paper.pdf>.

The real-time control system is frequently used to improve the performance of existing urban drainage systems, thus focusing more on the differentiation of the abbreviated levels pyramid hierarchy of the control and their impact on organizational aspects, as shown in the following figure.

Figure 04: Real-Time Control as a planning alternative: basic course of action.



Source : Stefan Kroll, (October 2019), Design of Real-Time Control Strategies for Combined Sewer Networks, ARENBERG DOCTORAL SCHOOL, Faculty of Engineering Science, Belgium, p 20.

2. Partnership for a Water Sustainability Strategy:

In light of reforms related to climate and sustainable development, the municipality of Aarhus has focused its attention on the water resource and how to preserve it by exploiting all sources, recycling and rational use, relying on the involvement of public and private companies.

The cooperation strategy between local government and water companies to achieve water sustainability. Aarhus Municipality Case Study - Denmark –

2.1. Strategy for Water Sustainability in Aarhus Municipality:

The coastal city of Aarhus aims to be a blue and green city, and in order to obtain the right quality of water and prevent flooding as a result of climate change, about €50 million has been invested in the construction of sewer networks and reservoirs with the aim to increase the treatment capacity of the rainwater the city's wastewater treatment plants. The real-time warning and alarm system has saved nearly half of the storage capacity needed for less than 5% of total costs. The control system also optimizes the use of storage capacity in the common sewage system by real-time control of dams and pumps, sequentially reducing collected sewage flows during heavy rainfall.

A- Rainwater Recycling:

The municipality of Aarhus cooperated with the water facility and an engineering company for setting up of a central facility for non-potable water, where rainwater is collected in brooks and passes through small lakes to a central collection tank, and then the filter removes the particles and keeps plants and animals outside, before transferring the water from the reservoir to the treatment plant where it is purified and redistributed for local use.

From there, pure water is distributed for domestic consumption, local "wasted" water covers 40% of the water consumption in the area, and an important part of the project is to set quality standards for non-potable water used in toilets and washing. The municipality of Aarhus has thus insured the health of citizens (Zerkov & al, 2018, p. 72) .

B- Separation of rainwater from sanitation:

The blue city of Aarhus is a pioneer in separating rainwater from wastewater, so increased rainfall no longer poses a threat to the city's infrastructure, but it provides an opportunity to develop new recreational areas in and around the city. (State of Green, 2017, pp. 12-13).

C- The Recreational activity:

As part of the implementation of Vision the year 2100, and in support of recreational use opportunities for the lake, river and port, the City of Aarhus decided in 2005 to improve the quality of healthy water in the receiving water which is mainly achieved by limiting the frequency of sewage flow (Germany water partnership, 2019, p. 17).

Aarhus opened the old riverbed through the city, to enable citizens to enjoy the open water areas in central Aarhus, and the water quality of the upstream lakes has also been greatly improved, transforming water bodies into safe areas accessible for recreational use (3 vand, p. 12). The municipality has focused on improving the quality of water monitored online and related to port water, sewage and corridors, and a new model of water quality has been developed for port areas.

D- Improving water quality:

The municipality of Aarhus seeks to achieve the goal of pesticide-free zones by preventing farmers from using them around drinking water extraction wells (OECD, 2019, p. 86).

E- Pricing and Investment Policy in the Water Sector:

The investment, operation of public water supply and wastewater treatment are fully funded by user fees. All water users (households and industry) are also measured, and both public water supply and wastewater treatment are charged according to regulated consumption .

Price increases have stimulated significant reductions in water consumption over the past decade, with the exception of agriculture and industry, but since its establishment in 2009, the Danish Water Utilities Regulatory Authority has set annual price limits for all companies water supply and wastewater treatment municipal's owned.

The Water Sector Act 2009 sets out the requirements regarding the prices cap and the efficiency of the operating costs of water companies. In 2016, the Water Sector Law was amended in order to meet efficiency targets for total costs (i.e. operation and investment). This has led to some policy uncertainty that contributed to the decline in investment in 2016, which has affected planned investment levels in the near term, the Parliament has agreed to strengthen regulation in the coming years by limiting revenue to be adjusted real investment, rather than be fixed, helping to improve the ability of companies to invest in new technology.

