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White papers for a green transition

SMART CITIES

Creating liveable, sustainable and prosperous societies

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Digitisation as a key enabler for smart cities
Extracting value from data

Sustainable smart city solutions
Taking a holistic approach to waste, mobility, water, energy and buildings

Smart partnerships
Driving smart city development through innovative partnerships

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SMART CITIES
Creating liveable, sustainable and prosperous societies
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Front page photo
Queen Louise's Bridge
Photo: Martin Heiberg & Copenhagen Media Center

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EXECUTIVE SUMMARY

Cities account for 70% of global CO_2 emissions today. As the pace of urbanisation only quickens, cities face immense challenges related to sustainable waste management, mobility, climate adaptation and energy.

However, as their political, economic and technological power grows, cities can harness this trend to act as leaders in the green transition and drivers of the green economy – contributing to solving the UN Sustainable Development Goals. Cities need smart solutions to ensure that they are optimised for sustainable economic activity, energy consumption and positive environmental impacts.

Digitisation as a means to reach the goal

Digital technology, both ICT and IT, is crucial to create smart cities that fuel sustainable development. For many years, cities have applied digital technology to solve major metropolitan challenges, however the rate at which this adoption takes place is rapidly increasing.

Creating smart cities is not an aim in itself. Being smart is only the means with which to achieve a city's goals of sustainable growth and liveability. To do so, a solid foundation of basic digital structures have to be in place. This includes infrastructure, datahubs for data sharing and standards for data security and privacy. Chapters 1 and 2 of this white paper set the framework for the concept 'smart cities' as well as address the role of digitisation in this context.

A holistic approach to developing sustainable smart cities

Rather than addressing challenges of sustainable waste management, mobility, water, buildings, heating and cooling, and energy systems independently, substantial economic and environmental gains can be made from adopting a more integrated and holistic approach. Chapters 3-8 of this white paper address specific, green solutions related to each sector and demonstrate the potential of taking a cross-sectoral approach to these.

Smart partnerships

The inherent complexity of building smart cities and societies implies a strong focus on both the development of new organisational structures and the establishment of horizontal technical specifications across the public and private spheres. Chapters 9-10 explore the potential of establishing smart, national and international partnerships across sectors and stakeholders to foster smart city innovation.

Find inspiration for your own smart city projects

This white paper features lessons learned from smart cities applying sustainable solutions. Through state-of-the-art case examples across waste management, mobility, water, buildings, heating and cooling and smart energy systems, the white paper illustrates how taking a smart approach to urban development creates liveable, sustainable and prosperous societies globally. It is meant to serve as a tool for inspiration for reaping the benefits of implementing sustainable, smart city solutions in your city.

Photo: Martin Heiberg & Copenhagen Media Center

GREEN AND LIVEABLE CITIES ARE SMART CITIES

We want to reduce Denmark's greenhouse gas emissions by 70 per cent by 2030. While Denmark's greenhouse gas emissions only account for a fraction of total global greenhouse gas emissions, we believe that it is important to set an example for other nations to follow. The same goes for our cities. Cities account cumulatively for 70 per cent of the world's CO_2 emissions. There is thus an urgent need, as well as a great business potential, in looking at how cities can become greener and more liveable. The move toward smarter cities can help tackle climate change and make urban areas a better place to live at the same time.

By Simon Kollerup, Minister for Industry, Business and Financial Affairs

Across the globe, cities are looking for solutions to combat the negative impacts of increased urbanisation and climate change and as a result to become more green and liveable. Some of the challenges that cities are facing can be solved by applying technology and data. As a nation known for its multitude of green, liveable cities, Denmark wishes to play an active part in helping to solve global challenges in cities by sharing our experience and solutions with others, thus contributing to the UN Sustainable Development Goal 11 on Sustainable Cities and Communities.

Tapping into the potential of smart city solutions

Greener, more sustainable and more efficient urban development can be achieved by applying new technologies. Consequently, the global demand for smart city solutions is growing rapidly. This is primarily driven by three global mega-trends: urbanisation, green transition and digitisation.

Unique access to public data sources

When talking about smart city solutions, it all starts with data. With one of the most digitized public sectors in the world. Denmark has a unique starting point for developing smart solutions to meet the challenges of urbanisation and climate change, such as traffic congestion and flooding of urban areas.

Exploring Danish smart city solutions

Visitors to Denmark will experience how smart city technologies are being applied in practice. Many Danish municipalities work with national and international businesses to develop and implement smart city solutions in their efforts to create smart, green and liveable cities. Solutions related to waste handling, mobility, water, energy and buildings are some of the many ways in which smart city technologies are being applied to enhance urban environments, from both a sustainability and a liveability perspective. At the same time, Denmark is home to the largest smart city living lab in Europe – the Danish Outdoor Lighting Lab (DOLL) – where companies can carry out real-life tests of urban services and showcase their performance.

Collaboration and partnerships drive the green transition

Denmark has a long tradition for being at the forefront of implementing green solutions and green technologies. New smart city solutions make it possible to create a more sustainable society for the future. Working in public-private partnerships as well as working across sectors and borders is essential to scale the potential of smart city solutions and accelerate the global green transition together.

This white paper highlights the Danish experience and best practice solutions on creating smart cities.

I hope you feel inspired.

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1. FROM A SMART VISION TO A SMART SOCIETY

Leveraging the Danish experience

Today, cities account for 70% of global CO_2 emissions. Increased urbanisation places additional pressure on traffic congestion, waste and water management systems and overcrowded, polluting transportation systems, all of which create negative impacts on citizens' physical health and wellbeing. We need smart solutions to ensure that cities are optimised for sustainable economic activity, energy consumption, and environmental impact.

Associate Professor in interaction technologies, Martin Brynskov, Aarhus University
Head of Smart City Programme, Lone Pie Kelstrup, Gate 21

The smart city concept came to Denmark in the early 2010s. Closely related to concepts of liveability and sustainability, the 'smart city' notion was primarily applied by Denmark's larger cities such as Copenhagen (the country's capital) and Aarhus. Smaller cities such as Albertslund rapidly embraced the concept and began to work with it actively.

The focus of this work was not only to address the major challenges cities and communities are facing via the use of data, sensors and autonomous machines and vehicles, but also to do so while embedding the services in a holistic, human-centric governance framework based on open standards and strong international collaboration. This ambition led to the formation of the Danish Smart Cities Network, which continues to be the key forum for a broad range of stakeholders.

Scaling solutions
Since then, a number of Danish cities have adopted the concept and are working with national and international businesses to develop and implement solutions within mobility, e-government, lighting, welfare technologies, waste management and energy. Future emphasis for the smart cities agenda in Denmark will be on enhancing the scalability of solutions in a global context, development of regional and national data hubs, and a broader focus on society and communities instead of only cities. The latter is to emphasise the need to apply smart, digital solutions to address challenges in smaller cities and less populated areas, which constitute the majority of Danish society, as well as the rest of the world.

A holistic approach to smart solutions
Rather than addressing challenges of sustainable waste management, mobility, climate adaptation and energy independently, substantial economic and environmental gains can be made from adopting a more integrated and holistic approach. This implies that one solution can address several problems e.g. electricity, health and security simultaneously. Therefore, the multi-layered process of building smart cities and societies requires a strong focus on both the development of new organisational structures and the establishment of horizontal, technical specifications across public and private spheres. These two elements are essential to foster smart city development and innovation.

Common technical ground and new governance
An essential goal is to base solutions on a common technical ground across a range of systems, rather than using a variety of closed platforms. This involves open standards and standard specifications of interoperability and portability. New modes of organisation across silos and among a variety of organisations (public, private, universities and civil society/NGOs) enable new business models and create optimal preconditions for innovation, test and demonstration through e.g. living labs (read more about living labs in chapter 9). This development is in its early stage compared to the envisaged potentials. However, as this white paper shows, Denmark has made substantial ground.

