CITY OF CAPE TOWN
ISIXEKO SASEKAPA
STAD KAAPSTAD

REPORT TO: THE EXECUTIVE MAYOR AND MEMBERS OF THE MAYORAL COMMITTEE

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1. ITEM NUMBER

2. SUBJECT

FEEDBACK ON THE INTERNATIONAL/OUTSIDE THE BORDERS OF THE RSA TRIP UNDERTAKEN FROM 27 SEPTEMBER 2021 TO 22 OCTOBER 2021 TO ATTEND THE CLIMATE CHANGE: ADAPTATION, MITIGATION AND RESILIENCE LEARNING PROGRAMME IN DENMARK

ONDERWERP

TERUGVOERING OOR DIE REIS NA DIE BUITELAND/BUITE DIE GRENSE VAN DIE RSA ONDERNEEM VAN 27 SEPTEMBER 2021 TOT 22 OKTOBER 2021 OM DIE LEERPROGRAM OOR KLIMAATSVERANDERING: AANPASSING, VERSAGTING EN VEERKRAGTIGHEID IN DENEMARKE BY TE WOON

ISIHLOKO:

INGXELO ENGEHAMBO KUMAZWE APHESHEYA/ANGAPHANDLE KWEMIDA YASEMZANTSI AFRIKA EQHUTYWE UKUSUSELA NGOWAMA27 KWEYOMSINTSI UKUYA KOWAMA22 KWEYEDWARHA 2021 UKUZIMASA IZIFUNDO EZINGOQEQESHO KWEZOQHELANISO, KWEZONGENELELO NEZOKUQILIMA KWICANDELO LEZOTSHINTSHO LEMOZULU, EZIQHUTYELWA EDENMARK

N2967

3. EVENT SUMMARY

EVENT DETAILS	
CONFERENCE/SEMINAR	CLIMATE CHANGE: ADAPTATION, MITIGATION, AND RESILIENCE LEARNING PROGRAMME
OTHER	N/A
DATE	27 SEPTEMBER 2021 – 22 OCTOBER 2021
VENUE	MULTIPLE
TOTAL COST TO THE CITY	R0.00
CITY	COPENHAGEN, AARHUS
COUNTRY	DENMARK

ATTENDEE DETAILS	
NAME AND SURNAME	DESIGNATION
INA NEL	PRINCIPAL PROFESSIONAL OFFICER

PROVIDE SUMMARY OF HOST ORGANISATION / CITY

Danida is the term used for Denmark's development cooperation, which is the area of activity under the Ministry of Foreign Affairs of Denmark.

South Africa (the City of Tshwane and other Metropolitan Municipalities / South African Cities Network) are affiliated with a Danish supported Strategic Sector Cooperation project. The focus of cooperation is centered around smart cities, city planning / urban development, growth and liveability, water, and energy. The Strategic Sector Cooperation is a partnership between Danish and local authorities and takes place in areas where Danish businesses have special competencies and in countries that have particular strategic and commercial significance for Denmark. Sector councillors with sector-specific expertise are posted at Danish embassies. The Sector counselor at the Royal Danish Embassy selected and endorsed the candidates in collaboration with the affiliated organisations (CCT) and submitted the application to Danida Fellowship Centre (DFC).

DFC is responsible for the educational, administrative and practical aspects of the training.

DFC has contracted NIRAS to develop and implement the learning programme.

NIRAS is one of the largest consulting engineering companies in Denmark, employing 2500 staff.

4. OBJECTIVE

The knowledge acquired during the Climate Change: Adaptation, Mitigation and Resilience learning programme in Denmark has the potential to assist the City in assessing and discussing options for low carbon, resource-efficient and climate-resilient development.

5. OUTCOMES

Information sharing of climate change mitigation and adaptation measures witnessed in Denmark applicable to all sectors (Energy, Transport, Buildings, Spatial Planning, Waste generation and management) of interest to the City.

6. ACTIONS REQUIRED

A well-written feedback report to the Executive Mayor and Members of the Mayoral Committee after returning from the learning programme on the knowledge acquired, lessons learned and examples witnessed (this report).

7. IMPLICATIONS

7.1	**Constitutional and Policy Implications**	No ☒	Yes ☐
7.2	**Environmental implications**	No ☒	Yes ☐
7.3	**Financial Implications**	No ☒	Yes ☐
7.4	**Legal Implications**	No ☒	Yes ☐
7.5	**Staff Implications**	No ☒	Yes ☐
7.6	**Risk Implications**	No ☒	Yes ☐

7.7 <u>POPIA Compliance</u>

☒ It is confirmed that this report has been checked and considered for POPIA Compliance.

8. RECOMMENDATIONS

It is recommended that:

a) the feedback report on the Climate Change: Adaptation, Mitigation and Resilience learning programme undertaken by Ina Nel from 27 September 2021 – 22 October 2021 **be noted**.

AANBEVELINGS

Daar word aanbeveel dat:

a) Daar kennis geneem word van die terugvoeringsverslag oor die leerprogram oor klimaatsverandering: aanpassing, versagting en veerkragtigheid wat van 27 September 2021 tot 22 Oktober 2021 deur Ina Nel onderneem is.

IZINDULULO:

Kundululwe ukuba:

a) Makuqwalaselwe ingxelo eyinkcazelo ngokumalunga nehambo engokuzimasa inkqubo engezifundo zoQhelwaniso, ezoNgenelelo nezokuLuqilima kwicandelo lezoTshintsho lweMozulu, ethe yaqhutywa nguIna Nel ukususela ngowama27 kweyoMsintsi ukuya kowama22 kweyeDwarha 2021.

9. GENERAL DISCUSSION

9.1. Introduction

The Danish Climate Act of 18 June 2020 mandates that Denmark is to reduce emissions of greenhouse gases by 70% in 2030 relative to the 1990 level. By 2019, total greenhouse gas emissions have already been cut by 40% from the 1990 level. Based on current adopted policies (i.e. continuation of the current business as usual) the Danes expect to reach a reduction of 55% in 2030, 15% short of the demands of the Climate Act. The following reductions are required in specific sector emissions from 2019 - 2030[1]:

- **Electricity and district heating (excl. waste incineration):** expected reduction of 4.7 million tonnes of CO_2e. Sector are expected so emit less than 0.3million tonnes CO_2e.
- **Biogas**: Expected to account for 72% of mains gas in 2030, with emissions 2.3 million tonnes CO_2e lower than in a scenario with strictly non-renewable mains gas.
- **Waste:** Emissions from waste incineration are expected to be reduced by 1 million tonnes CO_2e. Overall, waste incineration is expected to emit 0.6 million CO_2e by 2030. Emissions from other waste management and from F gases will be reduced by 0.6 million tonnes CO_2e, emitting 1.1 million tonnes CO_2e in 2030.
- **Transport**: Expected to reduce by 2 million tonnes CO_2e, so that the sector will contribute 11.5 million tonnes CO_2e in 2030. Reductions in emissions from passenger cars are expected to contribute half of overall sector reductions.
- **Agriculture, agricultural land, forests, horticulture and fisheries**: Expected increase of 1 million tonnes CO_2e by 2030.
- **Carbon Capture and Storage (CCS)**: Expected reduction by 0.9 million tonnes CO_2e in 2030.
- **Manufacturing industries**: Expected reduction of 1.5 million CO_2e. The reduction is primarily due to a reduction in energy-related emissions from manufacturing industries.

[1] Source: Denmark's Climate Status and Outlook, 2021, accessible at Denmark's Climate Status and Outlook | Energistyrelsen (ens.dk)

- **Households**: Expected reduction of 1.5 million CO_2e, stemming primarily from individual heating.

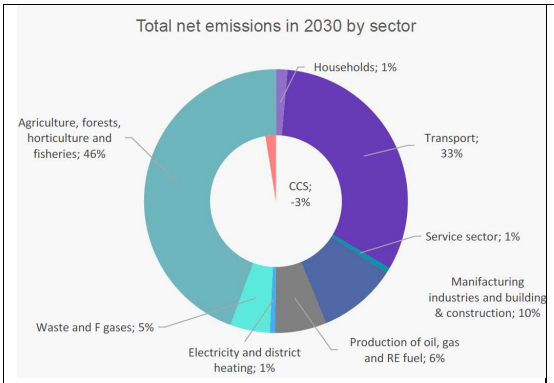


Figure 1: Expected contribution in percentage of each sector to total net emissions in 2030.

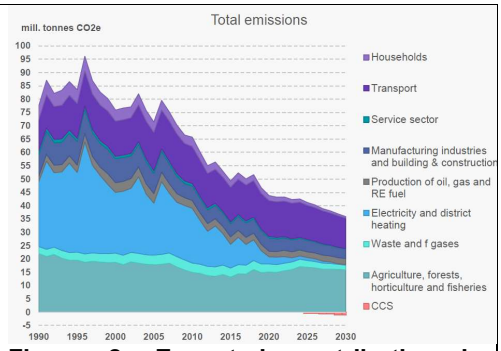


Figure 2: Expected contribution in million tonnes of CO2e of each sector to the total net emissions. Notice the large reduction in Electricity and district heat emissions since 1990.

The Climate Change: Adaptation, Mitigation and resilience course that I attended presented several real-life examples and case studies of how Denmark is slowly but surely achieving the climate action goals mandated in the Climate Act.

9.2. Teaching Methodology

The teaching methodology throughout the learning programme was premised on Case Based Learning. This methodology entailed a three-step process:

1) Research, lectures, internet searches, reflection, and a group discussion before visiting the case.
2) Excursions, information gathering at the site, and interviews with on-site personnel.
3) Each group shares the information with the rest of the delegates through presentations and discussions after attending the site visit.

The presentation and discussions covered the following elements:

1) Context, background to the practice, concept, or business model
2) Any synergies or multiple benefits or cross-sectorial aspects
3) Main learning points from the visit.
4) How does the case relate to the six pillars of Green Growth and the Sustainable Development Goals (SDGs)?
5) Is the practice, concept, or business model transferrable to our home countries?
6) Strengths and weaknesses in the practice, concept, or business model. Can it be improved, developed, downscaled or upscaled to fit our home countries better?
7) Challenges or barriers to implementation in our home countries, considering legal or policy, owners or investors, market mechanism, stakeholders, investments requirements.

9.3. Green Growth principles and Sustainable Development Goals

We spent the first week in isolation attending online courses in Green Growth principles and sustainable development goals (SDGs). Niras and Aarhus municipality enshrine the SDGs in everything that they do. Projects are developed and motivated for funding in accordance to multiple SDGs, thereby realizing synergies and achieving the SDGs on several fronts. Awareness about the SDGs is achieved through naming their meeting rooms or boardrooms after the SDGs (refer to Figure 6) and having signage or stickers in public or frequently visited areas (refer to Figure 3 and Figure 5).

Figure 3: Me and another delegate at the SDGs at Niras's Offices in Allerød.

Figure 4: SDG cubes in the studio of Niras's Green Tech Hub

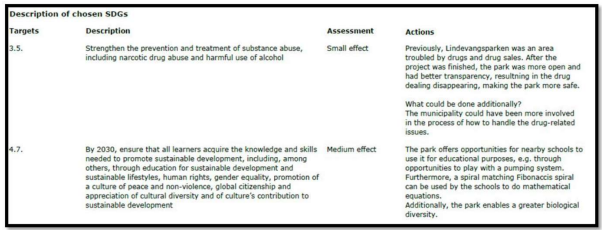
Figure 5: SDG signage on columns in the common area of Niras's Aarhus offices

Figure 6: SDGs used to name the different boardrooms at Niras's Aarhus offices

Niras developed an SDG Capture Tool (refer to Figure 7) that is free to the public and easy to use. The SDG Capture Tool is demonstrated and explained in the following guideline "Guidance on integrating the sustainable development goals in urban climate change adaptation projects", citing the benefits of integrating the SDGs at project level (refer to Figure 8 and Figure 9).

Figure 7: Landing page of the SDG Capture Tool

Figure 8: The completed result of the SDG Capture Tool



Description of chosen SDGs

Targets	Description	Assessment	Actions
3.5.	Strengthen the prevention and treatment of substance abuse, including narcotic drug abuse and harmful use of alcohol	Small effect	Previously, Lindevangsparken was an area troubled by drugs and drug sales. After the project was finished, the park was more open and had better transparency, resultning in the drug dealing disappearing, making the park more safe. What could be done additionally? The municipality could have been more involved in the process of how to handle the drug-related issues.
4.7.	By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development	Medium effect	The park offers opportunities for nearby schools to use it for educational purposes, e.g. through opportunities to play with a pumping system. Furthermore, a spiral matching Fibonaccis spiral can be used by the schools to do mathematical equations. Additionally, the park enables a greater biological diversity.

Figure 9: Example of the level of effect identified for each action about the SDG targets identified for Lindevangsparken, Denmark

Applicability to the CCT

On Thursday, 24 June 2021 the City of Cape Town and the City of Aachen launched the joint edition of the Mayor's Portfolio of Urban Sustainability to mark the 20th Anniversary of the Aachen – Cape Town LA21 Partnership. This publication states *"The City of Cape Town is in the process of localizing the SDGs through, among others, developing an SDG implementation plan, establishing a cross-departmental SDG task team, and working towards aligning its IDP (2022 – 2027) with the 2030 Agenda for Sustainable Development."* Refer for instance also to the report: *"Localisation of the 2030 Agenda and its Sustainable Development Goals in Cape Town."* by Sylvia Croese, November 2019. The opportunity exists for the City to potentially adopt some of the examples seen from Niras to entrench the SDGs in Cape Town.

The City's vision for the most recent new Climate Change Strategy incorporates five out of the six Green Growth Principles: "To become a climate-**resilient**, **resource-efficient**, and **carbon-neutral** City that enables **inclusive** economic development and **healthy, thriving** communities and **ecosystems**." The only

lacking Green Growth principle from the vision, i.e. Innovation and Job Creation, is one of 10 principles underpinning the City's Climate Change Strategy.

9.4. NMT

Even although transport was not necessarily an individual topic in the learning programme, there were two City walks, one in Copenhagen and one in Aarhus to observe and discuss several climate- and environment-related features, including bicycle infrastructure, flood control measures, and climate adaption measures. Since the NMT infrastructure in Denmark is so prominent and forms such an integral part of their 2025 Climate Plan, I decided to report on some of my observations during my stay.

Copenhagen is more than a decade into its current Bicycle Strategy (2011 – 2025) with the ambitious goal of becoming the world's best bicycle city. "A bicycle-friendly city is a city with more space, less noise, cleaner air, healthier citizens and a better economy". The Bicycle Strategy, therefore, promotes the City of Copenhagen's official health policy and making Copenhagen carbon-neutral by 2025.

A summary of Copenhagen's Bicycle Strategy is presented below. Notice the key objectives of the strategy: improving the safety of the cyclist, ensuring that travel times on bicycles are competitive with other modes of transport, and making the journey as comfortable as possible for the cyclist.