Water companies determine customs duties for the following year on the basis of price's ceilings, provided that the tariff is approved by the municipality. The regulations has been effective in halting noticeable price increases since 2004, tariffs have remained relatively stable since 2009, investments have increased particularly for wastewater facilities, while operating expenses for both drinking and wastewater facilities have declined. and the price borne by users for drinking water (which is almost entirely groundwater) covers the cost of groundwater (OECD, 2019, pp. 144-145).

2.2. The Partnership between the Municipality of Aarhus and Water Companies:

Aarhus Municipality has executed its strategies through cooperation and partnership with four public or private companies to achieve the sustainability of water.

A- Cooperation between the Municipality of Aarhus and the Aarhus Vand Company:

The Municipality of Aarhus acts as the owner, authority and contractual party of the Aarhus Vand Company and this includes the management of various tasks, including (Aarhusvand, 2019, p. 6) :

- As the owner: what the municipality of Aarhus wants and what you expect from the Aarhus Vand Company;
- As an authority: the vision of the municipality of Aarhus to the observance of the rules by Aarhus Vand Company;

- As a contractual party: such as the purchase by the Municipality of Aarhus of services from the Aarhus Vand Company and cooperation in projects.

Aarhus Vand Company As the owner, the municipality of Aarhus may have an interest in relation to the Aarhus Vand Company's strategy and results, risk, capital structure, corporate management, company culture, directors' remuneration as well as social responsibility. Among the ways in which the municipality of Aarhus can exert influence over the company is through the annual general meetings .

A.1. Objectives of Aarhus Vand Company:

The municipality of Aarhus has developed a new strategy for Aarhus Vand Company in 2017, which is a set of goals and objectives that were set when the company was founded, so the latter must achieve the following:

- Ensuring clean drinking water;
- Ensure stable supply and achieve customer satisfaction;
- Contribute to a clean environment;
- Contribute to climate efforts and adaptation to climate change;
- Assume social responsibility through training and work on special terms;
- Provide the citizens of Aarhus with high-quality water, at the lowest cost.

The municipality of Aarhus also expects Aarhus Vand Company to focus on efficient investment of the environment and improving its work.

Aarhus Vand seeks to provide a sewage system that separates rainwater from wastewater, where this goal was achieved in 2018 for an area of 75 hectares, as well as the use of resources through the extraction of phosphorus from wastewater for use as fertilizers, and this goal was achieved in 2018 with the extraction of 250 tons (danva, p. 39). Also, it supplies about 85% of the population of the municipality of Aarhus with clean drinking water, operates eight water plants and treats more than 30 million m³ of wastewater annually, thus contributing to improving public health and steadily improving the aquatic environment (3 vand, p. 16) .