DEFINING 'SMART CITIES'

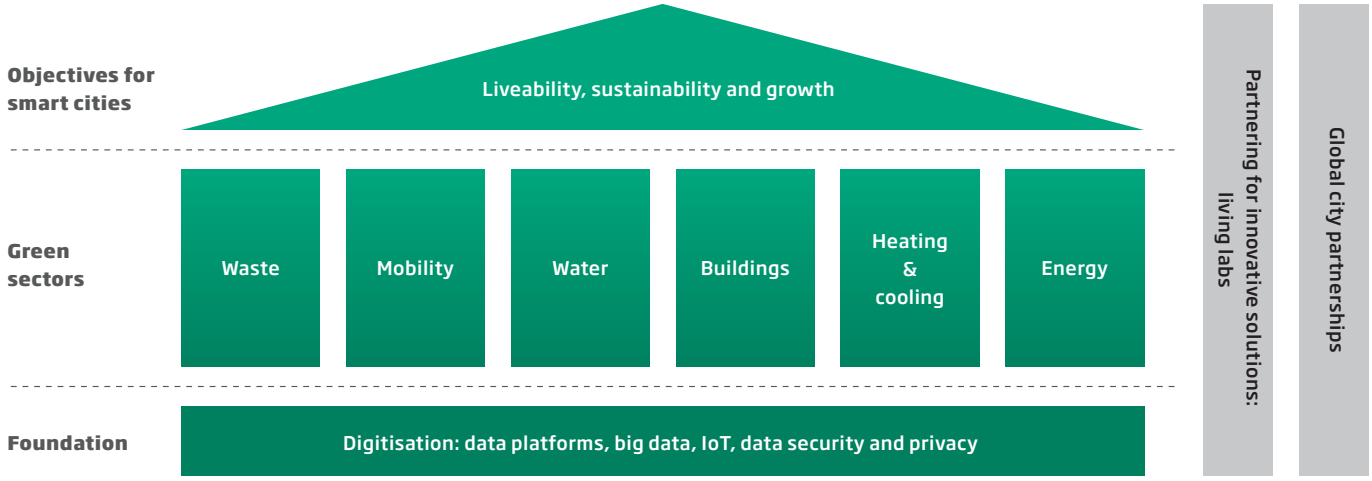
In this white paper, 'smart cities' are defined as cities and societies that leverage digital solutions constructed according to a common, technical foundation, and that possess organisational structures that enable citizen involvement in innovative ecosystems with the aim of increasing liveability, sustainability and prosperity. The main point is that technologies and new modes of governance are seen as enablers, rather than the solution in itself, for citizens' welfare and sustainable growth.

Framework for Smart Cities white paper:
Top level: *Creating smart cities is not an aim in itself. Being smart is only the means with which to achieve a city's goals of liveability, sustainability and growth.* ***Bottom level:*** *In order for a city to reach its objectives, a solid foundation of basic digital structures have to be in place. This includes infrastructure, datahubs for data sharing and standards for data security and privacy, as discussed in chapters 1-2.* ***Middle level:*** *The specific digital solutions should be applied both across and within the city's green sectors. Chapters 3-8 identify smart solutions within each of these.* ***Crosscutting level:*** *Both national and international partnership models across the different sectors are necessary in order for a city to reach its objectives. Chapters 9-10 explore the potential of partnerships.*

Open Data DK
Denmark's five largest cities have joined forces to establish the partnership City Pack, which supports smart city development at a national level. Additionally, Denmark's five largest cities and the Central Denmark Region also established 'Open Data DK' in 2015. The purpose of this open source platform is to create transparency in public administration, while creating a base for data-driven growth through free and available data to support productivity and innovation. Accordingly, developers, entrepreneurs, businesses, institutions and citizens get the opportunity to access data and insight about their cities and to transform data into new applications and services. Gathering all data sets from participating municipalities on a common platform makes it more manageable for municipalities to start working with open data and for data users to find data, thus creating added value to the data already collected in the municipality. Partnerships and knowledge sharing is key to Open Data DK as the initiative is based on a bottom-up approach and is learning by doing. 40 out of the 98 Danish municipalities participate in the initiative.

City Pack (City of Aarhus, Copenhagen, Odense, Aalborg and Vejle) & Open Data DK

Framework for Smart Cities white paper:



2. DIGITISATION AS A KEY ENABLER FOR SMART CITIES

Extracting value from data is crucial

For many years, cities have applied digital technology to solve major metropolitan challenges. However, the pace at which this adoption takes place is rapidly increasing. Data is the lifeblood of the smart solutions needed to address environmental challenges across energy, water, waste and environment in smart cities.

Managing Director, Helle Juhler-Verdoner, The Danish Intelligent Energy Alliance

Digital technology is crucial to create smart cities that fuel sustainable development. However, the application of digital technology should not be seen as a goal in itself. It is merely a means with which to reach the goal of sustainable growth and increased liveability in cities, as the figure in chapter 1 indicates.

Converting data to valuable information

The rapid spread of digital technologies means that the generation of real-time data from IoT sensors, network remote control and automation systems, continues to increase. Now the key objective is to extract value from data on e.g. energy consumption patterns, the amount of waste in garbage bins, traffic flow and air pollution.

Stable, green energy for smart cities

A key challenge in developing smart cities is to ensure access to stable, green and inexpensive energy for all purposes – transportation, heating and commercial use. To achieve this, it is paramount to build smart energy systems that can make use of the insights obtained from the available data. The abundance of data in the Danish power sector can be traced back to 2013, when the government ordered distribution system operators to install smart meters in all households by 2020. Today, Distributed System Operators are ahead of schedule and approaching full implementation of smart meters in private households. Once fully implemented, hourly data will automatically flow from all households via the electricity companies into the so-called DataHub where it is made available for e.g. settlement. In other sectors such as gas, water and heating the amount of data is also starting to increase significantly.

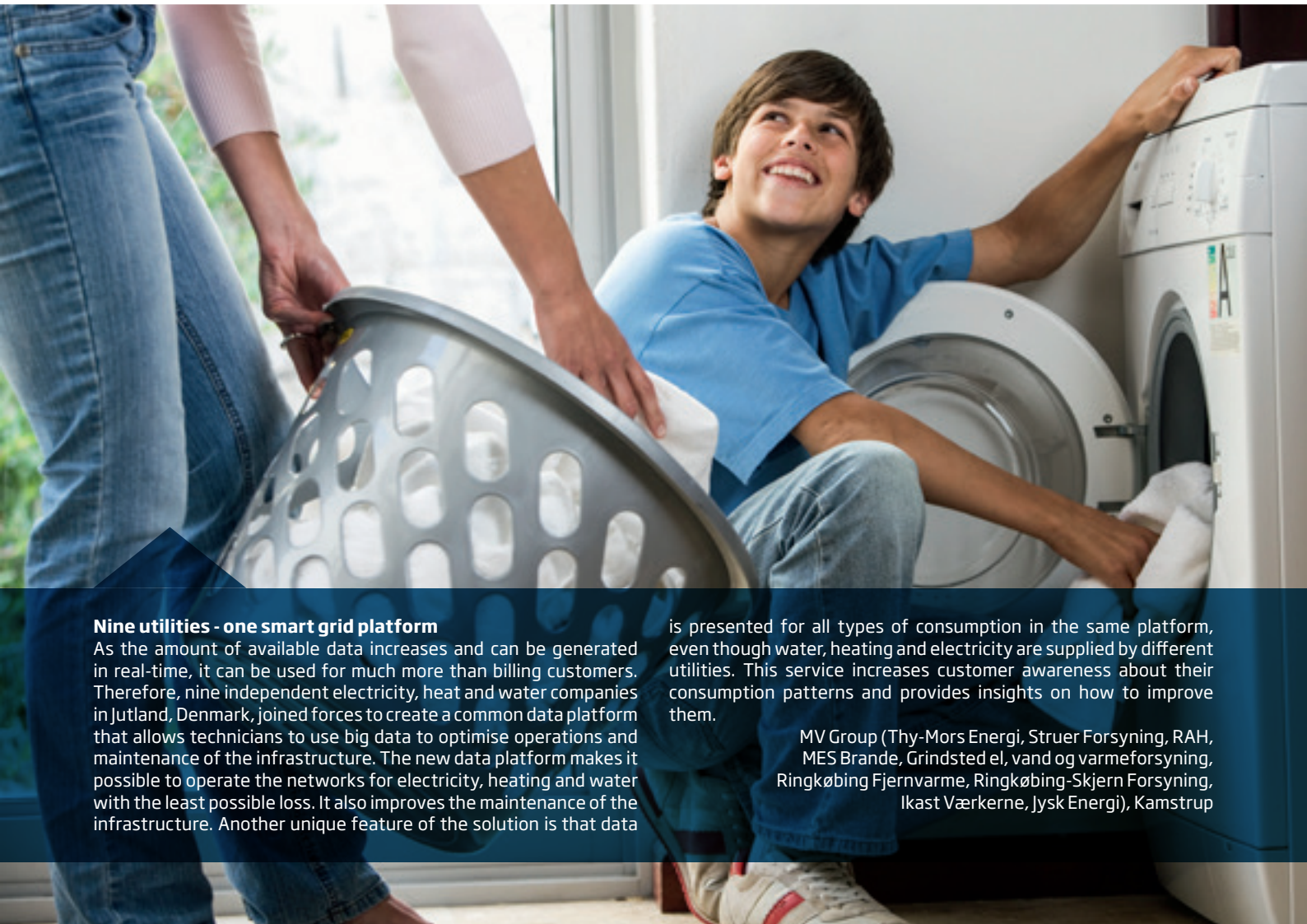
Creating value for customers and companies

In a digitised energy system, utilities can use the collected data to gain knowledge about how to optimise existing grid operations. They can also use the data to improve investment decisions regarding maintenance and the future development of the grid. This potential is not limited to the power sector but can also be realised in other sectors such as water and heating. Data can also be used to develop products and services that enable end users to consume energy when it is green and inexpensive. Hence, data is the key resource that binds the future energy system together and enables the development of smart city applications. By combining data from the infrastructure with new business models it is possible to create value for customers and companies involved.