Figure 10: Summary page from Copenhagen's Bicycle Strategy (2011 - 2025)

I had the good fortune of witnessing several of the above-mentioned initiatives during my time in Copenhagen:

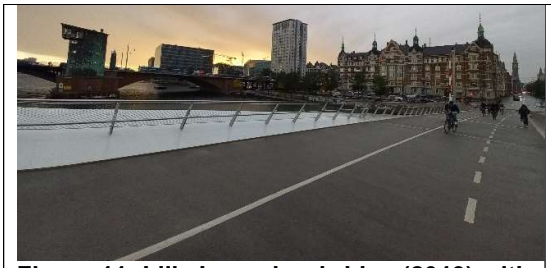


Figure 11: Lille Langebro bridge (2019) with 3m wide pedestrian path and 4m wide bi-direction cycleway. +/- 10 500 users a day.

Figure 12: Cykelslangen, bicycle-only bridge completed in 2014. 20 700 cyclists per day.[2]

Figure 13: Circlebroen, bicycle and pedestrian bridge connecting Christianbro with Applebys Plads, +/- 5 000 daily users.[3]

Figure 14: Hand- and footrests for cyclists

Figure 15: Signage to indicate a green wave cycle route and the average speed to maintain to ride the green wave.[4]

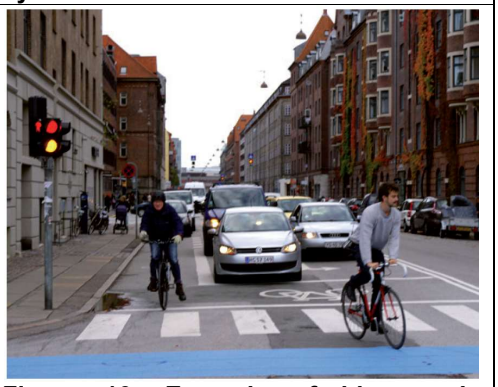


Figure 16: Example of blue cycle crossings and bike boxes to give cyclists an advantage when the light turns green.[5]

[2] Source: Rasmus Hjortshøj – COAST Studio, copied from Copenhagen's Bicycle Bridges — Copenhagenize Design Co.
[3] Photo Credit: Valeria Finnemore, another delegate on the Climate Change Adaptation, Mitigation and Resilience learning programme.
[4] Source: Bikes Now Get Green Waves Along Folsom, North Point, Fulton – Streetsblog San Francisco
[5] Source: Focus on cycling: Copenhagen Guidelines for the design of road projects.

Figure 17: Bicycle repair station, wheel pump, and tools.

Figure 18: The cargo bike is used to transport children and shopping with a weight allowance between 40 – 250kg. 26% of all families with two or more children have a cargo bike.[6] Cargo bikes can be borrowed from Miljøpunkt NGO to try out on a trial basis before families invest.

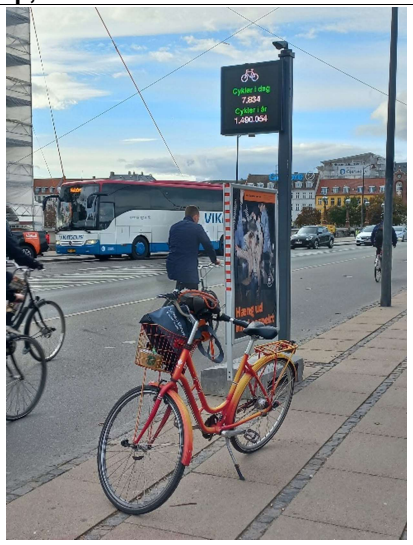


Figure 19: To determine the success of the Bicycle Strategy, facts and figures have to be counted. Signage also assists with creating awareness and motivation.

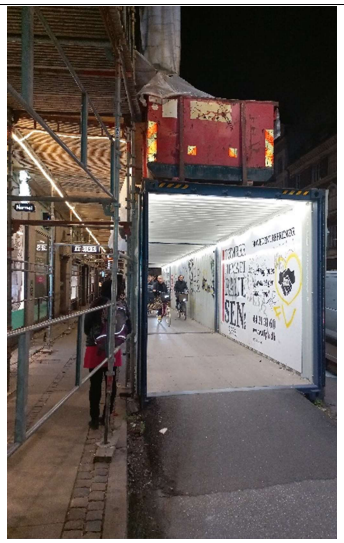


Figure 20: Pedestrian walkways and cycle lanes are kept open using scaffolding and open-ended containers whenever there is roadside construction work in progress.

[6] Source: Copenhagen City of Cyclists, The Bicycle Account 2018.

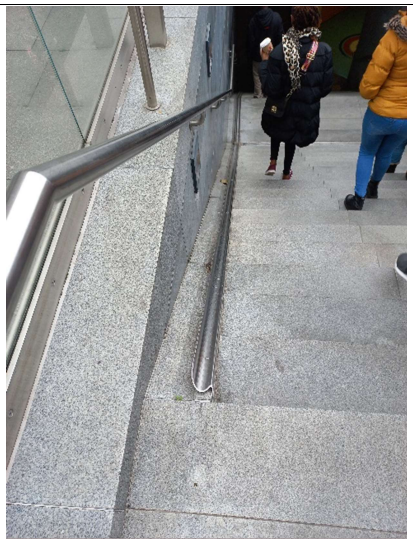


Figure 21: Bicycle rail for ease of carrying a bicycle to the underground metro trains.

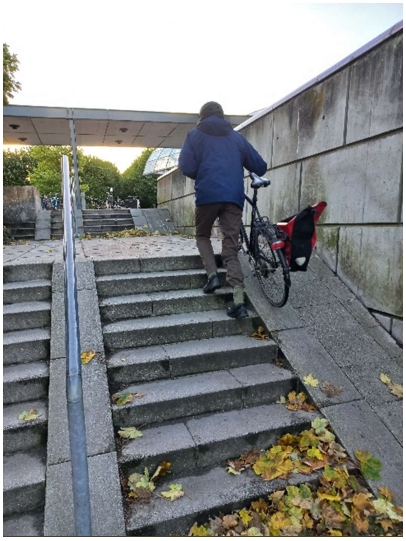


Figure 22: Bicycle siding next to staircases

Figure 23: Double Storey bicycle racks save on storage space at the train stations.

Figure 24: symbols used for the Cycle Superhighways and the public trains.

Figure 25: Bycyklen (The City Bike) are leasable public bike-share E-bikes all controlled from an app on your smartphone or the touchscreen tablet located on the handlebars.

Figure 26: Seating in the middle of the S-train is less popular with passengers and is therefore used as bicycle compartments.[7]

Figure 27: S-Train compartments were designed with 60 fold-up seats and bike racks beneath each seat.

[7] Source: The Life-Sized City Blog: Massive Passenger Increase After Bikes Allowed Free on Trains (copenhagenize.com)

Public entities lead by example. The City of Copenhagen's transport habits is included in their 2025 Climate Plan's goal to become carbon-neutral by 2025. From 2011 – 2017 concentrated efforts were put into working with an internal transport plan including better bike-share options, bicycle-parking facilities, We Bike to Work campaigns, purchase of e-bikes and e-cars. In 2018 parking enforcement officers in the City of Copenhagen switched from e-cars to e-bikes improving the health of employees and making it easier to get around town.[6]

Preference is given to cyclists above cars to either deliver on reduced commuting time or make it safer for cyclists. **Intelligent Traffic System (ITS)** provides green waves (not to be confused with the green routes) for cyclists and busses. Green waves for cyclists means a series of traffic lights synchronized so riders don't hit a red light if they maintain a speed of 20km/h (refer to Figure 15). Sensors embedded in the asphalt register the number of cyclists and the traffic lights adjust to give green lights to groups of cyclists. The intelligent signal system requires buses to communicate their position, passenger load, and schedule delay to the traffic lights ahead of time. The light network would then extend a green anywhere from eight to 30 seconds, to avoid bunching and make up for lost time. The sophisticated signals can cut travel times for transit riders by 5 and 20 percent and for cyclists by 10 percent.[8] **Blue bicycle lanes** through intersections and pulling back the stop lines for cars at intersections increase the visibility of cyclists in traffic and provide them with an advantage when the light turns green (refer to Figure 16). You can bring your **bicycle on the metropolitan rail service (S-trains)** at all hours (except at Nørreport Station) free of charge (refer to Figure 26 and Figure 27). For the Harbour Bus, the Metro, and the National rail you have to purchase a ticket for your bicycle and there are rush hour restrictions on the Metro and National rail.

The general tendency is that cycling is increasing in the bigger cities and decreasing in the metropolitan outskirts and the countryside. To curb this phenomenon, 27 municipalities and the Capital Region of Denmark have joined forces to create the **cycle superhighways** to help encourage more people to cycle longer distances. The aim is to offer a mode of transport that is equal to public transportation and the car. To achieve this it is paramount to have a brand and a concept with which inhabitants of the region are familiar. To this end the C-logo was designed, to promote wayfinding and hopefully become as recognizable as the "M" used for Metro's and "S" used for the S-train (refer to Figure 24).[9] The average commute on the cycle superhighways is 11km. To date, eight cycle superhighways have been built with another eight on the way, hoping to expand to 45 routes, totaling 746km, by 2045. The total investment in the cycle superhighway network is estimated at 295 million euro by 2045, while estimations suggest a socio-economic saving of 765 million euro. It is believed that the cycle superhighways can save 1500 tonnes of CO_2 annually, resulting in 92% less CO_2 emission when encouraging commuters to switch from car to bike. It is believed that the cycling phenomenon could result in 40 000 fewer days of sick leave annually and that 30 minutes of daily cycling contributes to 30% reduced mortality in adults.[6]

[8] Source: Copenhagen's New 'Intelligent' Traffic-Light System Will Giving Bicycles Priority - Bloomberg
[9] Source: Cycle Superhighways, Capital Region of Denmark, 2019

Another means of reducing the number of vehicles in Copenhagen is to define **Park and Pay areas** which are divided into four pay zones with different levels, ranging from 11DKK/h (+/- R26.4/h) to 39 DKK/h (+/- R93.6/h). EVs, hydrogen cars and electric motorcycles can park for free at street level in public parking spaces. In Aarhus, NIRAS employees, could pay up to DKK 1305 (± R3132 / month) per month in parking fees if they choose to travel by car.

Applicability to the CCT

The City has good **strategies** and **policies** in place to promote NMT and bicycle use in the metropolitan area with similar key focus areas as the City of Copenhagen, most notably:

- Volume 1 (2005) & 2 (2014) of the NMT Policy and Strategy
- Universal Access Policy for Transport for Cape Town (2014)
- Cycling Strategy (2017)
- Comprehensive Integrated Transport Plan (2018 – 2023)
- Travel demand management strategy for the City of Cape Town (2017)

The City, being a large employer, is considering several **Travel Demand Management (TDM) measures** through initiatives tailored to City staff such as a Parking Cash-out Strategy to encourage more efficient commute modes, the Flexible Working Programme encouraging telecommuting; or working remotely or at-home options, and the Travel SMART's pilot staff bike-share project which was launched in 2013.

The City is not averse to employing **Intelligent Traffic Systems**, being home to the first integrated public transport, traffic, and safety and security management centre in South Africa, officially opened in May 2010. There might however be room for utilizing ITS to provide preference to cyclists. The City normally indicates cycle lanes using green paint. The City can consider the design of infrastructure (Figure 21, Figure 22, Figure 23, Figure 24, Figure 26, and Figure 27) and fee structure of the S-trains, Metro, and National rail in Copenhagen wrt allowing bicycles on trains in light of the planned Public Transport Interchange and Light Rail Transport of the **Bellville CBD Opportunity Area.**

Although maybe not yet termed "cycle highways", there are several examples of **long-distance cycle routes within Cape Town**[10]**,** with cyclists having access to at least 450km of cycle lanes across the City, designed according to different bicycle route classes.

Only time will tell when the uptake of **E-bikes and cargo bikes** (e.g. for last-mile delivery) will prosper but it might be a good idea to already incorporate this in our forward thinking and design of road infrastructure.

[10] Source: CAPE TOWN COMMUTER ROUTES & BIKE MAP - Bicycle South

9.5. Water and Waste[11]

Water

Water scarcity is a growing problem in many parts of the world. According to the UN, **global water consumption will increase by 30 per cent by 2030** due to population growth and increased wealth. For Denmark, addressing this concern is a combination of a strong political focus on reducing leakages in water pipes, introducing compulsory use of water meters and taxes for both water use and wastewater discharge as well as carrying out save water information campaigns and encouraging the use of water saving devices. As a result, **Denmark has reduced its water consumption by nearly 40 percent** since 1980 and household water consumption has been reduced to just **104 litres per person per day.**

Today, **water is considered an asset** with enormous potential to **enhance daily life** for people living in cities through new **blue and green urban spaces with better recreational opportunities for the local residents**.

Providing safe and affordable drinking water is a cornerstone in the UN Sustainable Development Goal 6 (SDG 6). This requires a combination of **high quality water sources, effective treatment plants and an efficient distribution network with minimum water loss.** Water supply in Denmark is highly **decentralised** with waterworks situated all over the country. Quite uniquely, the country uses **groundwater as its sole source of drinking water**. As a result, only simple treatment is needed and tap water is not chlorinated thanks to a highly efficient distribution system where bacteria and other impurities are minimised.

Globally, less than half of all wastewater is collected and even less than 20 per cent of it is treated before it is released back into nature. **In Denmark, 95 per cent of all wastewater is treated** – and often to a higher standard than the legal requirements.

Danish water treatment solutions include UV disinfection systems, electrolysis technology, membrane technology for water purification and desalination of seawater, treatment technologies for stormwater runoff and nature-based solutions for improving the overall quality of our water environments.

In Denmark, water resources management is often handled in **partnerships between the public and the private sector.**

Waste

The most efficient form of **waste management** is simply to reduce the amount of waste we produce. Taking the **end-of-life phase** of a product into account during the **design phase** is one approach to **waste prevention**. In Denmark, if

[11] The introductory paragraphs gives a high level explanation of water and waste resources and treatment in Denmark. The information was sourced from Water | State of Green and Waste | State of Green

waste prevention is not possible, the **waste hierarchy** provides a guiding principle for municipalities' waste management strategies as priority is given to pre-treatment for reuse, recycling, alternative utilisation such as incineration and finally disposal into landfills.

Figure 28: Waste Hierachy for Municipalities' waste management strategies in Denmark

Successful waste management is about utilising the potential of waste by increasing recycling and reuse of materials while limiting the amount of waste that goes to landfill. By considering the choice of materials, how a product is assembled, and equally important disassembled, designers can improve the recyclability of products and drastically reduce the amount of waste produced. Denmark has an ambitious national strategy that aims at **recycling 50 per cent more waste by 2020** and to increase utilisation of **waste as a resource**.

Denmark has succeeded in diverting municipal waste from landfills using an efficient policy mix of regulatory and economic instruments, such as the 1997 ban on landfilling waste that can be incinerated and the gradual increase of the landfill tax (e.g. DKK 475/tonne in 2018).[14] **Each year,** the Danish waste sector collects and processes **15 million tonnes of waste** and the Danish **waste-to-energy plants** convert the waste for heat and electricity production. Energy recovery from the combustion process, which occurs via cogeneration of electricity and heat, covers around 6% of the Danish electricity supply and 24% of the Danish heat supply.[12] **Danish incineration plants are the cleanest and most efficient in the world**, and they are part of the reason why less than **5 percent of the country's waste goes to landfills.**

Achieving a climate-neutral waste sector by 2030 (The Danish waste dilemma)

The Danish government and a wide majority of the Danish Parliament has entered into an agreement in June 2020 securing a climate-neutral waste sector by 2030. The agreement will reduce Denmark's greenhouse gas emissions with 0.7 million tonnes by 2030.