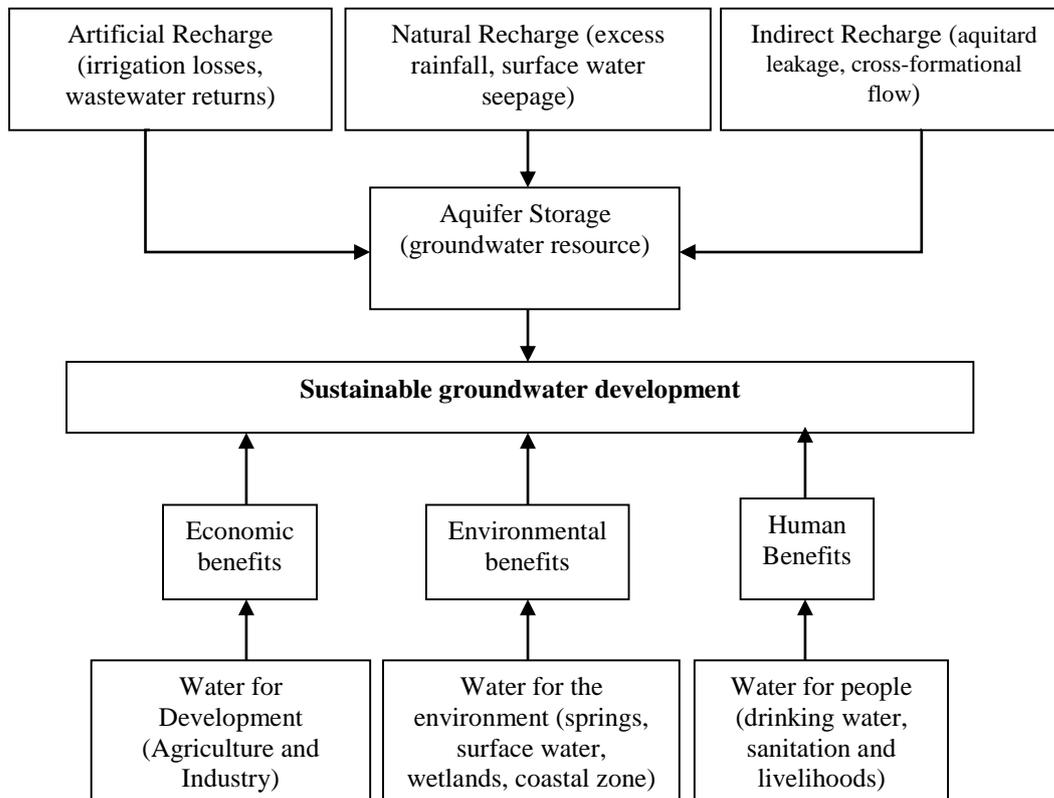
In addition, It manages rainwater, including climate adaptation projects, as well as the safe protection of a balanced cycle water. Aarhus Vand Company has four wastewater treatment plants that are vital plants that produce green energy and valuable fertilizers from wastewater.

A.2. Aarhus Vand's policies in Groundwater Resources Management:

Groundwater is an important part of the hydrological cycle, as groundwater is connected to surface water and forms a single source, which is why groundwater and surface water must be managed together in river catchments, so groundwater use is evaluated with a review of its impact on both surface waters (such as wetlands and depletion of waterways) and on the aquifer. The risk of salinity leakage in river deltas and coastal areas also increases with groundwater pumping, as the flow between aquifers and surface water bodies is changed, and groundwater protection and pollution control are closely linked to surface activities and land-use management (The Rethink Water Network, Danish Water Forum & State of Green, 2016, p. 15) .

In Denmark, public and private water consumers pay €0.04 per m³. These funds fund the Mapping and Groundwater Management Program, and how groundwater maps are used is the first step to a stable and sustainable water supply, and this requires data collection and safe management (3 vand, p. 15).

Figure 05: Balancing groundwater recharge and water reuse



Source: Greater water security with groundwater, The Rethink Water Network, Danish Water Forum & State of Green, (2016), Danmark, p 15.

B- The Partnership between the Municipality of Aarhus and Aarhus water company:

Aarhus water company is a public water company, founded when the state dated the division between Danish municipalities and water management, Aarhus water is the second largest water company in Denmark, and was established in 2009 as a joint stock company, where the municipality of Aarhus owns 51% of the shares, and the technical and environmental management of the municipality and Aarhus water are working on a range of projects. Water utilities are now a private entity that has been separated from the municipal government (Jensen, Nielsen, & Nielsen, 2016, p. 35) .

B.1. Ensuring water supply :

Aarhus water ensures the public water supply in the municipality of Aarhus by extracting groundwater from less than 100 groundwater wells, the depth of groundwater extracted from wells varies between 30 and 140 meters, which are surrounded by a

protection zone of 10 meters, and zone for 300 meters where there is no wastewater leakage, and the extraction is carried out on the basis of the groundwater plan managed by the municipality of Aarhus, where they are drawn up A guide on how to distribute groundwater between waterworks, agriculture and nature .

Aarhus Water pumps about 16 million m³ of water annually, and the water level in individual wells is constantly monitored to ensure that no more water is pumped than groundwater reserves can provide (Aarhus Water A/S, p. 4).