Photo: Søren Svendsen, Realdania

Public open data fosters climate adaptation projects
The investment in the Danish Basic Data Program has significantly improved public sector data, not least in terms of geographical data. The high quality data on e.g. water and climate is open to all via public websites and makes it possible to develop useful tools. One example is a tool that can simulate the direction of surface-water flow and predict the accumulation of water during extreme rainfall or increased water levels. A detailed dataset on the elevation levels of the Danish landscape is a key part of such tools. Danish municipalities use this data in the planning of climate adaptation projects, as seen in e.g. the modernisation of St. Anne's Square in central Copenhagen. Using public data, the project team could complete its early planning without sending out surveyors to plot the surrounding area. In 2016, the project was completed and the public square of a little more than an acre had been modernised to protect 18 acres of the surrounding area's historical buildings from damages due to extreme rain.

The Danish Basic Data Program, Ramboll



Nine utilities - one smart grid platform
As the amount of available data increases and can be generated in real-time, it can be used for much more than billing customers. Therefore, nine independent electricity, heat and water companies in Jutland, Denmark, joined forces to create a common data platform that allows technicians to use big data to optimise operations and maintenance of the infrastructure. The new data platform makes it possible to operate the networks for electricity, heating and water with the least possible loss. It also improves the maintenance of the infrastructure. Another unique feature of the solution is that data is presented for all types of consumption in the same platform, even though water, heating and electricity are supplied by different utilities. This service increases customer awareness about their consumption patterns and provides insights on how to improve them.

MV Group (Thy-Mors Energi, Struer Forsyning, RAH, MES Brande, Grindsted el, vand og varmeforsyning, Ringkøbing Fjernvarme, Ringkøbing-Skjern Forsyning, Ikast Værkerne, Jysk Energi), Kamstrup

3. DATA IS KEY TO SMART WASTE MANAGEMENT

Cost-effective, clean collection of waste

Waste collection is an essential city service. One of the main problems arising from the logistics of collecting waste in cities is the lack of space. Conversely, in the countryside it is the distance between collection sites. In Denmark, both challenges are overcome with smart use of data.

Anders Gideon, Waste & Resource Specialist, DAKOFA, Waste & Resource Network Denmark

The bins are talking!
In Denmark, modern waste bins communicate with both the user, the collector and the waste planner. Users receive information about sorting and collecting waste as well as waste management. The collector is notified when the individual bins are full and in need of service. The waste planner can see how much the individual bins are being used, and if the collector has missed the bin.

How is that smart?
The user is nudged to use the bins instead of littering, while being more motivated to sort. Through the smart system, information on how much and what kind of waste is produced is generated, which can be compared to other cities, other parts of the city or even the next-door neighbours. Businesses can stop worrying about full containers. The automated collection planning ensures that full containers are emptied on time.

Saving time and fuel while reducing emissions
The collector only empties the bins, where it is necessary and can take the smartest route doing so. This equates to reductions in heavy traffic in cities and shorter distances driven in the countryside. Through these technologies, the collector saves time and fuel and reduces emissions. That is not only smart, but also environmentally beneficial.

Waste planners can plan smarter, as data provides them with information on how much waste is generated, where and when. It enables smart adjustment of collection schemes, amounts of bins and bin sizes. Again, saving time, fuel and reducing emissions.

The data managing systems are key to making smart waste management successful. Securing and storing data is crucial, but the smart part lies in the possibilities of combining the data sets. Imagine a live overview of the capacity of each individual bin, live updates and smart route planning for emptying only the bins that are full, as well as live traffic and weather data updates. The data can also provide detailed knowledge about waste habits. This could enable more focused communication from both government and businesses, leading to better quality of products, services and waste.

In a not too distant future, waste trucks are not only collecting waste and data on waste. They are also collecting data on live traffic and congestion, while scanning for unlawfully parked vehicles and collecting data from other smart city devices. The possibilities are endless and Danish technology and knowledge is already available.

Robots revolutionise waste sorting for recycling
More than 25,000 tonnes of waste is incinerated annually and the waste is utilised for the production of energy at Denmark's largest waste management company, Vestforbrænding. Very soon, robots will be revolutionising this process. According to research conducted by Vestforbrænding, almost half of the waste delivered will be re-sorted for recycling by a new robot-led sorting operation that will be in operation by the end of 2018. The new robot-driven process will be the first of its kind globally and will ensure that more types of waste materials are recycled and sent back into the resource-circuit. The pilot project was selected by the Danish Ministry of Environment in 2017 as a lighthouse project for future environmental solutions and granted approximately EUR 1.7 million in funding. The goal is that the use of this new technology will provide useful experiences that are beneficial for the industry as whole, both in Denmark and abroad.

I/S Vestforbrænding, Stena Recycling A/S,
Trasborg Denmark, Combineering A/S

Photo: Rasmus Degnbol

Using sensors to ensure cost-efficient waste handling
Together with a number of waste solution sensors and system suppliers, the Municipality of Albertslund is testing different waste solutions in a living environment. The outcome will be business cases that improve knowledge on how to optimise the collection and route planning of waste. Different sensors are installed in the same living environment in order to compare their functionality and collect data. This involves the development of new sensors and technical testing of different communication methods (Lora WAN, NB-IoT, SigFox) between sensors and the underlying systems. The sensors are installed in a number of larger housing associations, institutions, public areas, industries and office environments. They cover various waste fractions and include public waste bins, mini containers, semi- and buried containers and industrial pick-up containers. The expected results are closer relations between citizens and carriers, as well as cost-efficient waste handling with better services and fewer complications.

TDC, SEAS, Cisco, Nordsense, Joca, Wastecontrol, Sweco, Veksoe, Smart Bin, Gate 21, Albertslund Municipality, DOLL Living Lab

Green waste-to-energy plant and recreational area
Across the globe, citizens are increasingly migrating from rural to urban centres. Furthermore, young urban dwellers are choosing to remain in the city, rather than electing to move to the suburbs when starting a family. This calls for innovative redesign of the modern cityscape – also in Copenhagen. CopenHill is Denmark's newest and cleanest combined heat and power, waste-to-energy plant. It is located close to the city centre and successfully realises an ambitious vision of combining a green waste-to-energy plant with a recreational area. Inside, the entire energy plant is in operation 24 hours a day, 365 days a year converting waste from Copenhagen households and companies to inexpensive, green district heating and electricity for the capital area. On the roof slope, citizens have the opportunity to engage in alpine sports activities, or simply enjoy the spectacular view of the city. The façade of the building will feature the world's tallest climbing wall, increasing the liveability of the city.

ARC (Amager Ressource Center)

4. SMART MOBILITY

Decreasing congestion and improving air quality in the cities

As more and more people move to urban areas, commuting and transportation of goods will increasingly challenge the transport system and therefore increase congestion and emissions. At the same time, politicians are seeking to create more liveable cities which entails more green spaces, cleaner air, biking lanes instead of car traffic etc.

Senior Advisor, Søren Jakobsen, The Danish Electric Vehicle Alliance

For many, the answer is smart mobility and smart cities, where digital services foster the sharing economy, self-driving cars and e-mobility that change how we move around and make transportation more efficient and cleaner while taking up less space.

Car sharing and public transport must go hand in hand

Parking occupancy is close to or even above 100% in many cities. The result is many cars taking up large amounts of available space, while driving very few kilometres to find parking. Congestion and the fear of not finding a parking space when returning home makes public transport and bikes more attractive for commuting, as well as for undertaking other short distance trips.

No single mode of transport can do the job alone. In order for citizens to move away from car ownership, easy access to multiple, alternative mobility solutions at reasonable prices offering high enough levels of convenience are required. By providing car sharing programs in combination with public transport, citizens' transport needs are likely to be covered, without having to own a car.

In addition, citizens need easy access to multiple modes of transport without having to register a driver license and credit card in multiple apps. In Berlin, Copenhagen and other cities there is an increasing awareness of the need for mobility packages to be combined in one account to make the registration process easier and offer a single application to help users compare prices and find the option that best matches their needs.

Electric vehicles as a solution

Electric vehicles play a key role in solving problems of increased CO_2 emissions in the cities. Not only do electric vehicles encourage smart mobility, they also enable the realisation of an intelligent energy system with increasing amounts of fluctuating power. Charging of the electrical vehicle can be moved to outside of peak hours, without reducing the comfort of the consumer. This brings several socio-economic benefits due to cheaper electricity production and energy savings for the end consumer. With a smart approach to urban mobility, where renewable energy is part of the solution, future challenges can be met.