[12] Source: Environmental assessment of amending the Amager Bakke incineration plant in Copenhagen with carbon capture and storage - V. Bisinella, J. Nedenskov, Christian Riber, Tore Hulgaard, Thomas H. Christensen, 2022 (sagepub.com)

This new agreement entails the following requirements[13]:

- Danish residential household waste must be sorted in 10 different waste types
- A standard detached house shall have no more than 2 - 4 waste bins with several compartments for the 10 waste types.
- *A strong(er) recycling sector.* The municipalities are required to treat all recyclable waste. Municipalities must be able to document where and how citizens' waste is recycled. Investments should be geared towards recycling rather than incineration.
- 60% of all plastic must be recycled, assisting with the goal to remove 80% of plastic waste from reaching incineration plants.
- The capacity of the Danish incineration plants must be reduced to match the Danish waste volumes.

Denmark has reported the highest amount of municipal waste per capita in the OECD since 2007, reaching 785 kg per inhabitant in 2017, far above the OECD average of 524 kg.[14] Denmark has 23 incinerators capable of burning 3.8 million tonnes of waste a year, requiring more waste than the Danes produce however. To this end, Denmark nearly imported 1 million tonnes of waste in 2018, mainly from the U.K and Germany.[15]

Imposing a capacity ceiling for Danish incineration plants to match Danish waste volumes requires a 30% reduction**. The action plan** to implement this reduction will look at drawing up a **list of plants that will close** according to the capacity ceiling. At the same time, the plan must ensure that the most environmentally unfavourable plants close and improvements implemented to benefit businesses and consumers. If the plan does not meet the set criteria, a supply-based model will take effect instead, where **capacity will be reduced through increased competition.** If this does not ensure that capacity develops in line with waste volumes, a **tax on incineration** may be introduced unless another method proves to be more efficient.

As Denmark moves towards more recycling and less incineration (as imposed by the new regulation), it is experiencing excess incineration capacity. This is problematic, as incineration costs increase significantly if less waste is processed than the plant was designed for. Neighbouring Germany, the Netherlands and Sweden also experience excess capacity, and the UK extending its own incineration capacity, is creating rising price competition, which might very well cause certain incineration plants to close pre-maturely.

Closing down incineration plants before end-of-life have two (domestic) problems of their own. Firstly, as previously mentioned, incineration plants contribute up to 24% of the Danish district heating supply and 6% of the national

[13] Source: New political agreement to ensure a green Danish waste sector by 2030 (stateofgreen.com)
[14] Source: Waste, materials management and the circular economy | OECD Environmental Performance Reviews: Denmark 2019 | OECD iLibrary (oecd-ilibrary.org)
[15] Source: Denmark's 'devilish' waste dilemma – POLITICO

electricity supply. Reduction in these supply streams will have to be mitigated by other means.

Secondly, municipalities own most of the waste management infrastructure – 90% of the 40 operating landfills and all waste incineration facilities – whereas some 300 out of the approximately 350 recycling plants are privately owned. Waste incinerators have been financed mostly through public funding in the form of municipal loans from a special credit institution, Kommunie Kredit, with municipal guarantees. The agreement aims to compensate municipalities for stranded costs setting aside EUR 26.8 million to this effect.

Without efforts to reduce emissions, the country's waste to energy plants are expected to generate around 1.5 million tonnes of CO_{2eq} in 2030 or almost 4% of the national total. The government sees plastic waste behind much of the CO_2 released and hence imposed the requirement of removing 80% of plastic from the residual waste stream reaching the WtE plants. Current estimates put the amount of plastic waste incinerated in Denmark at 370,000 tonnes a year.[16]

Note that Denmark currently already impose taxes on the greenhouse gases emitted by WtE plants and it is therefore in their own financial interest to reduce the waste stream contributing the most to the greenhouse gases taxed:

- The CO_2 tax is levied per tonne of CO_2 emissions from waste incineration, except for waste loads containing pure biomass. By 2018 the tax amounted to DKK 173.20 (EUR 23.2) per tonne. In addition, most waste incineration plants take part in the EU Emissions Trading System (ETS), and pay emission allowances for heat and electricity production. Waste incineration plants are therefore subject to double regulation on CO_2 emissions.[14]
- Taxes on emissions of NO_X and sulphur are imposed on some waste incineration plants. The tax on sulphur emissions is DKK 10.50 (EUR 1.41) per tonne, and that on NO_X emissions is DKK 5.10 (EUR 0.68) per tonne.[14]

Imported RDF contains a higher plastic content than domestic Danish post-sorting waste. Denmark is therefore also considering ways of reducing refuse-derived fuel (RDF) imports. The Netherlands achieved a 50% reduction in waste imports after applying a €32 per tonne waste import tax. Danish incineration plants is however the cleanest and most efficient in the world, and the concern is that the displaced waste (due to a lack of imports) will cause more overall / international environmental damage when either incinerated or worst, landfilled in the countries from which it was previously imported. Some authors propose a different approach, suggesting that RDF should be seen as a fuel, processed

[16] Source: Danish ministers call for cuts to waste imports | EUWID Recycling and Waste Management (euwid-recycling.com)

to an end user's specification and therefore Denmark should consider reducing plastic content through specification rather than a blanket tax addition.[17]

The fact of the matter remains that waste to energy plants are expensive capital investments that brings about their own challenges and should be carefully considered before constructed, operated and maintained. If it is in a countries ability to perform waste management better, faster, cheaper with any of the first three methodologies (prevention, re-use, recycle) in the waste hierarchy, it should be pursued instead of incineration. Jens Hjul-Nielsen, the director of Bornholm's waste company, said it so aptly: **"So if you don't have incineration plants today, you should start with recycling."**

This section will furthermore explore successful Danish case studies of green water and waste management that were presented to us during our trip.

9.5.1. Aarhus Vand Ltd

During our week in isolation, we viewed a presentation from Aarhus Water Utility. Aarhus Vand is a Danish public limited company owned by the Aarhus Municipality. They are involved in operations throughout the entire water cycle from groundwater protection and abstraction, providing 15 million m^3 of drinking water to treating 30 million m^3 of wastewater per year.

Aarhus Vand provides drinking water to 85% of the Municipality's residents (± 275000) through 1 500 km of pipelines sourced from 90 production wells, 8 waterworks, 11 elevated storage tanks/pumping stations, and 1 water tower. The source of the **drinking water is 100% groundwater**, abstracted 60 – 140m below ground level.

The groundwater is however vulnerable to pollution from pesticides. Analysis of monitoring data has indicated that 35% of the wells contain traces of pesticides and 18% exceeds the limit for drinking water. The present threat of groundwater pollution in Denmark has been a main driver in developing new methods in the mapping of the geology and the groundwater resources, pinpointing vulnerable areas, and defining policies to protect the groundwater.

Groundwater protection is achieved by securing all wells with a ten-meter protection zone and a 300-meter hygiene zone within which there must be no percolation of wastewater. Additionally, Aarhus Vand has entered into voluntary agreements with landowners regarding pesticide-free cultivation of the vulnerable areas, invests in afforestation, and runs information campaigns together with the local waterworks and joint councils to reduce the use of pesticides in private gardens.

Thanks to the good quality of the groundwater, **water treatment** is quite simple and only involves aeration and filtering through sand filters at the 8 waterworks. All waterworks are unmanned and controlled automatically by electronic control, regulation, and monitoring system. Day-to-day monitoring occurs from a 24-hour operating centre. Truelsbjerg water treatment plant (WTP) in the northern part of Aarhus sets new technological, architectural, and operational standards for

[17] Source: Waste Import Tax In Denmark (linkedin.com)

WTPs since 2014. This WTP introduced a brand-new design for elevated stainless steel storage tanks without direct contact with the ground. All of the pipework and tanks are visible and accessible for easy inspection and maintenance. The multipurpose design criteria combine[18,19]:

- The separation between building and process constructions
- Closed and pressurised treatment and storage from groundwater to tap, preventing pollution or contamination of the drinking water.
- Automation and intelligent prioritized operation to ensure optimal energy consumption and raw water quality. Note that the plant is fitted with 300 m^2 of PV panels to ensure a carbon-neutral building (excluding the pumps).
- Proportional oxygenation with pure oxygen from an onsite oxygen generator.
- Self-cleaning sludge tanks minimising human contact with sludge.

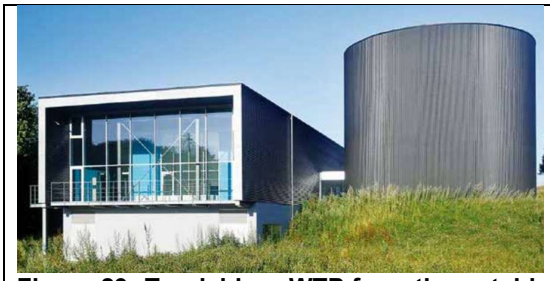


Figure 29: Truelsbjerg WTP from the outside in Aarhus

Figure 30: Pressure filter tanks at Truelsbjerg WTP

The 1500km of pipelines forming the distribution system is divided into sections to enhance reliability and improve water monitoring. The sections are kept separate from each other and most of them are supplied via two connections. The distribution wells contain measuring equipment that registers pressure, water flow, and temperature on an ongoing basis. This operating data is used to identify operating problems such as leakages timeously and provide input to a simulation model. The simulation model is used to identify sources of pollution, areas affected, and how the pipeline network can be flushed out, as well as to plan for new pipe installations. Aarhus Vand achieved urban water loss of only 5% due to these interventions.

Aarhus Vand services 95% of the inhabitants in Aarhus Municipality (+/- 335 000 customers), as far as **wastewater treatment** is concerned. Aarhus Vand purifies and drains off between 32 – 37 million m^3 of wastewater a year through 2800 km of main sewer pipelines, 4 wastewater treatment plants (WWTP), 100 pumping stations, and 2 phosphorus recovery plants (Aaby and Marselisborg).

Aarhus Vand has introduced several initiatives to reduce energy consumption and increase energy production at **Marselisborg WWTP** since 2010 to achieve an energy self-sufficiency ratio of 151% by 2020. This has been achieved without adding FOG (fats, oil, and grease) or external carbon to the WWTP, or

[18] Source: Tomorrow's waterworks in Truelsbjerg - Aarhus (stateofgreen.com)
[19] Source: Waterworks of the future - Truelsbjerg waterworks (eurowater.com)

using any external energy sources (e.g. wind or solar). The most common approach for a WWTP to achieve energy neutrality is for the sludge to undergo anaerobic digestion to produce biogas (mostly methane). Biogas can be burned to generate electricity and heat, which can be used to meet the needs of the WWTP itself and the surplus can be sent to the electricity grid or the district heating system. If this is not possible, the gas can be cleaned and exported to the natural gas network or used as fuel for buses and other road vehicles.

Figure 31: Marselisborg WWTP

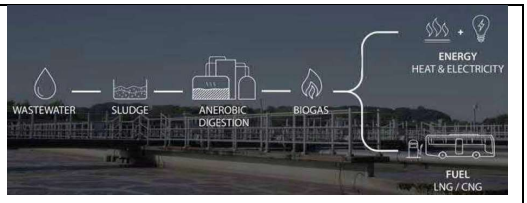


Figure 32: Common process for generating biogas from wastewater sludge

Initiatives to reduce energy consumption and increase energy production at Marselisborg WWTP:

- 2010 – 2012: Replacement of three biogas engines with 2 X 250kW more power-efficient biogas engines.
- 2011: Replacement of three older HV turbo blowers with one highly efficient ABS HST compressor.
- 2013: Installation of new heat exchanger and surplus heat sold to the district heating system, representing approximately 2 GWh/year.
- 2014: Introduction of a side-stream anammox treatment process reducing the nitrogen load to the main process tanks by approximately 20%, requiring less aeration and no carbon.
- 2015: Installation of high-efficiency combined heat and power (CHP) plant (355kW biogas engine)
- 2016: Replacement of the Alfa-Laval 550 decanter centrifuge with a newer and more energy-efficient Alfa-Laval G3 decanter centrifuge.
- 2016: Implementation of an advanced SCADA control system with online sensors to monitor and control ammonium, nitrate, and phosphor.
- Fitting Danfoss AC variable speed drives (VSDs) on all rotating equipment in the catchment area, a total of 290 VSDs, enabling operations to be accurately matched to load variations. Utilising the VSDs in parallel with the online ammonium sensors also ensured that the maximum amount of carbon is secured for digestion and energy production.

In 2013 Aarhus Vand opened the first full-scale demonstration plant in Denmark at Aaby WWTP to test the viability of renewable phosphate production in Denmark. Today the plant extracts 60% of the amount of phosphorus in the wastewater. Aarhus Vand opened the largest **phosphorus-recovery plant** in the Nordic countries in 2019 at Marselisborg WWTP. The plant has the potential to utilise up to 30% of the phosphorus that enters the treatment plant. Recovering phosphorus has great potential. Phosphorus accumulates in pipes and pumps at treatment plants as the mineral ‘Struvite’, recovering it before it

clogs pipes and pumps extends the lifetime of equipment and minimise maintenance. At both plants, the struvite is precipitated as a 'ready-to-use' fertiliser and sold to the market for composting and agricultural purposes.

Figure 33: Struvite build-up in WWTP pipes.

Figure 34: Scaling in WWTP pumps

Figure 35: Phosphorus recovery plant at Marselisborg WWTP

Figure 36: Official commerical fertiliser (PhosphorCare) produced from struvite at Aaby and Marselisborg WWTP.

The annual precipitation measured in Denmark is about 750mm. This has increased by about 15% - 100mm – since records began in 1874. The frequency of extreme rainfall events in Denmark shows both a general increase from 1874 to the present and a cyclic pattern with a period of 25 – 35 years. It is expected that winter precipitation will increase by 10 – 40% and reduce in summertime by 10 – 25% for the period 2071 – 2100 in relation to 1961 - 1990. Global and regional climate models show a clear tendency towards more episodes with very heavy precipitation, particularly in autumn and lengthy dry periods in summer.[20]

To this end, Aarhus Vand is hard at work to adapt the city of Aarhus to climate change and avoid damage to properties and infrastructure following heavy rain episodes. Wherever possible they try to **handle rainwater on the surface, "creating time and space for water"**. The idea is to separate the domestic sewage system from rainwater/stormwater systems and use the water for embellishment or recreational purposes. Aarhus Vand has carried out two major

[20] Source: Climate change - Denmark - Climatechangepost.com

climate adaptation projects with rainwater being handled at the surface – one in Lystrup north of Aarhus and one in Risvangen in the northern end of Aarhus.[21]

Figure 37: Aarhus Vand's climate adaptation and rainwater management project in Risvangen

Figure 38: Sunken recreational areas that double up as retention ponds during heavy rain episodes to prevent flooding.