B.2. Groundwater Treatment :

Groundwater from wells is diverted to the ten water plants owned by Aarhus Water where it is treated before being sent for final consumption. Thanks to the good quality of groundwater in the municipality, water treatment is very simple and involves only ventilation and filtering of water through sand filters.

Water plants process a total of 4800 m³ per hour, with each citizen of the municipality of Aarhus using about 41 m³ of water for domestic purposes each year, which corresponds to the annual water consumption of about 117 people per hour. All ten water stations are unmanned and are automatically controlled by an electronic control system (Aarhus Water A/S, pp. 4-5).

B.3. Wastewater Treatment:

Aarhus Water operates four large plants and six smaller wastewater treatment plants, and together receives about 35 million m³ of wastewater annually, as wastewater goes through different purification stages in the wastewater treatment plant namely mechanical, biological, chemical and finishing treatment. Mechanical purification involves the removal of larger particles, while biological and chemical purification removes nitrogen, organic matter and phosphorus, while finishing processing removes pollution residues by directing water through a sand filter (Aarhus Water A/S, p. 5) .

C –The Partnership between the Municipality of Aarhus and Rewater Aarhus:

The Municipality of Aarhus seeks to develop sustainable and innovative wastewater treatment, that is why it participates to treat wastewater, where aims to be the world's most efficient resource facility in 2027, it is contributing to the strengthening of the water sector nationally and internationally, where students and companies from all over the world can submit new business ideas and projects.

Aarhus Rewater is interested in converting wastewater into new materials, products and energy over the next 50 years, in the form of heating, biogas, electricity and fertilizers. Aarhus Rewater is designed as a "digital" application with a platform for processing water information and big data, which is a platform of innovation and collaboration that will bring real and tangible value in the form of (Aarhusvand, 1 May 2019, p. 29):

- Provide easy data feeding;
- Use of IoT data, SCADA remote sensing of data;
- Provision of geographic information systems, key performance indicators and performance measurements;

- Provide strong visualizations and periodic reports;
- The possibility of cooperation between trading partners, allowing them to combine products and services to meet demand;
- Remote sensing of data using drones, to monitor Aarhus Rewater and Inspect treatment plants and tanks;
- Use robot technology (e.g. support for maintenance automation).

D -Support Truelsbjerg Water-works project:

Located a few kilometers outside Aarhus, Truelsbjerg Water-works is an example of a new and innovative research project on how to develop water plants in the future. The Truelsbjerg Water-works project was developed as a turnkey contract based on the utility company Aarhus Vand's ambitious vision for future water works, this latter allocating €7 million to support the technical and architectural implementation of the project. The project contains clean water tanks with an area of 2000 m³ made of stainless steel and is adjacent to the water works. Technical installations and construction works have been carried out with great respect for the surrounding environment and landscape. Truelsbjerg Water-works serves as a research and experimental facility at Aarhus Vand where new technologies can be tested. The project also places particular emphasis on adaptable, sustainability and flexibility solutions in relation to the supply structure and requirements (State of Green, 2017, pp. 12-13).

Conclusion:

The local government of the municipality of Aarhus has contracted with public and private water companies to achieve the goals and vision of the municipality in achieving water security, and these companies have used the latest technologies to operate water plants and control all processes with wastewater treatment plants using digital technology, where automation connects all processes, engines, pumps and factories in both water plants and wastewater treatment plants respectively, which allows the protection of the environment and reduce the risk of flooding.

Automation has been facilitated by the use of a water network and smart meters, as well as the use of an integrated operational real-time control and alarm system in achieving efficiency and effectiveness in water supply, rainwater recycling, sanitation and hygiene services, groundwater conservation and expanding the field for the recreational activity of the residents of Aarhus Municipality, all of which has saved time and cost, and ensured water sustainability.

Private and public water companies work in integrated harmony with the objectives set by the Municipality of Aarhus, aware of their social responsibility towards society, and believing in the need to preserve the water resource, which has become a rare wealth, and exploit it with guidance and intelligence so as not to be wasted, thus guaranteeing the right of future generations to water.

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