Electrification of public transport

In 2025, the City of Copenhagen has the ambition to be the first CO_2-neutral capital in the world without air pollution affecting the citizens' health. A large proportion of local emissions originates from bus and car traffic. Part of the solution can be e-mobility, which reduces the local emissions. For buses, the city council has decided to demand zero-emissions in all procurement of buses. In the municipal plan, the city ensures that urban bus chargers can be installed at bus terminal stations, and agreements with the local grid owner secure that sufficient electricity is available for fast-charging of the buses (450 kW). Currently two electric buses are tested and in 2019 around 40 zero-emission buses will be in regular service. The entire bus fleet will be renewed by 2031 at the latest. For cars, shared EVs are key to reduce emissions. 850 A to B shared EVs are made available to the citizens by two private operators. The expectation is that the existence of easy-to-use cars all over the city, will reduce the need for people to actually own a car - and when a car is needed, it will be without emissions.

City of Copenhagen

Data driven traffic management to improve air quality
Health problems related to bad air quality has become one of the biggest global expenses. Research shows that 80% of the population worldwide is exposed to pollution levels higher than recommended, where pollution from traffic is a major contributor. Today, traffic signals in Copenhagen are set to reduce travel time for the citizens, but a new project is focusing on guiding the regulation of signals according to what causes least air pollution. The purpose of the experiment is to generate new knowledge about data-driven traffic management in relation to air quality. In the future, this could lead to new ways of improving air quality in cities through changes in traffic management. During the testing period, two similar intersections in Copenhagen will be monitored, gathering information about air quality and traffic counting. The data is combined with external environmental data and traffic speeds to create deeper insights about the connection between traffic regulation and air pollution, and to understand the health benefits that can be derived from environmentally focused traffic management.

Leapcraft, Copenhagen Solutions Lab,
Technical University of Denmark, Citelum, OrganiCity

Electrical zero-emission passenger ferry
The transport sector is responsible for a large percentage of GHG emissions worldwide. This is certainly the case on the island of Ærø in the Southern Danish archipelago, where transport accounts for up to 40 percent of the total GHG emissions. Together with eight European partners from research and industry and with co-funding from the European Commission's Horizon 2020 Innovation Fund, the Municipality of Ærø has therefore started the E-Ferry project. The goal is to design, build and demonstrate a fully electric, zero-emissions vehicle and passenger ferry. The E-ferry will be able to cover distances seven times longer than current battery-electric vessels, due to its 4.3 MWh battery capacity and its 4 MW charging effect. The E-ferry will be charged with certified green electricity and will be a zero-emission vessel. Compared to existing ferries servicing the island of Ærø, the E-ferry will reduce emissions of 2 000 tonnes of CO_2, 41 500 kg of NOx and 1 350 kg of SO2 annually.

Leclanché, Danfoss Editron, Tuco Marine Group,
Consulting Naval Architect Jens Kristensen, Hellenic Institute
of Transport, Danish Maritime Authority, Søby Shipyard, Danish
Institute of Fire and Security Technology, The Municipality of Ærø

5. WATER SOLUTIONS FOR SMART CITIES

Smart water systems make cities more liveable, resilient and sustainable

Conventional water infrastructure is challenged by urbanisation and climate change while solutions aim at increasing urban liveability and resilience. It is time to integrate and smarten urban water systems and connect with the broader smart cities agenda.

Professor, Peter Steen Mikkelsen, Department of Environmental Engineering, Technical University of Denmark

Urban water systems - for drinking water provision, wastewater collection and treatment, and stormwater management – are key to human health and environmental protection in cities around the globe. They are also challenged by urbanisation, by decades of neglected maintenance and by an increased frequency of floods and droughts due to extreme weather events exacerbated by climate change. The digital era, however, is currently transforming urban water systems from passive, single-purpose infrastructure elements into active, adaptive and multifunctional units that can respond differently according to the situation and be operated in an integrated manner as part of the broader smart cities concept.

Digital solutions for more efficiency in design and operations

Advanced GIS network databases and hydraulic modelling software allow simulating the performance of the widespread underground pipe networks. Increased use of online monitoring furthermore contributes to smarten network management, through household and district metering and noise logging aimed at detecting leaks in distribution networks, as well as level and flow gauging in sewers aimed at optimising the storage capacity to minimise combined sewer overflows during rain. Increased combined use of IoT-driven, system-wide monitoring and real-time modelling is expected to increase efficiency further.

Visibly multifunctional water solutions increase liveability and resilience

Digital elevation models (DEMs) that reflect the physical features determining water flow at the city surface during cloudbursts and storm surge events, as well as associated software solutions, enable integrated planning and design of climate change adaptation measures. These employ both underground pipe networks and aboveground public amenity areas and traffic ores for water storage and transport. These 'grey' infrastructure elements are combined with 'green' and 'blue' water sensitive urban design (WSUD) elements. A wave of city-wide monitoring efforts to document performance and optimise operation and maintenance is expected. These should be based on Open Data standards that allow new smart city services to be developed by third parties.

Resource conservation and integrated solutions

Wastewater treatment plants are increasingly operated with advanced control systems to minimise energy consumption by utilising the biogas potential. With time, they are also expected to minimise GHG emissions and utilise the nutrient content to produce fertilizers. Digital solutions are increasingly used to optimise performance across sectors, e.g. wet-weather control of wastewater treatment plants aimed at temporarily increasing their capacity to avoid combined sewer overflow and bypass during rain. The next generation of integrated control is focusing on scheduling the aeration at treatment plants by buffering wastewater in the upstream drainage system to ensure a primary use of renewable energy sources (wind and solar) during dry weather. In both cases, reliable forecasts from weather radars and numerical weather prediction models are used. These will also increasingly be used for scheduling maintenance activities and flood forecasting, which allows for improved mobility services during rain and flooding.

Increasing liveability and climate resiliency through integrated control and warning systems

The coastal City of Aarhus aims to be a blue and green city. This involves restoring the old industrial harbour area into residential and recreational areas and reopening a cased river flowing through the old city center into the harbour. To obtain proper water quality and prevent flooding as a result of climate change, approximately EUR 50 million was invested in constructing trunk sewers, storage tanks and increasing rainwater handling capacity at the city's wastewater treatment plants. A real-time control and warning system was also developed, which has saved nearly half of the needed storage capacity for less than 5% of the total costs. The control system optimises the use of the storage capacity in the combined sewer system through real-time control of weirs and pumps, which subsequently minimises combined sewer overflows during heavy rain. The warning system forecasts deteriorated water quality in the receiving waters based on automatic operation of integrated models of the sewer system and receiving waters. The models use real-time data from the sewer systems and wastewater treatment plants as well as forecasted rainfall data from a Local Area Weather Radar.

Aarhus Vand, DHI and Krüger

Combining multiple data sources in automatic leakage management

In the capital region of Denmark, they listen carefully to their water distribution networks. The country's two largest water suppliers, HOFOR and Novafos, are transforming parts of their water distribution networks around Copenhagen with state-of-the-art technology. Here, noise loggers now listen for the sounds of leaks. Smart water meters measure end user consumption. Intelligent valves and pumps enable active pressure management which reduce the risk of bursts. The collected data is combined with SCADA and GIS in real-time hydraulic modelling and processed in online management information systems to facilitate automatic leakage management and online monitoring of KPIs. This enables leakage teams to target the weakest pipeline segments with the goal of reducing Non-Revenue Water levels to 4-6%.The project is called LEAKman and consists of nine Danish partners representing technology providers, consultants, water utilities and the Technical University of Denmark, who have joined forces to demonstrate Danish solutions and pave the way for new technology. The ambition is to make water utilities more smart, efficient and sustainable – in Denmark as well as worldwide.

NIRAS, Grundfos, AVEVA, AVK, Kamstrup, Leif Koch,
Technical University of Denmark, HOFOR and Novafos

6. SMART BUILDINGS IN SMART CITIES

Buildings as active and flexible prosumers

Smart cities are sustainable cities that are able to use renewable energy sources of all types. When power generation is based on fluctuating energy sources, the demand side needs to adapt. Smart buildings as active and flexible prosumers are part of the answer to balance the energy system in the city.

Managing Director Helle Juhler-Verdoner, The Danish Intelligent Energy Alliance

Nations worldwide are setting ambitious renewable energy and CO_2 emissions targets. Large cities are significant drivers in achieving these targets. As buildings account for up to 40% of society's energy demand, they have a decisive role to play in making our cities more sustainable and liveable.

Automated buildings to balance the local energy system

In Denmark, as well as in many other countries, intermittent renewable energy sources account for an increasing share of power generation. This necessitates an increased focus on energy consumption and the ability to enhance flexibility in buildings in order to balance energy supply with energy consumption when production cannot be controlled or power, heat and water infrastructure suffer from peak demand. Enabling smart solutions such as the remote monitoring of energy consumption in e.g. heating, ventilation and cooling, as well as integrating local energy production and - storage e.g. from solar panels and batteries is the way forward. Automating buildings is particularly beneficial if energy savings and energy flexibility are combined and implemented during the construction phase of new buildings or in renovating existing building stock.