Aarhus Vand has recently also started experimenting with using **rainwater for toilet flushing and laundry** in the new neighbourhood of Nye. The system is completely separate from the drinking water system and is achieved by rainwater harvesting in artificial lakes, UV-disinfection at a treatment plant, and purple-colored water pipes to residences' toilet and washing machines connections. It is estimated that such a system can cut water consumption by up to 40%.

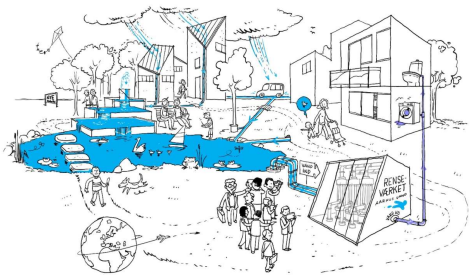


Figure 39: Representation of the alternative water system using rainwater instead of drinking water for washing machines and toilets

Figure 40: Overview of the suburban city, Nye, with the artificial lakes visible.

9.5.2. Solrødgård Climate and Environmental Park

During the second week, we had an excursion to Solrødgård Climate and Environmental Park. The park was commissioned by the Danish utility consortium, Hillerød Forsyning, with the vision to create a unique fusion of energy production, water purification, resource recycling, and climate adaptation features, all designed as a public recreational landscape. The master plan for the 51 ha area was developed by architect company C.F. Møller. The park as it currently stands was completed for 500 million DKK in 2019 and attracts about 350 000 visitors annually.

[21] Source: Climate adaptation and rainwater management at the surface (stateofgreen.com)

The park houses the new headquarters for the Hillerød Utility company fitted with solar panels for onsite electrical needs, the HCR Syd WWTP, and a recycling centre. The master plan also includes the establishment of a future geothermal plant. Another important consideration of the master plan was to design the buildings on-site from cradle-to-grave. Buildings were constructed with 80% recyclable or re-usable material at the end of their life.

Formerly the area consisted of primarily cultivated farmland, but now includes large wetlands and smaller parcels of forest. Amphibians and bats were protected during construction, and in addition to the paths and bridges (nearly 6km trail), small "hotspots" such as the bird tower and seating near the "Bat Hotel" were created for visitors to experience the natural environment. The two existing streams in the area (Havelse Å and Slåenbækken) have been re-directed to provide better spawning grounds for fish. The streams form the foundation for the wetlands and can receive and store nearly 52 000 m^3 of water, making it suitable for a 100-year flood event. To minimize the environmental impact caused by run-off water from paved areas, the water is lead through oil separators and swales with filter base for infiltration and cleaning before entering the wetlands and connected streams.[22]

The park is home to the **Hillerød Centralrenseanlæg Syd (HCR) WWTP** with 80 000 PE capacity (which can be increased to 100 000 PE during the rainy season), treating 15 000 m^3 of wastewater a day. This is the first Danish WWTP to be built indoors and therefore experiments with completely new methods and technologies. The plant is nearly invisible in the surrounding landscape, its inner workings hidden under a landscaped turf roof planted with stone herb. The roof is easily accessible through wheelchair-friendly pedestrian pathways. Visitors can witness the plant's processing wing and filtration facilities either from the skylights on the roof or the floor-to-ceiling glass facades on both sides of a landscaped corridor through the center of the plant. The central pathway was designed alongside a small creek passing through a narrow garden with natural foliage that cleans and filters groundwater. This design is deliberate, demonstrating the contrast between the natural water cycle and the industrial processes of the WWTP. The design concept allows the public to connect with their own use of resources without being in the same room as sludge and sewage and minimises the olfactory presence often associated with WWTPs. Biogas produced by the WWTP is burned and excess heat is sold to the district heating system. The plant is capable of recycling phosphorus even though it is not currently performed. This plant is also optimally situated near large pharmaceutical waste streams for which symbiotic relationships are paramount: "We are working with the local businesses and discussing specific needs for wastewater treatment and better use of their waste" – Henning Gade, project manager at Hillerød Utility company.

[22] Source: Solrødgård Climate and Environmental Park « Landezine International Landscape Award LILA (landezine-award.com)

Figure 41:Hillerød Centralrenseanlæg Syd (HCR) WWTP - Treatment plant fit for a picnic - with rooftop skylights and wheelchair friendly pedestrian pathways[23]

Figure 42: Central pathway alongside the small creek and the floor-to-ceiling glass facades on both sides.[23]

Figure 43: Aerial view of the entire Solrødgård Climate and Environmental Park

Hillerød Recycling Centre handles 43 fractions of recyclable material where any of the 50 000 residents of Hillerød municipality can drop of their waste. Material that can be re-used (e.g. glass, porcelain, cookware, toys, books, games, movies, smaller furniture) are sold at low prices in the on-site thrift shop. A common pictogram system used throughout Denmark makes it easy for visitors to identify the correct skips / bins in which to sort their waste.

Hillerød Utility also collects waste at household level and return it to the recycling centre for sorting. Households are encouraged to sort their waste in 10 fractions. Some of the refuse trucks can handle at least two fractions at a time.

The layout and design of the waste recycling centre is again very intentional. There is a physical road level (1.5m) and surface separation between one direction lanes used for Utility vehicles and visitor vehicles as a safety precaution. The bins / skips are laid out in a u-shape around a water retention pond as a psychological reminder of the beauty of nature. The roof of the entrance building to the recycling facility is used for rainwater harvesting that is used to clean and wash the utility vehicles.

[23] Source: Henning Larsen | In Denmark, a New Water Treatment Plant is Fit for a Picnic

Figure 44: Entrance to the recycling centre. Notice the surface separation between the inner (private vehicles) and outer (utility vehicles) lanes[24]

Figure 45: Recycling centre with retention pond in the middle. Skips / bins are stationed on the outer lane (1.5m lower) for ease of access to private vehicles (throwing waste down in the containers instead of up and over a high edge).[24]

Figure 46: Common Pictogram system used throughout Denmark for waste sorting

Figure 47: Example of a pictogram at Hillerød recycling centre

9.5.3.Kokkedal, the Blue-Green Garden City

The **Usserød stream** overflowed in August 2010 directly impacting 70 residences along the river. It was not the first time that the stream overflowed but this time the total damages from the flooded homes and basements rose to DKK250 million. The flooding event was an eye-opener for the Rudersdal, Hørsholm, and Fredensborg municipalities that the 8km stream traverses. A project was implemented from 2012 – 2016 with a total budget of DKK 18.5 million (DKK 7million EU LIFE funded) to climate adapt the stream to reduce the risk of flooding and improve the recreational environment around the river.

[24] Source: 17. august 2016: Genbrugsstation klar til indvielse - Hillerød Forsyning (hillerodforsyning.dk)

There were three project objectives:

1. To investigate and prepare recommendations for the necessary organizational framework for the inter-municipal cooperation.
2. To prepare the model simulation framework and online measurement systems for necessary joint climate adaptation actions and decisions. This work was to be encapsulated in a common technical climate change adaptation toolkit.
3. To initiate and implement joint civil works (demonstration projects) in the stream for improving water management and preventing flooding.

As part of the second objective, the project entailed the installation of 10 measuring units along the stream, monitoring precipitation, water flow, water level, and oxygen content. Data from the measurement system is presented on a shared website in the form of a dashboard for efficient stormwater management and early warnings to both professional utility staff and the public.

Figure 48: schematic representation of objective two and it concomitant activities

Figure 49: One of the online monitoring systems

Some of the initiatives undertaken for objective 3 comprise creating a wet meadow at Blårenden/Mortenstrupvej, with a storage capacity of 9 000 m^3 of water, which extends the natural water retention capacity of the wet meadows in the area by five times.[25] Historically the inlet to the Usserød stream from lake Sjælsø was regulated manually by an old weir at the outlet of the lake. This has been upgraded to an automatic system. In the event of a torrential rain warning, the retaining weir is closed and the water is retained in Sjælsø lake. Operation of the weir and the concomitant water level in Sjælsø lake is also used for ecological reasons, controlling the flow of algae-rich water which could result in oxygen depletion in the stream and assisting with the spawning of predatory fish in the lake. Wherever possible, the Usserød river was planned with a double

[25] Source: LIFE 3.0 - LIFE Project Public Page (europa.eu)

profile and dikes were installed where needed. If necessary, pumps were installed to avoid water building up behind the dike, pumping excess water into restored wetlands.

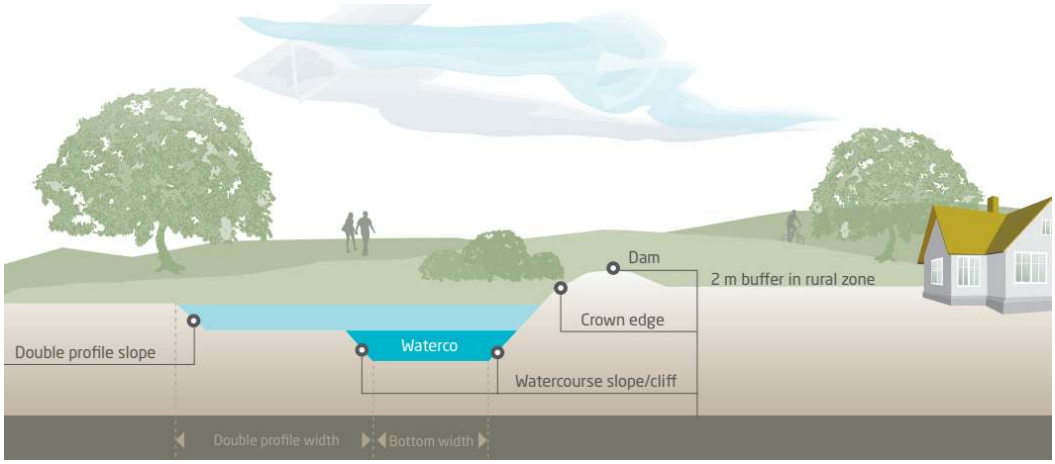
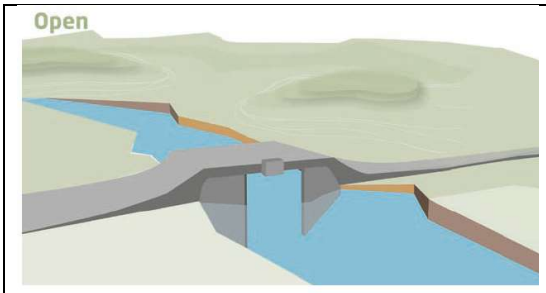


Figure 50: Graphical representation of the Usserød stream's double profile and dike preventing flooding in the surrounding areas.



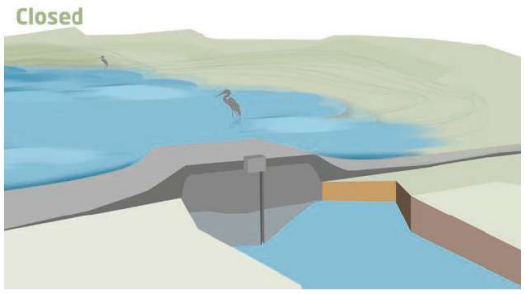


Figure 51: Conceptual automatic regulation of the sluice to retain more water in Sjælsø lake.

Figure 52: Photos from the new regulating sluice at Mortenstrupvej (18 Sept 2016)

Kokkedal used to be a typical mono-functionally planned suburban area of the 1970s. Kokkedal has long suffered from social division, lack of safety and security, and low investment. The suburb borders the Usserød stream and consequently suffered from flooding in 2010. This event motivated the municipality to establish a unique partnership with public housing organizations, the sewer utility, and the Danish foundation Realdania. Together they decided to protect the neighbourhood against future floods by climate adaptation measures while creating attractive new urban spaces, setting the scene for a good social community that boosts urban renewal.

Kokkedal Climate Adaptation is the largest and most complex climate adaptation project in an urban context in Denmark, consisting of 35 sub-projects, that use **Landscape-based stormwater management (LSM)** for urban development. The project covers an area of 170 000 ha that includes a green river valley, a school, a nursing home, a sports centre, a shopping mall, and two large subsidized residential developments (home to nearly 3000 residents). The new urban spaces include three gardens, the Nature Hinge (a beautiful wooden staircase connecting the residential area with the adjacent river valley), and the Wave square which holds rainwater but when it is dry provides sports fields for basketball, skateboard, and parkour. The artist Eva Koch created a large bowl-shaped space that is filled with projected images of flowering poppies at night. New recreational areas are popular and have driven out the shifty activities which previously dominated the area.

Figure 53: One of the three sunken public gardens

Figure 54: The Nature Hinge - a wooden staircase from the residential area to the Usserød stream

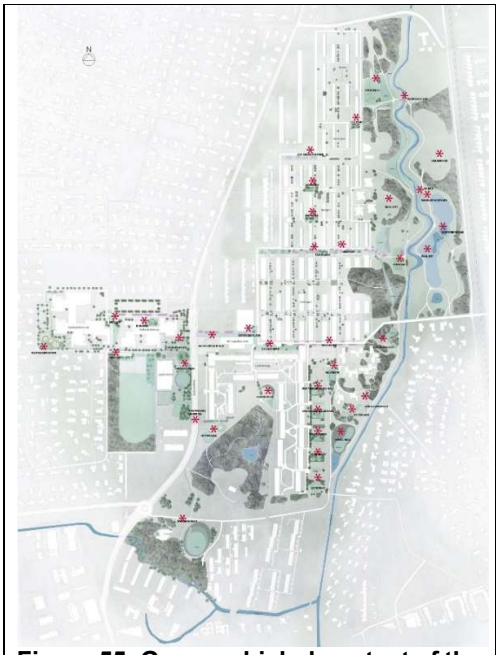


Figure 55: Geographichal context of the 35 sub-projects making up Climate Adaptation Kokkedal

Figure 56: Eva Koch's flowering poppies

Figure 57: The Wave Square

Water previously hidden underground in pipes was brought to the surface, which is more visible, allowing for new recreational urban possibilities. Rainwater is collected from smaller basins, on to soak-aways and trenches until finally reaching the large basins and the Usserød river. All the water is directed through cleansing elements such as rainwater beds and basins.[26]

Figure 58: Stormwater is managed on the surface as far as possible

Figure 59:Rainwater harvesting from nearby roofs are collected in detention ponds with "wild on purpose" vegetation.

Another factor that impressed me, was the amount of information that was shared with the public at strategic project locations, enticing participation and interaction. Information boards normally contain a QR code that easily directs a person to a website with additional information or video content.

[26] Source: Kokkedal Climate Adaptation: Improved Urban Living | urbanNext

Figure 60: One of several notice boards in Kokkedal providing information on the climate adaptation projects performed.

Figure 61: Walking along Usserod Stream, the current water level can be read from measuring stations, using QR codes.

9.5.4.Østerbro Climate-resilient neighbourhood

Our excursion commenced with a presentation at the offices of Miljøpunkt Østerbro, and continued with a site visit of Tåsinge Plads and Skt. Kjelds Plads with a view of Bryggervangen, along Kildevældsparken to Det Vilde Røde Hus (The Wild Red house) and therafter Borgervænget Genbrugsstation (the Citizen's recycling station).