Engaging the residents through demand response

Today, many larger, newer buildings, primarily from the year 2000 and onwards, are partly or fully equipped with building management systems: Energy System Management (EMS), Konnex (KNX), Building Management System (BMS) or equivalent. EU building regulations support and enable the consumer to engage in demand-response activities through an aggregator. By 2020, smart meters and hourly billing of consumers will be implemented across Denmark. These and other elements in the electricity market will improve consumer and prosumer engagement in demand-response activities. Today, the financial reward is limited and hence the business case for household flexibility is also limited. In just a few years, we expect to see a market with more differentiated prices and more price peaks. Market developers see a first-mover advantage for buildings to benefit from this development without significant additional costs.

Regulation of buildings and the energy market need to be able to easily adapt to these changed circumstances and the whole value chain must be involved in order to establish an intelligent interaction between intermittent power production and end-user consumption. In this matter, the European Union is crucial in securing a common platform for flexible energy use in Europe.

Full scale energy savings in Danish municipality

In the EU, buildings account for 40% of total greenhouse gas emissions. Denmark is already reducing greenhouse gas emissions in the utilities sector, and therefore energy efficiency in buildings is central to achieving further reductions. Since 2017 and for the next four years, Middelfart Municipality, in close cooperation with Schneider Electric, has been using the analytical software Building Analytics at the municipality's 80 properties. The software platform analyses the large data volumes generated by the buildings' management systems and creates action reports within energy, indoor climate and maintenance in real time. The action reports encompass specific suggestions on how to resolve an inappropriate operating situation. This enables the operating staff to respond quickly and take decisions anchored in fact-based analysis. The expectation is an annual energy saving of 5%, in addition to the 21% the municipality has already saved through renovations compared to 2008 levels. Thus, the Municipality of Middelfart achieves a total saving of at least 26% of energy consumption in buildings.

Middelfart Municipality, Schneider Electric

Photo: ABB

Buildings act as valuable heating storage

Several buildings in Copenhagen's new harbour district, Nordhavn, play an important role as intelligent pieces in an ambitious energy puzzle. A refurbished silo and a new apartment building form part of the demonstration project EnergyLab Nordhavn. Here, building automation systems collect data on electricity and heat consumption, CO_2 and number of people present in several apartments. Based on weather forecasts, weather station data and demand for heating, the project demonstrates that buildings can act as valuable heating storages in the energy system without compromising on comfort. All data is sent to the Technical University of Denmark, which develops the algorithms that allow the energy system to self-control. The main driver is to relieve pressures on the district heating system, especially during the winter season where the demand for heating is high, and it becomes expensive for district heating plants to increase production quickly. Reductions in CO_2 emissions, cost reductions and energy efficiencies are achieved if district heating companies can regulate the temperature for apartment blocks instead.

ABB, Technical University in Denmark, Balslev, HOFOR

The world's second-tallest skyscraper is packed with smart technology

With its 632 metres, the Shanghai Tower is the world's second-tallest building. More importantly, it is one of the world's most sustainable buildings. The recently opened Shanghai Tower has achieved the Leadership in Energy and Environmental Design's platinum certification and a Chinese Three Star Green Building award. Located in one of the world's fastest growing cities, it is designed to reduce energy consumption and air pollution. To transform these ambitions into reality, several Danfoss solutions have been installed. 6,700 Danfoss valves ensure a stable water flow all around, so the temperature needed on the top floor can be obtained, regardless of the temperature required on lower floors. More than 50% of Shanghai Tower's total energy use goes to heating, ventilation and air conditioning. 20% of this has been cut by using the control valves. Additionally, 660 Danfoss variable-speed drives ensure that pumps, compressors, and fans never run faster than required to deliver the correct temperatures. This technology contributes to reducing energy consumption by 20-40%.

Danfoss

7. URBAN HEATING AND COOLING

District energy – a smart infrastructure

Energy-efficient heating and cooling solutions based on green energy is key to achieving sustainable cities. While many cities have opted for individual, on-site heating and cooling solutions, collective heating systems are considered a smart way to heat and cool urban areas.

Senior Market Manager, Anders Dyrelund, Ramboll & Senior Advisor, Sune Thorvildsen, Danish Energy Industries Federation

District energy contributes to smart cities by supplying heating and cooling collectively instead of individually. District energy is feasible in densely populated areas, where demand for heating or cooling is high. It is an important part of a future integrated energy system. In Denmark, 64% of Danish homes have their heating and hot tap water needs met by district heating.

Infrastructure investments

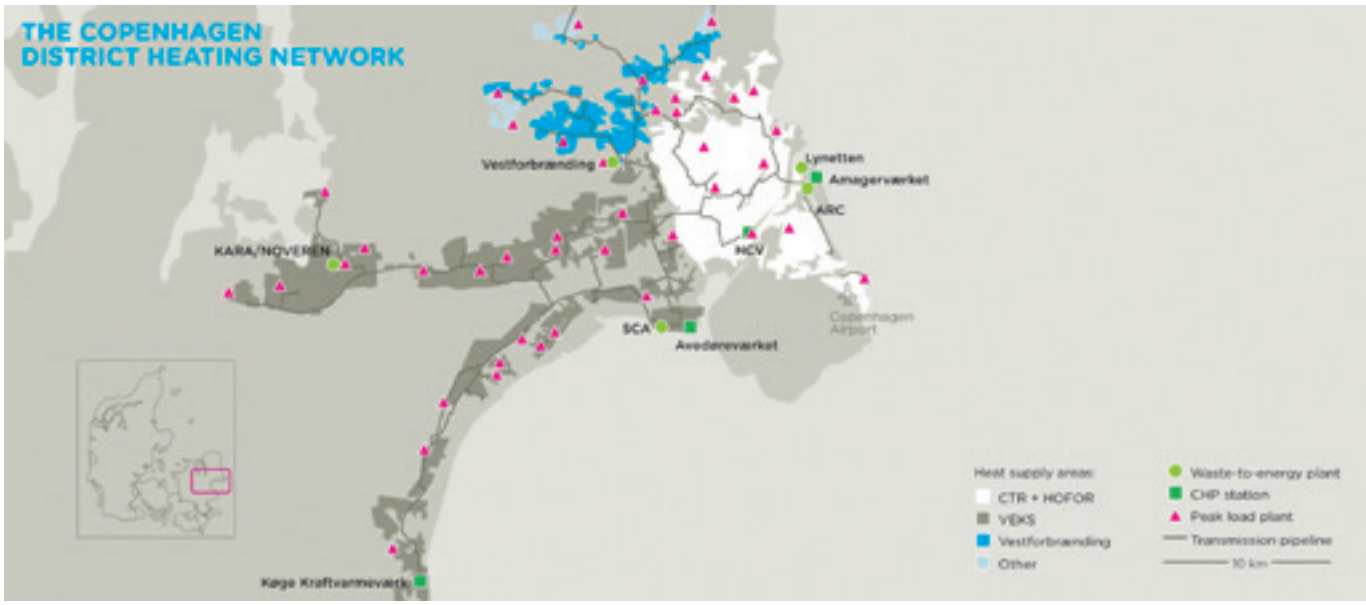
Establishment of district energy systems requires large investments in infrastructure compared to individual heat supply options based on fossil fuels. However, the operational costs and the environmental impacts will be remarkably lower due to economies of scale. This is particularly true if the heat is produced by efficient combined heat and power (CHP) plants and waste-to-energy plants, or if heat is produced by utilising excess heat from an industrial plant, for example a steel or cement plant. Likewise, co-generation of heating and cooling reduces the investments and increases the energy efficiency.

Levelised Cost of Energy

Danish experience shows that when evaluating the feasibility of district heating, it is important to consider the costs over the full lifetime of a heat supply system. In many cases, district heating is the most feasible solution over a full lifecycle analysis. Large infrastructure investments will be recovered after some years by lower annual costs. Naturally, the viability of installing district heating is also dependent on multiple factors, including the heating and cooling density in the specific area.

Flexibility: Integrating electrical and thermal energy systems

An increasing share of electricity is produced from fluctuating sources such as solar and wind, which do not always meet the demand. An important feature of the smart city is that a district energy system, which includes large thermal storages for heat and cold combined with heat pumps, electric boilers and CHP plants, offers large capacities that can respond efficiently to fluctuating electricity production and prices. Electric boilers consume large capacities of electricity at very low prices and can prevent the curtailment of excess power from solar or wind. The heat pumps have a steady consumption the majority of the year, but can be automatically interrupted at high prices. The CHP plants operate in the market only above an optimal electricity price level or if needed to support the power system. In fact, the thermal system acts like a huge electric battery - only in a much more cost-effective manner. In the longer term, the fast regulating CHP plants could be based on renewable gas, produced by surplus wind energy and stored in gas storage facilities.



The integrated district heating system in Greater Copenhagen (20 distribution and 3 transmission companies) delivers heat to a combined total of 70 million m². The computerised system is important for the optimal use of energy from waste and sludge (25%), efficient biomass CHP (70%) and boilers (5%). There is a growing market for local district cooling plants that mainly operate in symbiosis with the district heating system. Access to the data is vital for the ongoing optimisation. The remaining steam network is e.g. converted to hot water, and companies invest in large heat pumps for heating and cooling, large electric boilers and large thermal storages. Almost all new buildings are connected to the network, which is extended to new districts whenever it is cost effective. Illustration: Greater Copenhagen district heating

Digitisation of district heating in Aarhus

In 2017, AffaldVarme Aarhus (AVA), the heating utility of Denmark's second largest city, completed the implementation of their new smart metering solution from Kamstrup, which included 56,000 remotely hourly read heat meters. This was the first step in their efforts to optimise their district heating system, which has to supply more and more buildings and support a carbon-neutral and energy-efficient future. The increased amount of meter data provided transparency in the distribution network and enabled a new level of troubleshooting and improvement options. As a result, AVA has seen significant benefits and savings in terms of the improved operations of their meter park. In addition, the administration involved in collecting and handling meter data has been reduced and expenses for rectifying missing or incorrect readings have been virtually eliminated. AVA is currently working on further digitalising the district heating system in Aarhus by using innovative analytics to improve customer relations, increase operational optimisation, and enable better targeting of their investments in the district heating network.

Kamstrup A/S
AffaldVarme Aarhus

Previously the surplus heat was not used. The steam disappeared into the blue. Photo: VEKS

Excess heat and organic by-product from pectin production supply city with heat

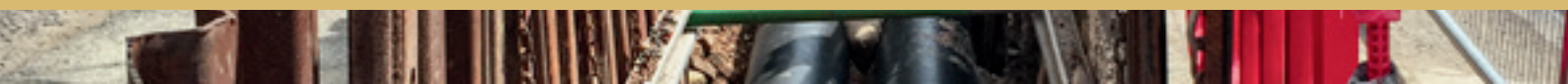
The production of pectin from orange peels at CP Kelco in the Danish town of Køge, induces both surplus heat and large amounts of organic by-products; resources which until recently were left unused. In 2017, a collaboration between the district heating company, VEKS, and CP Kelco was established in order to utilise the excess heat present in the local district heating network. Now the excess heat provides 2/3 of the energy required to reheat the cold return water from the district heating network, and provides 25% of the total heat demand in Køge District Heating Company. The overall Coefficient Of Performance (COP) is 18.5, which reveals the high efficiency of the system. The excess heat project went into operation 1 January 2018 and the production of district heating is estimated at 40,000 MWh/year. Furthermore, the organic by-products are sent to Solrød Biogas Plant where they are converted to biogas, which VEKS buys and uses for combined heat and power (CHP) production. In 2017, the annual production of green district heating was 28,500 MWh and green electricity 24 GWh.

VEKS, Solrød Biogas

Smart heating and cooling in London

There is a huge untapped potential for waste heat to replace fossil fuels in London. This potential cannot be utilised without district heating. Islington Council has created a publicly owned heat network inspired, among others, by Danish smart city solutions. The first phase began in 2012, where a 1.4 km network that serves 850 dwellings and four office blocks was established. The network is powered by a 1.4 MWe gas fuelled combined heat and power (CHP) plant combined with a heat storage tank. The second phase, which is still under construction, includes a 1 km expansion of the network supplying 450 existing social housing units, 150 new-built homes and a school. This extension includes an additional heat storage tank and a 1 MW ammonia heat pump that recovers heat from the London Underground and is powered by two gas CHP engines. Furthermore, it will deliver cooling to the Underground during summer. A smart control system will ensure that the system allows demand response to the power grid, as the consumption to the heat pump and production from the CHP units can be adjusted according to the electricity price. Phase 1 has saved 2,000 tonnes CO_2/year and reduced tenants' energy bills by 18% in 2016/17.

Islington council, London, Ramboll UK and DK,
Colloide Engineering Systems, Logstor, DKGEA



8. SMART ENERGY SYSTEM INTEGRATION

Sustainable power, heat, gas and water for all

To secure cost-effective and sustainable electricity, heating and cooling, gas, drinking water and wastewater treatment for all, cities need local infrastructure and utilities that cooperate in a smart way. Digitisation of utilities enables an integrated energy system and thereby a successful green transition.

Managing Director Helle Juhler-Verdoner, The Danish Intelligent Energy Alliance

The focus on energy-efficient use of resources and the green transition of the economy has been a long-term focus in Denmark that was kick-started by the oil crisis in the 1970s. Integrating electricity, heating and cooling, gas and transportation into a combined energy system has enabled Denmark to use resources efficiently. The holistic approach to the energy system stems from the implementation of combined heat and power plants in the 1980s and 1990s. While separate production of power delivers an operating efficiency of around 38%, co-production of heat and power increases efficiency rates to more than 85%. In other words, Denmark has a history of driving its infrastructure and utilities towards a mind-set of energy system integration, especially within power and heat.

Integrating water, biogas and power production

The water sector is responsible for approximately 8% of global energy consumption. If the consumption can be based on power produced by renewable sources such as wind or biogas, positive climate impacts will ensue. In addition, sewage sludge combined with other waste segments can increase production of biogas, which can be used for power production or utilised in the natural gas system and/or as fuel in heavy transportation.

Smart power production and consumption

Making our cities green requires a strong focus on power production – replacing fossil fuels with energy derived from renewable sources. In regions with no hydropower this implies increased amounts of intermittent resources, such as wind and solar power, in the energy system. Taking a smart approach to the way power is produced is one thing. Another is taking a smart approach to the way we consume power. Smart cities must shift their focus to ensuring flexibility on the demand side. Besides the flexibility in heating and cooling of smart buildings, the use of batteries in the electricity grid or combining batteries with flexible demand in transportation play an important role. Solutions are being developed and tested that benefit utilities in the distribution grid and/or deliver frequency stabilisation to the transmission grid.

With ambitions of a green transition and no fossil fuels by 2050, Denmark continues to take a smart approach to solutions that enable energy system integration. It is vital that utilities and municipalities collaborate with the industry to demonstrate how energy system integration can provide cheaper and greener solutions to benefit a city's inhabitants.

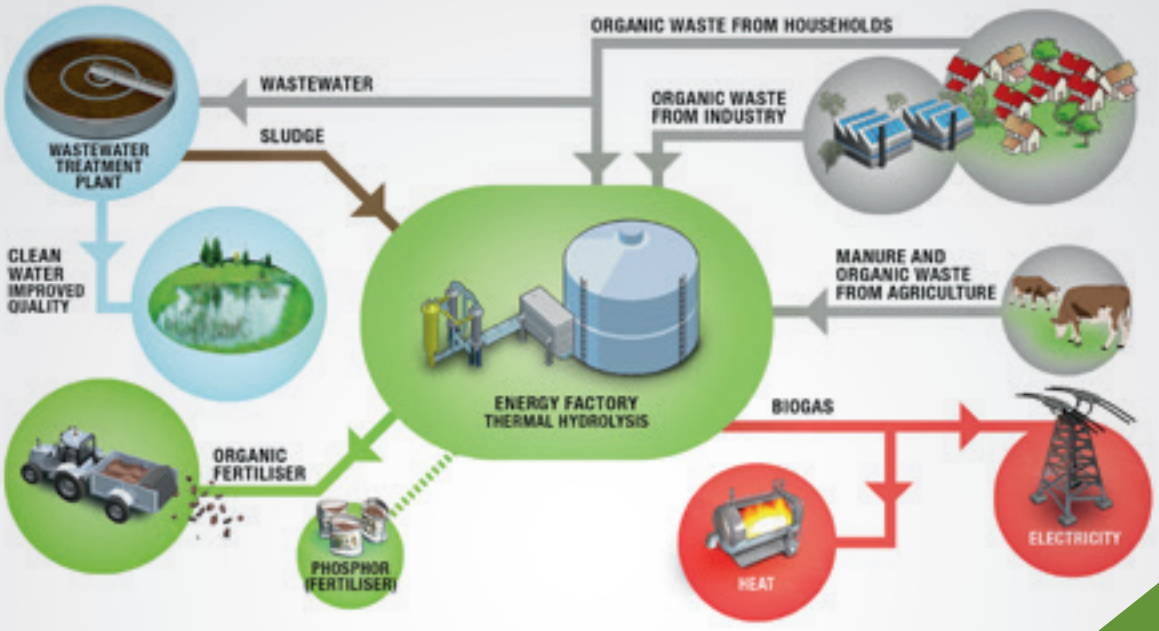
Vehicle-to-grid project to balance the electricity grid

How can series-produced, electric cars, as part of an operational fleet, be integrated into the power grid and deliver services that support the power grid both locally and on a system-wide level? This is the conundrum the Parker Project aims to explore. The electric cars are utilised as a flexible consumption source and as battery storage for the local and national energy systems. Involving the electric cars as an active part of the power grid poses regulatory and financial issues for the parties involved and requires continued support for research and development. The project is made possible because various actors across industry, research, distribution system operators (DSOs) and transmission system operator (TSO) have entered into a partnership where knowledge and best practices are shared. The results from the project will be used to further commercialise this type of technology – a technology that exploits the flexibility and features of the electric car to reduce and delay upgrades of the distribution network.