Miljøpunkt Østerbro is an independent Non-governmental Organization (NGO) serving two municipal areas: Østerbro and Nordhavn. The organisation is responsible for raising awareness around sustainable development. The organisation executes its objectives through the following actions:

- Media releases, publications (e.g "Save the food", Inspiration catalogues on green roofs, and 10 examples "Towards a sustainable neighbourhood"), and newsletters.
- Teaching in schools, giving talks, and hosting workshops. The organisation currently has three courses on offer teaching middle-class children about edible plants and useful insects, the use of senses and knowledge of food to minimize waste and connecting everyday consumption of clothes, phones, and other things to the global consequences of overproduction. They host tours to Copenhagen's plastic waste facility as well as plant and balcony workshops for adults.
- Collaborating with citizens, municipalities, and businesses on local projects such as assistance and guidance for waste sorting, greener inner yards, or roofs for housing associations.
- Lending out useful items free-of-charge (e.g. Hens, cargo bicycles, gear for waste collection, or hand-operated grinder and small apple press), promoting a more sustainable everyday life through local micro-production and shared resources
- Participating in and hosting events about climate change, nature, and the environment such as waste collection or trash pick-up events near the sea and lakes, exchange markets and the annual sustainable fashion festival (ReFashion), guided tours of climate districts, green roofs, bats of Fælledparken, and building insect hotels on these guided tours.

Figure 62: Inspiration catalogues on green roofs and examples of a sustainable neighbourhood

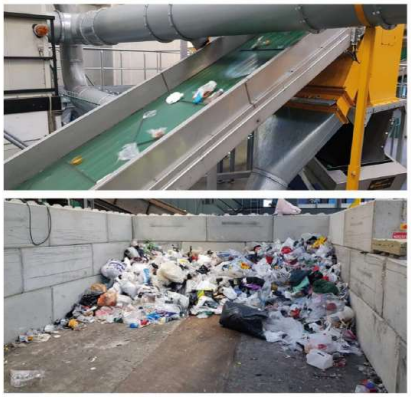


Figure 63: Tours to Copenhagen's plastic waste facility to raise awareness

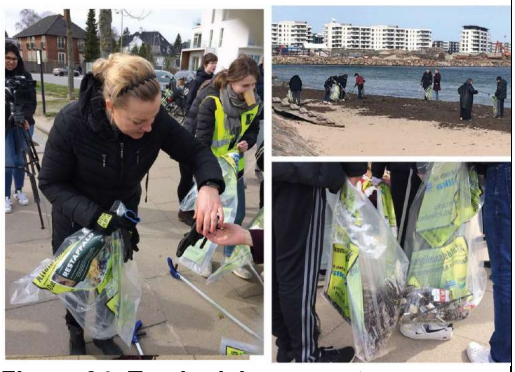


Figure 64: Trash pick-up events

Figure 65: Local micro-production and shared resources

There were several private and public projects undertaken to create Copenhagen's first **climate-resilient neighbourhood**, of which we visited Tåsinge Plads, Skt. Kjelds Plads, Bryggervangen and Østergro.

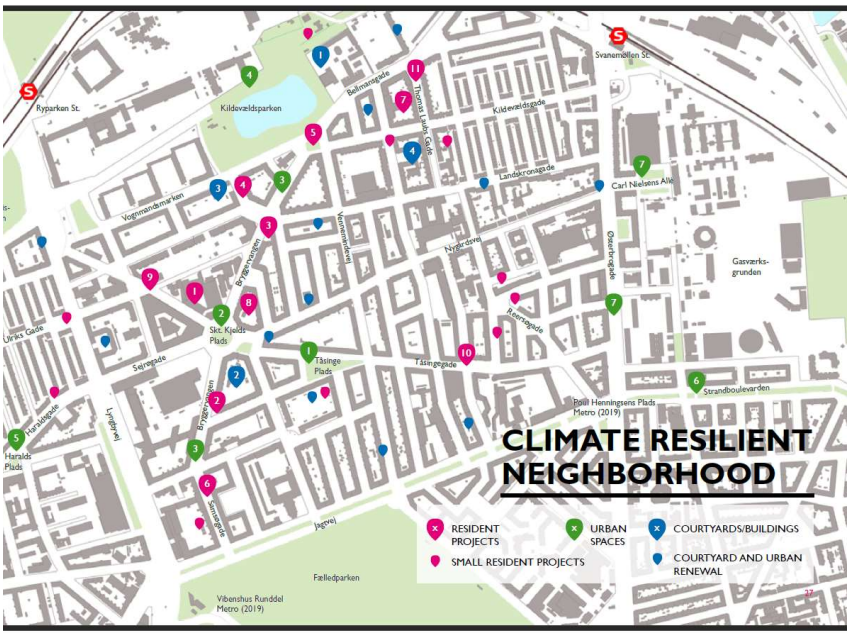


Figure 66: Projects initiated in the Climate resilient neighbourhood, and Projects (green) and resident projects (pink) visited: 1) Tåsinge Plads, 2) Skt. Kjelds Plads, 3) Bryggervangen, 1) Østergro.

The previous stormwater system was unable to handle the large volumes of rainwater during extreme rainfall events or cloudbursts. Enlarging the stormwater system by conventional methods would be expensive and create long-duration construction works throughout major parts of the Østerbro neighbourhood. The City of Copenhagen, therefore, decided to future-proof the neighbourhood with green and blue solutions that would disconnect 30% of the rainwater from the stormwater system at street / surface level. The project aimed to transform 20% of the asphalted areas in the neighbourhood to become green spaces that can be used for stormwater management. Climate adapting the Østerbro neighbourhood ito local rainwater drainage and harvesting is an example of a **Water Sensitive Urban Design** in Denmark (WSUD).

Tåsinge Plads was Copenhagen's first climate change-adapted urban space. It was officially opened in December 2014. More than 1000sqm of asphalt was greened with more than 50 new trees and the square was integrated with the surrounding urban fabric using reused cobblestones and granite stones. Shops and restaurants that used to be hidden behind a row of parked cars are now visible and accessible from the square. There are two air-raid shelters (bunkers) underneath the square that serves as rehearsal rooms for musicians. The entrances to the bunkers have been renovated and now serve as small seating niches. As far as vegetation is concerned, Tåsinge Plads represents a cross-section of the Danish countryside, with plant biotopes extending from hillside to lakeside. Plants were carefully selected taking soil conditions, sunlight, and shadow into consideration. A salt-tolerant mix[27] of herbs and grasses were chosen for roadside vegetation.

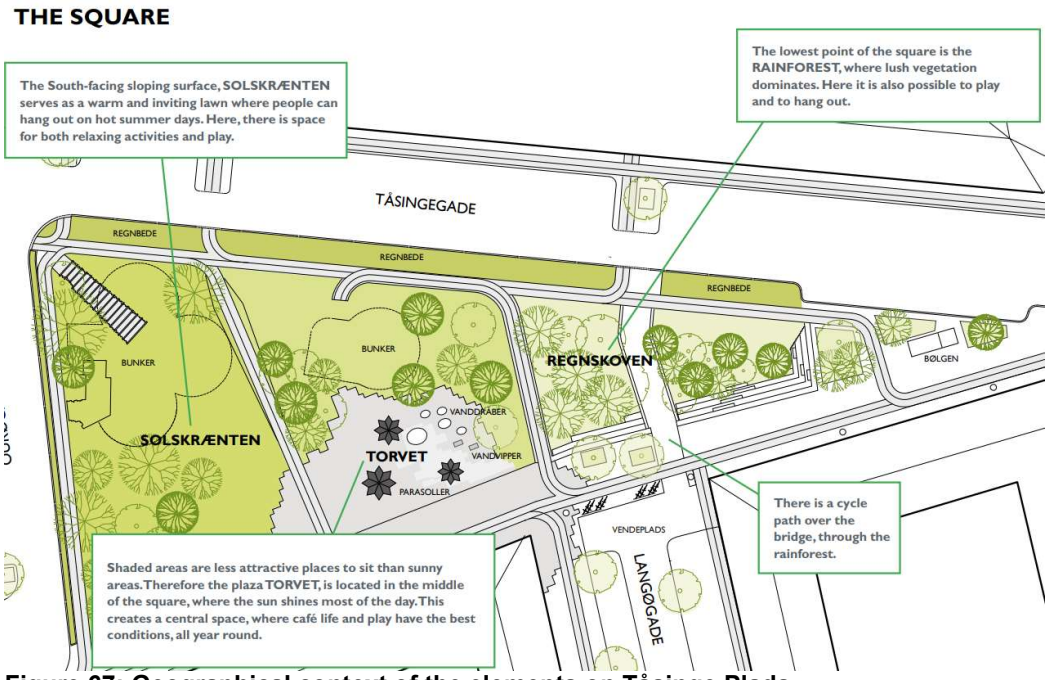


Figure 67: Geographical context of the elements on Tåsinge Plads

[27] Roads are kept free from ice and snow by ploughing and chemical de-icing (a sodium chloride salt solution) to improve road safety and accessibility during the winter season.

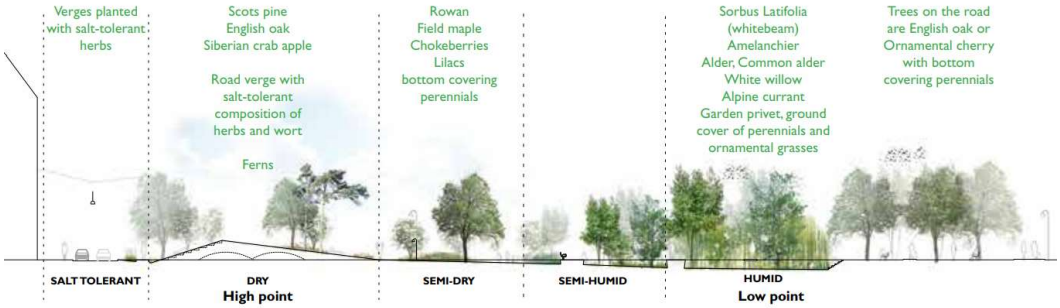


Figure 68: Carefully selected vegetation in Tåsinge Plads

To prevent groundwater contamination, rain from road-side surfaces flow into roadside swales, where it infiltrates trenches through a thin layer of filter earth. The roadside swales and infiltration trenches are connected to the cloudburst roads network that transports the water to the harbour where the salt concentration is not a cause for concern.

The sculptures / structures for Torvet plaza were carefully selected to symbolise and represent water features: Rain parasols and Water drops. The rain parasols collect the water and provide shelter from the rain. The water drops reflect the sky and invite people to touch and climb them. Rainwater that falls on the square naturally runs to the square's lowest point, the rain garden (retention basin), where it slowly infiltrates to become part of the groundwater. Rain from the surrounding roofs is diverted through gutters to reservoirs underneath the square. The rainwater goes through multiple purification processes (swivel well and UV purification) before reaching the reservoirs, making it clean enough for water play on the square. Residents can access the rainwater by stepping onto tilted plates that act as pumps, pushing the water from the reservoirs through the large raindrop onto the square**.** Tåsinge Plads with the infiltration basin and the reservoirs can delay and infiltrate 7000sqm of surface rainwater to groundwater disconnecting it from the surrounding stormwater system.

Figure 69: View of the rain garden (retention basin)

Figure 70: View of Torvet square with the rain parasols, water drops and tilted plates for water play

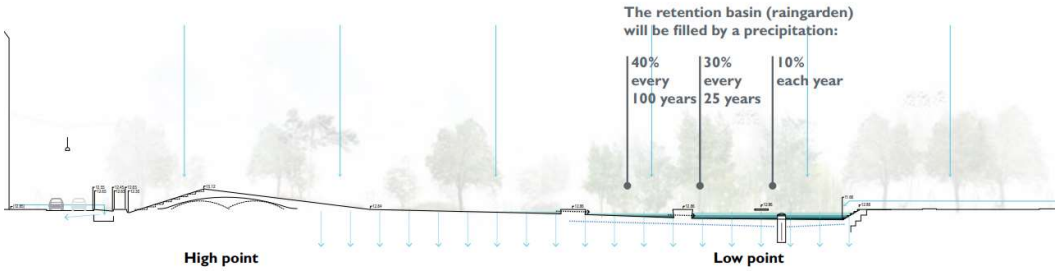


Figure 71: Natural rainwater management in Tåsinge Plads

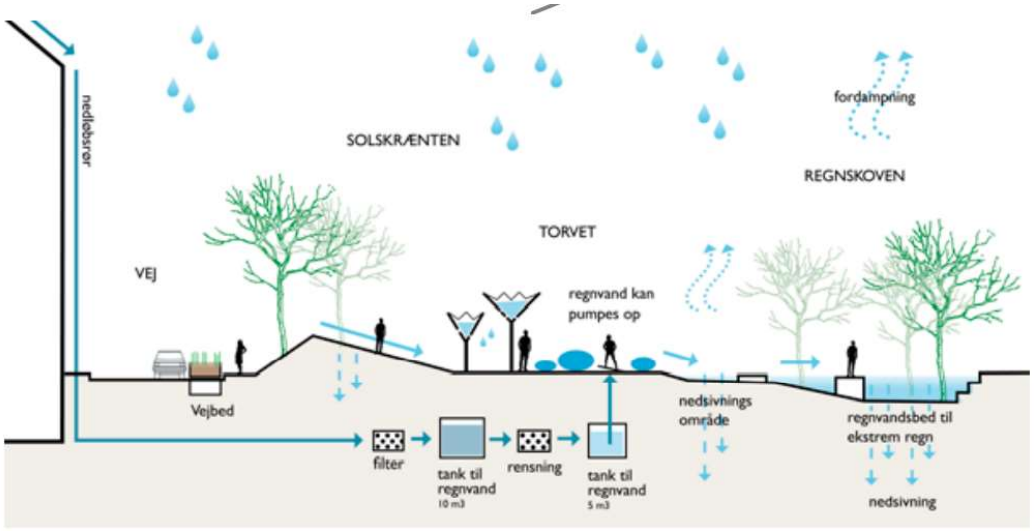


Figure 72: Rainwater harvesting from surrounding roofs are used for water play in Tåsinge Plads

At **Skt. Kjelds Plads and Bryggervangen**, 9000m^2 of asphalt have been replaced with 586 new trees of 48 local species, 3000m^2 of perennials, 500 m^2 of wild grass, and 30 000 snowdrops. The vegetation was inspired by natural areas in the Copenhagen area, e.g. Utterslev Marsh, Amager Common, and Kongelunden Forest. The vegetation is planted in a network of green rainwater beds, that together with canals, roads, and underground pipes, create a stormwater protection system that can withstand a 100-year (rain) event. The stormwater system in the square was designed so that surface water from roads is handled by “first-flush” solutions, directing polluted initial surface runoff to the existing stormwater system, and the cleaner, “second-flush” is directed to the green rainwater beds. Incorporating nature into the City like this provides valuable solutions to issues such as the heat island effect, lack of biodiversity and noise/air pollution. The project also had several social ambitions: a network of pathways has been laid out between the newly planted trees and benches have been placed, inviting everyone to connect with nature for reduced stress levels and increased general well-being. By narrowing the formerly trafficked roads, optimizing parking and adding new bicycle routes through the nature-rich spaces have calmed traffic in the area and ensured safe and stimulating mobility for all. The project covers a 34 900 m^2 area, a budget of DKK 48,45 million, and took six years to complete from 2014 – 2019.

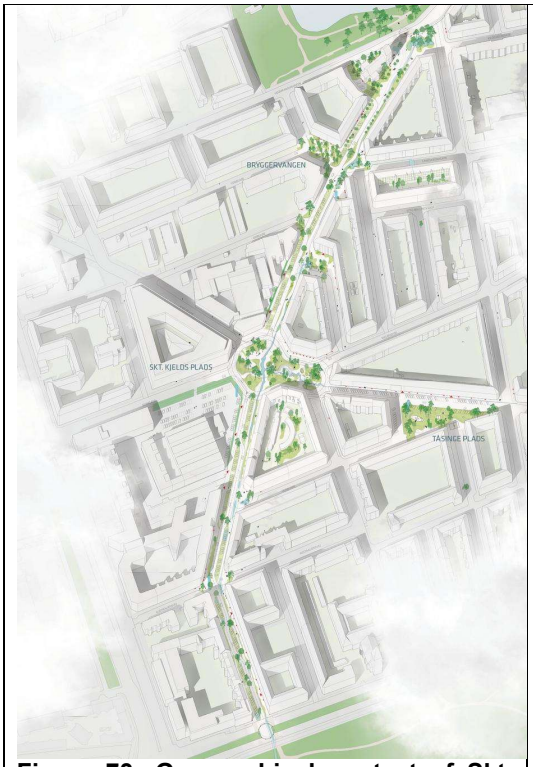


Figure 73: Geographical context of Skt. Kjelds Plads, Bryggervangen, and Tåsinge Plads

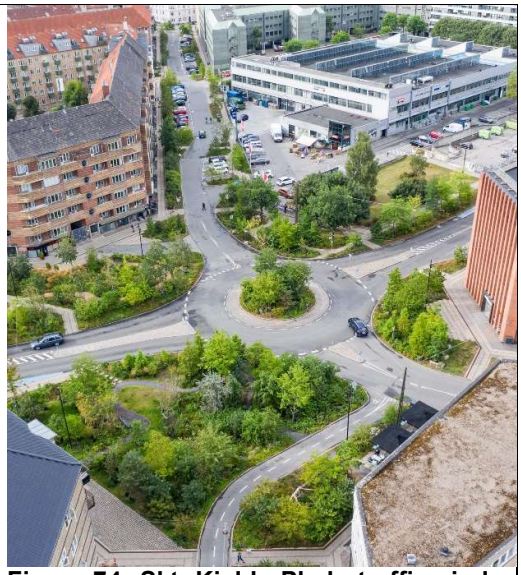


Figure 74: Skt. Kjelds Plads traffic circle and Bryggervangen in a north-south direction.

Figure 75: second-flush rainwater treatment on the surface

Another interesting and very enlightening thing to see in the Climate-resilient neighbourhood was the **"citizen's climate projects".** Local enthusiasts create and take care of planting beds, rain beds, and green roofs in the neighbourhood, sometimes even on public property. The Urban Renewal Office of the Climate-resilient Neighbourhood provides financial support (grants) and knowledge to projects initiated by locals. An example of such an urban garden in Bryggervangen even collects rainwater from 90m^2 of roof area for watering the plants. ØsterGRO rooftop farm is another example.

There are/were 11 **cloudburst management projects** (refer to Figure 76) in Østerbro's climate-resilient neighbourhood stemming from Copenhagen's cloudburst management plan of 2012. Figure 76 indicates that Bryggervangen is both a retention road as well as a

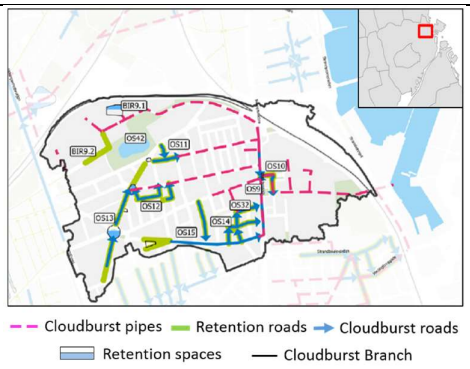
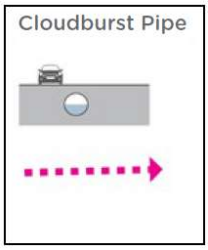
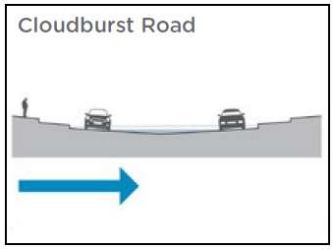
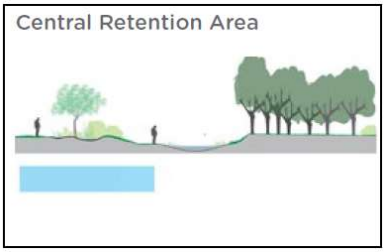


Figure 76: Cloudburst management projects in Østerbro.

cloud burst road with a retention space at Skt. Kjelds Plads. Copenhagen uses five types of cloudburst management elements or measures to protect the City.

Table 1: Cloudburst management elements or measures to climate adapt a City[28]

		
Detention streets are streets that are typically located slightly upstream of vulnerable lowpoints. In these streets there should be a detention volume established to handle stormwater before reaching the more vulnerable points downstream.	Green streets are proposed as upstream conections to all Cloudburst roads. The green streets should be established with a combination of smallscale channels and stormwater planters or permeable paving. Stormwater should be collected, delayed and then channelled towards the Cloudburst roads.	A Cloudburst pipe handles rainwater in the same way as Cloudburst roads. This is placed just below street level to ensure connection to other surface solutions. This solution is used if there is no useable space for aboveground solutions.
		
Cloudburst roads are used tochannel and direct cloudburst water. These streets can be formed with a unique V-shaped profile and raised kerbs to ensure water will flow in the middle of the road, away from the buildings – contrary to standard engineering practice. Channels and swales can be established along road edges so that water runs in urban rivers or green strips. Cloudburst roads may also be combined with Cloudburst piping below the surface to create tool synergies.	Central retention areas are proposed in the squares and parks where it is possible to delay stormwater, so that Cloudburst roads can be established in smaller dimensions. The central retention elements can be, for example, open depressions in the parkland or lowered seating areas. Alternatively, they can be established as underground storage such as soak-away crates or rain gardens. Central retention elements will typically be placed in connection with adjacent Cloudburst roads.	

On our way to Borgervænget Genbrugsstation (the Citizen's recycling station) we came across **Det Vilde Røde Hus (The Wild Red house)**. The Wild Red House is located right next to the recycling centre and was built by artist Thomas Dambo in early September 2021. The previous vacant piece of land featured in a Master Thesis titled "Re-balancing nature and culture in Copenhagen", released 4 June 2021, with a remark of "The exposure to sunlight on this patch made me wonder why it is kept so simplified still". The House acts as a community gathering place and was entirely built from recycled materials from the recycling station. The aim is to raise awareness about the climate crisis and acts as a resting or stopping point for visitors to the exchange shop at the recycling station every Sunday. The Danish Society for Nature Conservation have parterned with the Source School just across the road and created a hedgehog and insect dweller at The Wild Red House. There is already a large number of associations who use the house, celebrating its first climate festival in November, hosting debate and conversations about the UN SDGs and having plant and herb exchange markets. This is an excellent example of how different roleplayers in society can come together and forge partnerships to the benefit of the entire community while at the same time learning about and protecting nature.

[28] Source: Copenhagen_Cloudburst_Ramboll_April_20_2016 (4).pdf (acwi.gov)

Figure 77: Piece of land in front of / next to the recycling station before The Wild Red House.

Figure 78: The Wild Red House

After our short visit to the exchange shop at the recycling station, we visited **ØsterGRO rooftop farm,** which is one of the residential projects in the Climate-resilient neighbourhood (number 1 in Figure 66). ØsterGRO was established in 2014 and is the first rooftop farm in Denmark. ØsterGRO is an example of community-supported agriculture (CSA), selling its produce to 40 members, who pay in advance for half a harvest season. ØsterGRO covers a 600m^2 rooftop of an old car-auction house, with fields of organic vegetables, fruits, greens, herbs, and edible flowers, a greenhouse, henhouse, and three bee-hives. The farm is maintained by a few permanent employees and the rest is up to volunteers assisting every Wednesday from April to mid-December. ØsterGRO is not just for the members and volunteers but also a green breathing space for anyone who wants to visit the restaurant Gro Spiseri, where the best of the season is served from farm to table in the on-site greenhouse.[29]

The origin of ØsterGRO was a tale of synergies – Livia, one of the co-founders, was searching for a building that would be strong enough to become home to a rooftop farm. She managed to find it with the help of the team responsible for creating Østerbro Climate-resilient neighbourhood, who was stationed at the current Miljøpunkt offices. There were other examples in Denmark as well where the design teams (architects, engineers, accountants etc) all had to set up shop in the neighbourhood where the project was to be rolled out in order to become part of the neighbourhood, engaging with the locals to really understand their vision for the spaces and place.

[29] Source: In English — ØsterGRO (oestergro.dk)

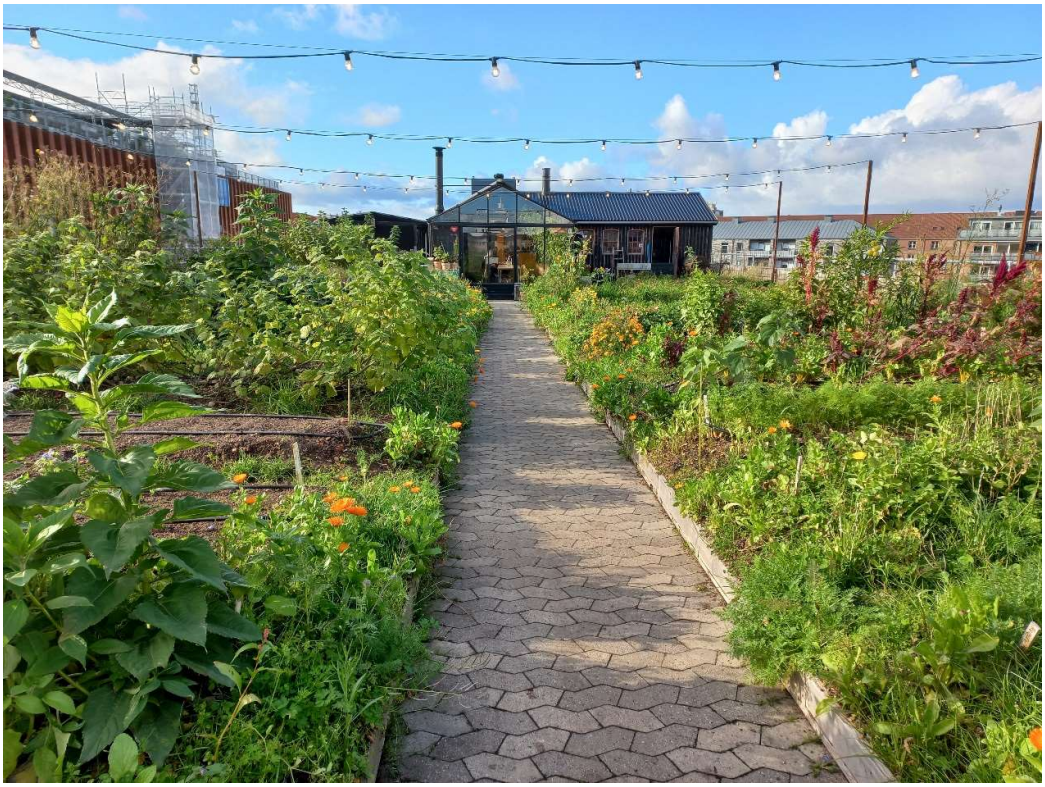


Figure 79: OsterGRO rooftop farm, with the greenhouse at the end of the footpath, home to Gro Spiseri restaurant

9.5.5.Amager Resource Centre – Waste-to-energy plant[30]

Amager Bakke is a combined heat and power (CHP) waste-to-energy plant and recreational facility in Copenhagen. The DKK 4.07 billion project was developed by the waste management company, **Amager Resource Centre** (ARC, Amagerforbraending). Amager Resource Centre is jointly owned by five Copenhagen-area municipalities, namely Dragør, Frederiksberg, Hvidovre, Copenhagen and Tårnby. Construction occurred from 2013 to 2017 and included several (11) contractors.

ARC manages and handles waste from 654 000 citizens and 68 000 companies. Around 100 000t of waste a year is collected at nine recycling centres, visited by 1 million visitors a year. The waste is sorted in 10 colour zones in more than 30 sections. 30 000t of CO_2 is saved annually from the work performed by the recycling centres. ARC receives around 11 250t of waste a year from the owner municipalities. ARC boasts a plastic sorting test plant which is currently used to gain knowledge on the different types of single use plastic that can best be utilized for recycling. 1.1 kg CO_2 / kg plastic is saved by using recycled plastic. ARC also handles 10 000t of hazardous (chemicals, paint, batteries) waste every year from 1.5 million citizens and 90 000 companies. ARC ensures the safe disposal of waste that can't be used for energy or

[30] Information in this section is mainly sourced from the informative presentation given to us during our site visit, alternatively the following websites were consulted: Amager Bakke - Wikipedia, About Amager Bakke - ARC (a-r-c.dk), Amager Bakke Waste-to-Energy Plant, Copenhagen, Denmark (power-technology.com)

recycling or that is hazardous waste at landfills. The waste disposed of at landfills include polluted concrete, soil, asbestos and other material. The waste is covered in a membrane that collects up to 95% of harmful gases, to reduce methane being released into the ground, water and atmosphere.

Amager Bakke receives 599 000 tonnes of waste annually, of which 160 000 tonnes is biomass and 57 000 tonnes imported waste. Every day 260 trucks deposits residual waste from the five owner municipalities into the silo. The silo has a capacity of 22 000 tonnes of waste. The air necessary for the combustion process is sucked from the waste silo so that no odour escapes to the surrounding area. From the silo, the waste (max 6 tonnes) is lifted with a crane/grabbers and fed to a double lane combustor grate with the use of a hopper. The facility includes two furnace lines connected to a boiler and a joint turbine and generator system. Each fuel line has a capacity to burn 35t of waste an hour. The temperature in the furnaces reach 900 – 1100 ^{o}C. The heat from the furnaces heats up the water in the boilers which is circulated as part of the district heating network or transformed into steam. The boiler consists of multiple pipes located next to each other. A pump keeps the steam pressurized at 69 bar and a temperature of 440 ^{o}C which drives the impellers of the turbine-generator to generate electricity. The plant is designed to change between operating modes, producing 0-63 MW electricity and 157-247 MW district heating, depending on the local heat demand and power price. In 2020 the plant produced 1601 GWh of energy, of which 1360 GWh was used for district heating (servicing 90 000 households) and 241 GWh of electricity (servicing 80 000 households).