Energinet, Frederiksberg Forsyning, Insero, Technical University of Denmark, Nissan, Mitsubishi Motors Corporation, PSA ID, Enel, NUVVE

EnergyLab Nordhavn - new urban energy infrastructures
The increasing amount of power obtained from decentralised and fluctuating energy sources such as wind and sun creates new challenges for the electricity grid. Hence, it is increasingly important to develop smart grids that use data-driven control mechanisms and batteries to optimise operations. This will assist in adapting power consumption to the current supply and to the conditions in local networks. With a new battery of 460 kWh, Radius and ABB test whether the battery can contribute to more cost-effective operations. Moreover, when Radius takes advantage of the excess battery capacity by making it available in the market, the electricity company also contributes to balancing the overall system. Denmark will need to make significant reinvestments in its distribution grid in the coming years and battery solutions may be a cheaper option than traditional grid expansions. The project is supported by EUDP (Energy Technology Development and Demonstration Programme) and runs from 2015-2019. The lessons learned from the project can be used in both a national and global context.

DTU, City of Copenhagen, CPH City & Port Development, HOFOR, Radius, ABB, Balslev, Danfoss, CleanCharge, METRO THERM, Glen Dimplex and PowerLabDK



Wastewater treatment, energy production and resource recovery all-in-one
The wastewater treatment plant, Billund BioRefinery, is based on circular economy principles. Here, the resources currently stored in wastewater and waste are handled in such a way that at least 98% are recycled to create green electricity, heat and organic fertilizers. By combining the latest technologies in water purification, energy optimisation and biogas production in a full-scale project, Billund BioRefinery has made it possible to produce three times more energy than the refinery itself consumes, while simultaneously cleaning/recycling wastewater and waste in a more efficient manner. The immediate savings on electricity consumption are approximately 20% compared to the electricity used for water purification prior to the reconstruction. Energy production has doubled, and the plant's processing capacity for receiving wastewater and food waste has increased by approximately 25% with minimal construction investments. The project has a total payback time of just under 10 years. Billund BioRefinery creates a completely new outlook on wastewater and waste as valuable resources.

Billund Vand, Billund Kommune, Krüger, Aalborg University, Aarhus University

9. SMART PARTNERSHIPS

Driving smart city development through innovative partnerships

The concept of a 'smart city' is closely interlinked with public-private partnerships. It is driven by public demands such as sustainability, services for citizens and growth.

Head of Smart City Programme, Lone Pie Kelstrup, Gate 21

Smart city technologies enable broader societal development that allows for both sustainability and growth. Therefore, partnerships between public and private entities, universities and citizens are key for a successful smart society.

Shared innovation is win-win
Public-private partnerships encourage synergies and help foster innovation that results in far-reaching, integrated projects directed at societal needs. For industries, partnerships mean stable regulatory frameworks and shared innovation costs. They also provide valuable insights into public demands. Cooperation across municipalities enables a much more interesting market for innovative companies. Public institutions obtain knowledge of innovative commercial solutions and can integrate them in long-term political visions. The partnerships make it possible to leverage investments and keep public costs down when investing in green solutions.

Public demand is the driver
Denmark has many such partnerships both national and global. Each create different values and address different challenges. Several are well-established entities, while others are established in connection with larger regional or local investment projects. Other partnerships emerge from the interest of working with specific technologies and solutions. Common for the partnerships is that public demand is the key driver of innovation and investments. The Danish tender legislation allows for public innovative tendering through structured marked dialogue, innovation partnerships and competitions. Several tools, methods and partnership models are applied and tested, using design thinking, hackathons and anthropological methods. The latter help secure citizen involvement.

'Living labs' as a method
Several partnerships in Danish cities are developed through so-called 'living labs'. Here, smart city solutions are tested and developed in user-centred, transparent ecosystems. Through co-creation processes, concepts are developed in real life, allowing citizens, public institutions and private actors alike to question and contribute to the development and exploration of emerging city solutions. The labs function as major showrooms of innovative solutions for both national and international customers, as well as unique platforms for public and private innovation.

Photo: Rasmus Degnbol

Outdoor lighting and smart city living lab
DOLL (Danish Outdoor Lighting Lab) is Europe's largest test field, showroom and innovation hub within intelligent lighting. It showcases smart city solutions across mobility and parking, IoT communication systems, environmental monitoring, waste management and much more. Addressing the needs of the emerging smart and connected cities, DOLL set out to create an innovative playground and provide transparency in new complex markets, combining research, education and innovation in public-private partnerships. Buyers and more than 45 manufacturers of intelligent street lighting and other smart city solutions meet in neutral settings that address the entire supply chain: municipalities, suppliers, advisors/architects and utility companies. Buyers can experience state-of-the-art solutions in a natural environment. This gives decision makers better insights and knowledge to make investments in new lighting and smart city solutions. The solutions are displayed and data is collected and analysed in DOLL Visitor Centre, located in the heart of the living lab.

Albertslund Municipality, Technical University of Denmark, Gate 21 and 50+ private partners

Spurring Copenhagen's smart development through innovative partnerships

Copenhagen has set the ambitious goal of becoming the first CO_2-neutral capital by 2025. Each month, an additional 1,000 citizens are added to the city, which requires smart solutions that can optimise the operations, sustainability and liveability of the city. Copenhagen Solutions Lab is a unit under the City of Copenhagen that works with innovative partnerships to foster intelligent technologies and data-driven solutions. The future proofing of Copenhagen takes place via partnerships between the city, start-up companies, leading multi-national companies and knowledge institutions. An example is the Street Lab, a laboratory in the city centre, where new solutions are tested under real urban conditions, with real citizens in real time. The objective is to test the solutions and assess which ones to scale up both in Denmark and globally. Street Lab offers a vital source of knowledge about smart city solutions, making it possible to be one step ahead of city operations and services, which ultimately will result in greener and cheaper services for Copenhageners.

City of Copenhagen, Cisco, Citelum and TDC Erhverv

Cleantech cluster reduces energy consumption in Philippine malls

The Philippines have committed to higher ambitions for their green transition. Especially retrofitting malls across the islands offers a large potential to reduce energy consumption in the cities. In collaboration with the Danish embassy in Manila, the nationwide cleantech cluster, CLEAN, established MoUs with three shopping malls and one office building. Subsequently, CLEAN formed a consortium consisting of a number of Danish SMEs and larger companies across disciplines of architecture, consultancy, as well as clean and smart technologies. Over the course of nine months, the cluster focused on developing and utilising both the business and social capital of the partnership to eventually deliver an integrated, energy-efficient solution consisting of different technologies. A feasibility study shows that the financial savings for the mall owners cover the investment in the energy-efficient retrofit. Currently, one mall is looking to develop the world's first energy-plus mall in collaboration with the Danish consortium of technologies.

CLEAN, North Q, Kamstrup, Lite, Danfoss, HVAC Consult, Enopsol, Racell-Saphire Group, Danish Management Consultancy and C.F Møller

Triple helix playground innovates smart grid solution

Increasing the share of renewable energy in cities requires the development of smart system solutions and business models. GreenTech Center plays an important role in this, being a triple helix innovation playground where dedicated green companies, utilities and academic institutions together with Vejle Municipality cooperate on developing innovative, intelligent, green solutions. An example is a project that tests how smart grid technology can help office buildings deliver flexibility to the power grid in terms of specific demand-response services. An IT-system is installed in two existing office buildings – Green Tech Center in Vejle and the Maersk McKinney Møller Institute in Odense – that collects and processes the energy consumption and comfort data. In periods of peak load, the office buildings will be able to adjust their energy consumption and thereby contribute to stabilising the electricity grid. The project actively includes the users to ensure a satisfactory indoor climate and enhanced comfort levels, while the building assists in ensuring grid flexibility.

Green Tech Center, The University of Southern Denmark, Insero and TREFOR El-net

Photo: Peter Sørensen, CPH City & Port Development

Smart financing of urban development projects
After the Paris agreement it is clear that cities will play a central role in designing, financing and delivering a wide array of climate solutions. In Copenhagen, vast amounts of public land has been transferred to a publicly owned, privately managed corporation called CPH City & Port Development. It is an urban development company, jointly owned by the City of Copenhagen (95%) and the Danish state (5%). The company rezones the land – primarily in the old harbour and an undeveloped area between the airport and the downtown – for residential and commercial use. The company then uses the revenues projected by smart zoning and asset management - not taxes - to finance cross-city transit infrastructure, thereby spurring the regeneration of core areas of the city into sustainable and liveable areas for the citizens and businesses. An example of an urban project developed through this financing model is Nordhavn (North Harbour), which has received a platinum award for sustainability under the DGNB certification system.

CPH City & Port Development (By & Havn)

Smart cities need smart citizens!
The public-private partnership, ProjectZero, was created to inspire and drive Sonderborg´s transition to a ZEROcarbon community by 2029, focusing on buildings, transportation, local energy production and data/ICT. Here, achieving carbon-neutral growth and sustainable urban development is based on strong citizen involvement right from the initial planning process up until the implementation phase. A core aspect of ProjectZero is providing education at all levels. From Kindergarten to PhD, citizens learn how sustainable solutions can help them co-create a better planet. The public motivation is clearly reflected in active citizen participation. Private homes are energy retrofitted, connected to green district heating, and in rural areas the use of heat pumps is increasing significantly. Trained local banks, craftsmen and real estate agents support the citizens' green journey by offering competitive services and solutions. The journey often starts with shifting to inexpensive LED-bulbs and biking to work.

Sonderborg´s House of Science and ProjectZero
(SE, Bitten & Mads Clausens Foundation,
Sønderborg Municipality, Ørsted, Nordea-foundation)

Interactive bicycle path in Egedal
Photo: Lolle & Nielsen

Lighting Metropolis – collaboration across borders
Lighting Metropolis is the first decisive step in realising a vision for Greater Copenhagen as the world's leading living lab for smart urban lighting. The living lab is based on a network of connected demonstration projects, where municipalities and regions across Sweden and Denmark collaborate with corporate partners and scientists, making city spaces and buildings available to development, test and demonstration. By bringing the region's unique competencies into play, the potential of new lighting and smart city technologies are realised, benefitting cities, citizens and businesses.

Lighting Metropolis features more than 20 demonstration projects focusing on:
- Outdoor lighting; safety, attractiveness and accessibility.
- Indoor lighting; biological light, health, learning, work environments and Power over Ethernet.
- Smart urban lighting; intelligent sensor networks, Internet of Things and Intelligent Traffic Systems.
- Climate and environment; energy efficiency, environmental impact and sustainability.
- Light and art in the public realm.

Each demo project in the living lab is the product of innovation workshops, where project owners, companies and universities collaborate to develop the projects.

Lighting Metropolis is supported by Interreg ÖKS and a partner group consisting of 2 regions, 9 municipalities, 3 universities and 12 companies and organisations

LOOP CITY – cooperation across administrative boundaries
Copenhagen's surrounding suburbs are facing challenges of increased congestion, lack of growth and liveability. To increase green collective transport, it has been decided to construct a light rail system, connecting 10 municipalities around Copenhagen. The amount of private investments in LOOP CITY will be around EUR 4.5 billion. Furthermore, 36,500 new jobs are created and more than 32,000 new citizens will move to LOOP CITY in the coming years. In order to facilitate this development, there was a need for cooperation across administrative boundaries. Therefore, the organisation LOOP CITY was formed at the end of 2014 by the ten mayors and the Chairman of the Capital Region in cooperation with the Danish Business Authority. The result is a diverse range of projects to realise this vision. Examples include building mobility networks in cooperation with private companies, developing a large data hub with specific focus on how real-time data solutions can help solve traffic congestion and create mobility changes in people's behaviour, and testing of autonomous minibuses for first and last mile along the coming light rail – all projects supporting intelligent urban development and improved liveability.

10 municipalities, The Capital Region of Denmark, The Danish Business Authority, Gate 21, Copenhagen Capacity, Rambøll, COWI, Ørsted, DTU, RUC, TI, IBM, Nobina Technology

Photo: BIG & Glessner

10. GLOBAL CITY PARTNERSHIPS FOR CLIMATE ACTION

How mayors inspire their fellow mayors to prepare cities for a climate safe future

The best advice a mayor can get is from another city leader that has already found a workable solution to the problem. Partnerships between cities and through city networks help advance the urgent climate action needed to secure a climate safe future.

Director of Regions, Simon Hansen, C40 Cities Climate Leadership Group

Mayors across the world are increasing their focus on delivering the action needed to realise the ambitious goals of the Paris Agreement. Through global city networks such as C40, they collaborate to tackle climate change and exchange best practice examples of smart climate solutions that can make cities healthier, greener and more prosperous. The former mayor of New York, Fiorello La Guardia, famously said "There is no Democratic or Republican way of fixing a sewer". When mayors from across the C40 network meet and consider the impacts of climate change already underway in their cities and the growing threat it poses to future generations, there is no place for ideological division.

Implementing solutions based on lessons learned in other cities

The best person to convince a mayor of the benefits of a policy is another mayor. Global city networks like the C40 Cities Climate Leadership Group bring together mayors, city officials and urban planners to share lessons, ideas and inspiration through peer-to-peer learning. This model for city collaboration has brought wide benefits to cities and significant emissions savings, and it has the potential to deliver transformational change in these crucial years ahead for our planet.

For example, when Paris launched the Velib bike share scheme, just six cities in the C40 network had such systems in place. Today, 43 C40 cities have bike share schemes and Chinese cities are now taking cycle hire to entirely new levels, with hundreds of thousands of bikes transforming travel in Beijing and Shanghai. The bike share schemes represent hundreds of millions of bike journeys in cities each year generating zero greenhouse gas emissions. Similarly, the speed with which Chinese cities have rolled out fleets of electric buses has inspired mayors in European and North American cities to reassess their own targets. In October 2017, 12 cities - London, Paris, Los Angeles, Copenhagen, Barcelona, Quito, Vancouver, Mexico City, Milan, Seattle, Auckland & Cape Town – set a goal of procuring only zero emission buses by 2025. Today more than 30 C40 cities have made this commitment by signing the Green and Healthy Streets Declaration.

Partnerships drive greater ambition

These collaborations and partnerships help drive greater ambition among the world's great cities. Mayors understand that the cities which achieve the transition to a low carbon pathway, will be the healthiest, most sustainable and liveable cities in the future. This in turn will bring growth, jobs, investments and greater prosperity. By working together, cities can create the climate-safe and thriving communities that their citizens demand.

Photo: Henri Garat

New York City and Copenhagen: collaborating on climate resilience

New York City and The City of Copenhagen experienced extreme weather events in 2011 and 2012, respectively. As both coastal cities face rising sea levels and more frequent cloudbursts, they have signed a collaboration agreement that builds upon the successes of their respective resiliency projects. The agreement focuses on climate change adaptation, with an emphasis on cloudburst management. Based on lessons learned from the Climate Resilient Neighbourhood at Østerbro in Copenhagen, the New York Agency Department of Environmental Protection developed a masterplan for a neighbourhood in Southeast Queens. The masterplan covers an area with limited storm sewer infrastructure that suffers from flooding. The Department of Environmental Protection and NYCHA (New York City Housing Agency) will now be implementing a number of pilot projects to demonstrate the added benefits of cloudburst management. By using a combination of blue-green and traditional infrastructure, added benefits of CO_2 reductions, increased liveability and biodiversity will ensue.

City of Copenhagen, Ramboll, Danish Cleantech Hub, Tredje Natur, Henning Larsen Architects, SLA, Cowi, Orbicon, Envidan, Niras og DHI

Smart cities share best practices

In 2013, the Chinese County Haiyan that consists of approximately 440,000 citizens, identified best practices in the Danish city Sonderborg. This resulted in a fruitful cooperation between the two cities. By drawing on experiences from the Danish example, Haiyan created a) a Haiyan ZEROhouse to demonstrate sustainable construction and b) a sustainable urban development plan for an old part of the city area. The established city-city partnership has helped Haiyan establish itself as an ambitious Chinese city and to take additional steps in its city journey. In a European context, Sonderborg is responsible for creating a network through the EU Horizon SmartEnCity programme that consists of ambitious European small and medium-sized cities that aim to be first movers in the smart city transition. The project aims to move European cities towards the Smart Zero Carbon City vision. 28 cities are already sharing their experiences from integrated solutions, citizen involvement, urban planning etc. and interested cities can join at www.smartencitynetwork.eu and learn from best practice across Europe.

Sønderborg Municipality, DEM & Esbensen consulting engineers, Danfoss, Velux, Grundfos, Rockwool, CD-Link, ProjectZero

Learn more about Danish solutions within smart cities, find more cases from around the world and connect with Danish expertise at:

www.stateofgreen.com/cities

State of Green facilitates relations between Danish and international stakeholders seeking to drive the global transition to a sustainable, low-carbon, resource-efficient society. We are a not-for-profit, public-private partnership founded by:

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