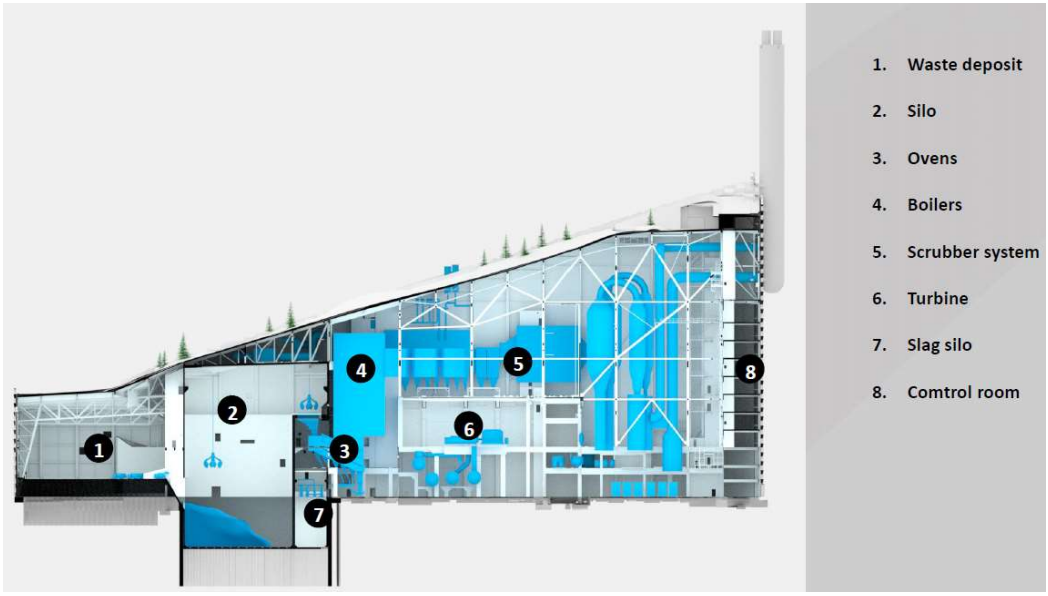


Figure 80: Process components of Amager Bakke

When the waste has been incinerated, a byproduct called slag is leftover. Slag consists of ash, sand, gravel and metals. Metals are extracted from the slag, and the remainder (100 000t) is used as a filling material under new roads. Amager Bakke allows Copenhagen to reuse 90% of its metal waste.

After the flue-gas has heated up the boilers it must be treated before it can be released into the air through the smoke stack. This process is presented in Figure 81. The flue-gas condensation technology used to optimize the heat production enables the plant to recover more water (100 million litres) than it uses. **Amager Bakke claims to be the cleanest incineration plant** in the world, achieving better values for dust particles, hydrochloric acid (HCl), Sulphur dioxide (SO_2), NO_x, Mercury, Heavy metals and Dioxins than the prescribed EU Directive, Environmental approval requirements and BREFs[31]. Amager Bakke is the first Danish incineration plant fitted with a flue-gas cleaning technology, called selective catalytic reduction (SCR), to reduce the NO_x emissions, achieving up to 95% reduction. Amager Bakke curbs 100 000t of CO_2 emissions, the equivalent of 490 000t of coal and 360 000t of oil.

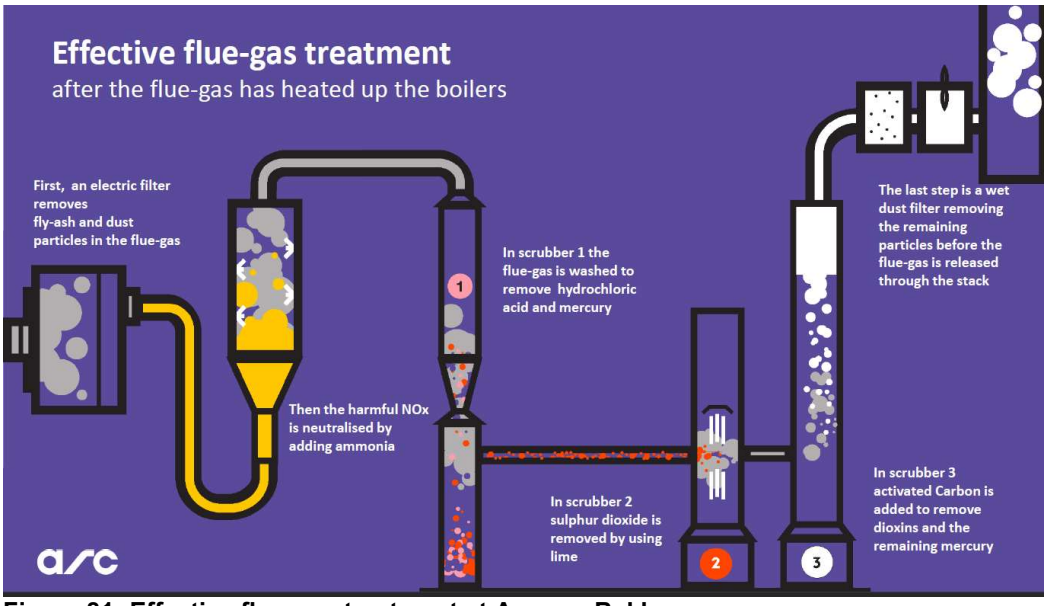


Figure 81: Effective flue-gas treatment at Amager Bakke

ARC is in the process of setting Amager Bakke up for **carbon capture** with the aim of having a pilot plant up and running from 2022 that will extract 5t of CO_2 daily. The goal is to capture up to 90% of CO_2 from the flue-gas by 2025. The intention is to temporarily store the CO_2 in liquid form before burying it underground. The selection process for the storage site is still ongoing. Potential locations are exhausted oil and gas fields in the Northern Sea.[32]

Not only is Amager Bakke a technological marvel, it also promotes environmental sustainability and state-of-the-art urban architecture that provides another revenue stream by attracting tourists since October 2019. Amager Bakke boasts a ski slope comprising four pistes laid out in difficulty levels over 370m with a fall height of 75m. Three carpet lifts and one plate lift transport skiers to the top. Amager Bakke provides running or hiking trails over

[31] The BREFs are a series of reference documents covering, as far as is practicable, the industrial activities listed in Annex 1 to the EU's IPPC Directive. They provide descriptions of a range of industrial processes and for example, their respective operating conditions and emission rates.

[32] Environmental assessment of amending the Amager Bakke incineration plant in Copenhagen with carbon capture and storage - V. Bisinella, J. Nedenskov, Christian Riber, Tore Hulgaard, Thomas H. Christensen, 2022 (sagepub.com)

670m. Amager Bakke furthermore has the tallest climbing wall in the world (80m), split into four pitches, with routes ranging from 5a (easy) to 8a (very difficult).

Figure 82: Amager Bakke waste-to-energy plant with the ski-slope, running trail and climbing wall visible

9.6. Energy[33]

The breakdown of emissions by sector presented in the Introduction (section **Error! Reference source not found.**) shows the economic activities and players that generate emissions. It, however, doesn't indicate the breakdown in types of emissions, nor whether the emissions come from energy consumption or other sources.

This information is provided in Denmark's emissions inventory submissions to the UN and the EU, which are based on the Common Reporting Format (CRF). The CRF tables break down emissions into five overarching CRF categories which are:

1) energy-related emissions (including emissions from waste incineration and transport);
2) emissions from industrial processes and product use;
3) agricultural emissions;

[33] Text and figures in the introductory sections of the Energy section before "Energy Islands" have been sourced from Denmark's Climate Status and Outlook 2021 report[1], unless otherwise stated.

4) Land use, land-use change, and forestry (LULUCF) emissions
5) waste-related emissions (excluding waste incineration).

Figure 83 shows total Danish emissions broken down by the five overarching CRF categories. As indicated, historically, total energy-related emissions across sectors have typically constituted between 70% - 75% of total Danish emissions. Energy-related emissions have come down significantly but are still expected to contribute more than half of the total emissions in 2030. It is expected that the transport sector will account for about 60% of the energy-related emissions in 2030.

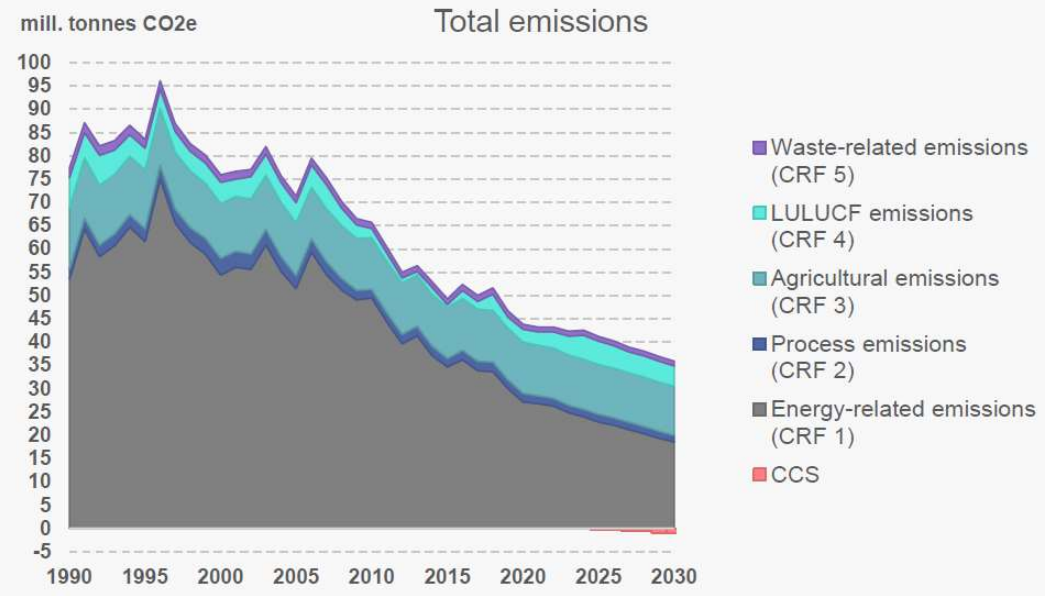


Figure 83: Total emissions per CFR category.

Energy-related emissions arise from fossil **energy consumption**, and the development in these emissions, therefore, depends on the energy mix in energy consumption. Figure 84 shows the energy mix and developments observed in Danish energy consumption from 1990 to today, and onwards up to 2030. Coal consumption in the electricity and district heating sector will be phased out during 2028, but it is expected that coal and coke will still be used in manufacturing industries and building and construction in 2030. The renewables share in electricity consumption (RES-E) is also following a strong upward trajectory from 65% in 2019 to an expected 97% in 2030 (without the energy islands). Wind and solar make up the largest renewables share in electricity consumption. The total share of renewables (RES) is also increasing steeply and is expected to reach 58% in 2030 (from 37% in 2019).

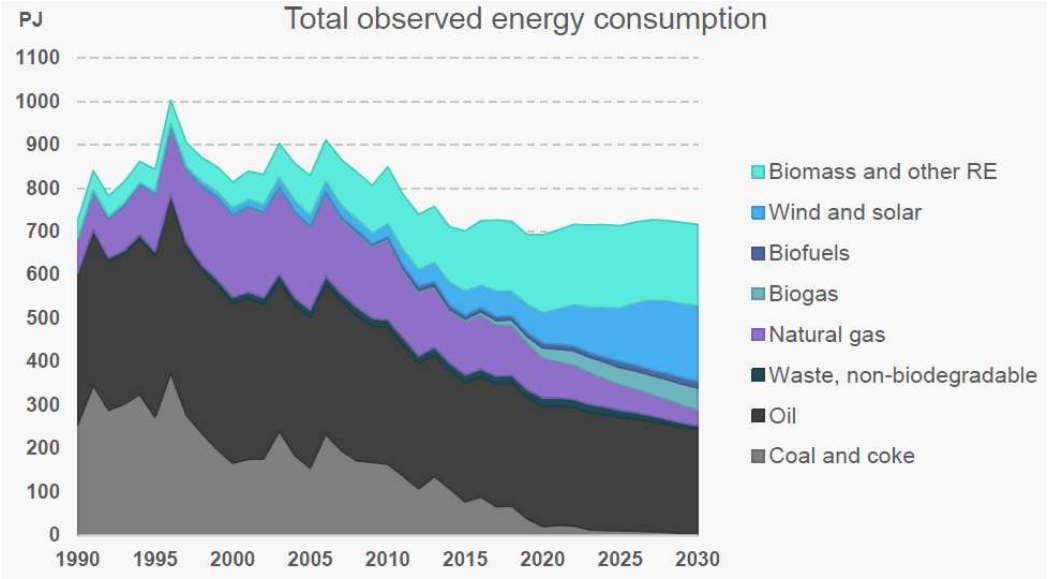


Figure 84: Total observed energy consumption from 1990 - 2030

Electricity consumption is expected to increase significantly in the period up to 2030. As shown in Figure 85 below, developments in the electricity and district heating sector are characterised by an almost full transition to renewable energy, and this is primarily a result of phasing-out coal-fired cogeneration at large-scale plants, conversion to biomass, and continued deployment of onshore and offshore wind power and photovoltaic modules.

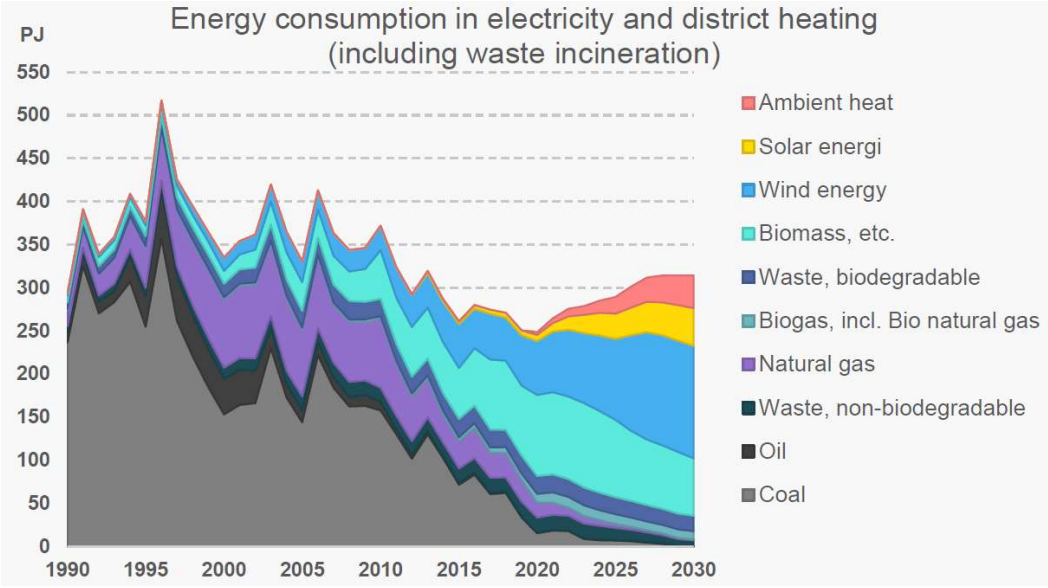


Figure 85: Energy consumption in electricity and district heating by type of energy

Growing contributions to district heating production from heat pumps and surplus heat from the corporate sector are expected to reduce the sector's burning of biomass in the period up to 2030 by around 18% compared to consumption in 2019.

Good neighbours

The Danish electricity system is strongly integrated into the northern European electricity market. The Danish electricity transmission system has connections to Norway, Sweden, The Netherlands and Germany (refer to Figure 86).

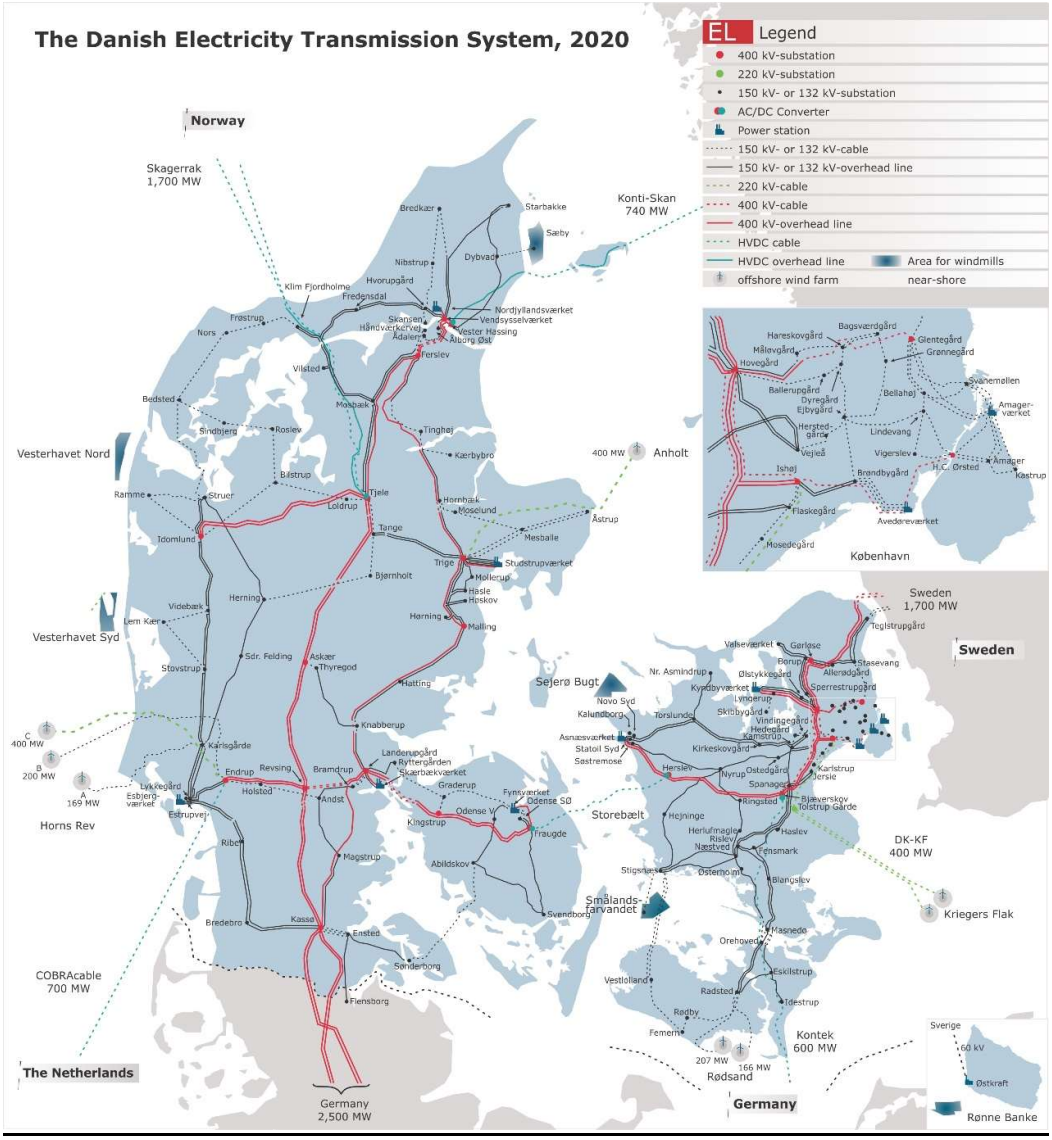


Figure 86: The Danish Electricity Transmission System in 2020[34]

The balance between domestic electricity production and electricity imports has fluctuated considerably, depending on conditions on the market, and these are affected by weather conditions such as precipitation, temperature and wind. Denmark typically import hydropower from Norway and Sweden, nuclear from Sweden and Germany, fossil-fuel electricity from the Netherlands and Germany.

[34] Accessible from Transmission system data | Energinet

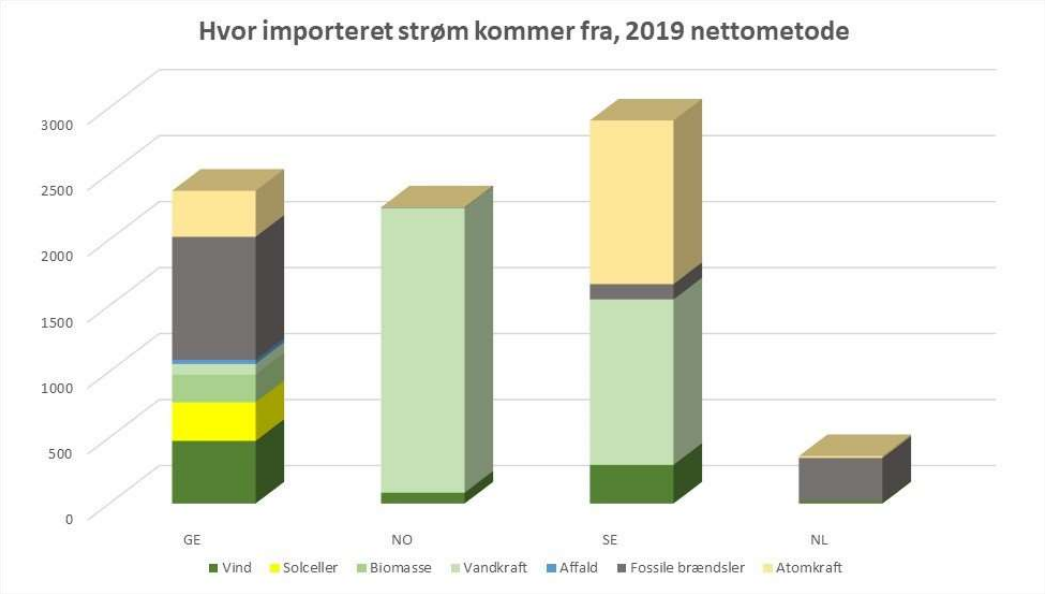


Figure 87: Contribution of imported electricity from Germany, Norway, Sweden and The Netherlands per type of fuel source (wind, solar, biomass, hydro, refuse, fossil and nuclear)[35]

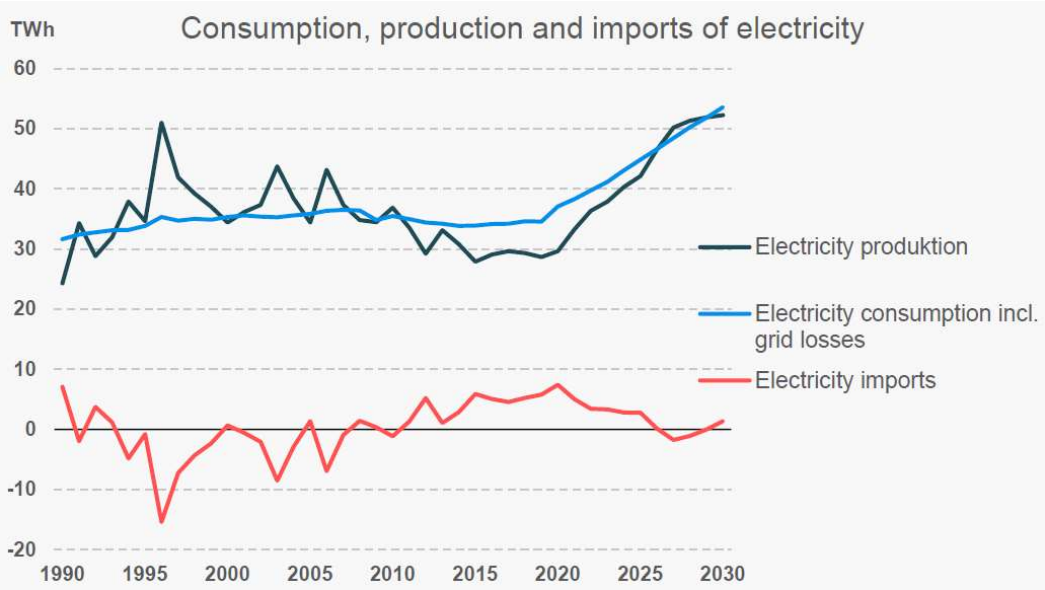


Figure 88: Electricity consumption, including transmission and distribution losses, electricity production and electricity imports.

Energy islands

Denmark is currently the largest oil producer in the EU. Denmark has introduced a cutoff date of 2050 for oil and gas extraction in the North Sea and canceled all future licensing rounds in 2020. Part of the plan to ensure a just transition for impacted workers is to establish two energy islands[36]:

[35] Source: Where does the power come from | Energinet
[36] Source: Denmark decides to construct the world's first windenergy hub as an artificial island in the North Sea (kefm.dk)

- An artificial island in the North Sea that will serve as a hub for offshore wind farms supplying 3 GW of energy, with the potential to expand to 10GW in future
- The energy island in the Baltic Sea will be Bornholm, where electrotechnical facilities on the island will serve as a hub for offshore wind farms off the coast supplying 2 GW of energy.

The artificial island is expected to cover an area between 120 000 to 460 000 m^2, comprising 200 – 600 wind turbines, potentially measuring more than 260m from sea level to tip of the blade. The hub will be the largest construction project yet for Denmark, with a total expected cost of 210 billion DKK, for constructing the island, building a 10 GW wind farm and deploying the necessary infrastructure.[37]

The aim is to have the two energy islands established by 2030.[38] Information presented from Denmark's Climate Status and Outlook 2021 report in the Introduction (section 9.1) and the paragraphs in Energy preceding Energy Islands excludes any consideration for the contribution from the energy islands to the reduction of greenhouse gas emissions. A sensitivity calculation with the energy islands shows an increase in the share of renewables in electricity consumption from 97% to 122% by 2030.[1] Denmark is therefore expected to have a large surplus of green electricity that can be utilised to reduce greenhouse gas emissions from other sectors through direct or indirect electrification or to displace fossil fuel electricity production in neighbouring countries. There is enormous potential inherent in the energy islands, such as electricity storage or the manufacturing of synthetic green fuels (Power-to-X, green hydrogen) that can be used for shipping, aviation, industry and heavy-duty vehicles.

Figure 89:The illustration is intended to serve as a visualisation of what the island in the North Sea may look like once it has been constructed.[39]

[37] Source: factsheet_Energy_hub.pdf (kefm.dk)
[38] Source: Energinet is ordered to start feasibility studies for the energy islands | Dea (ens.dk)
[39] Source: Denmark's Energy Islands | Energistyrelsen (ens.dk)

Biogas[40]

Since 2013, 51 biogas facilities have been connected to the gas system. At the end of 2021, biogas injected into the gas system was just shy of 25% of total gas consumption in Denmark, up from 21% in 2020. If this growth continues, it is likely that biogas will comprise 75% of Danish gas consumption in 2030. By 2034, biogas production is expected to fully meet Danish gas demand on an annual basis.

When biogas are upgraded to biomethane and injected to the Danish gas system, it can be used for heating, combined heat and power (CHP) production, for various types of production in enterprises and for cars, trucks and buses running on gas.

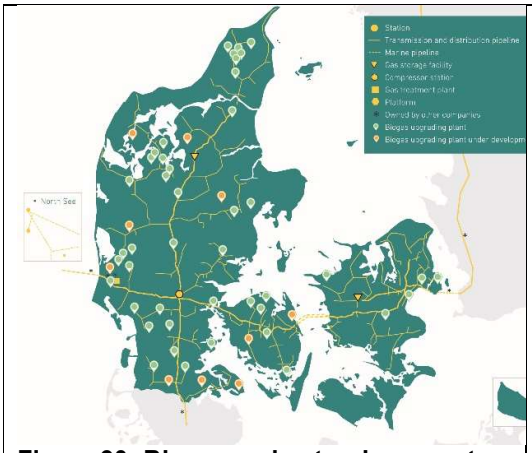


Figure 90: Biogas and natural gas system in Denmark

Figure 91: The public transport buses we commuted on while in Copenhagen uses biogas as fuel.[41]

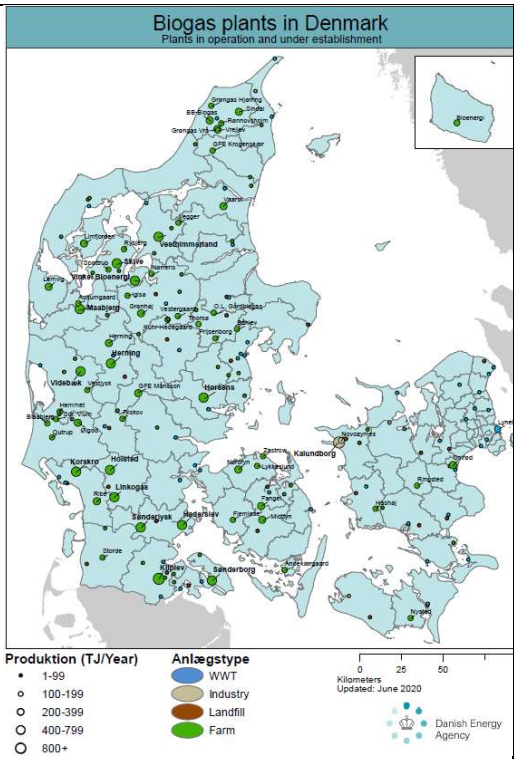


Figure 92: Biogas Plants in Denmark

During our trip we visited the island of Samsø where we explored an on-shore wind turbine, visited the energy academy and a smart micro grid at the harbour. During our last week, we also visited Horsens Bioenergi Biogas plant with an upgrading facility to transform the biogas to biomethane before injecting it into

[40] Source: Record biogas 2021 | Energinet

[41] Source: In future, millions of Danes will ride with MAN (mantruckandbus.com)

the distribution gas network. These site visits and case studies are further explored in the sections below.

9.6.1.Excursion to the island of Samsø

Samsø's conversion: Version 1.0 (1997 – 2007)[42]

We travelled from Copenhagen with a ferry to Samsø island. Samsø island is Denmark's third smallest municipality with 3727 inhabitants. Samsø island is renowned for the fact that it is the **world's first renewable energy island.**

It all began in 1997, with a competition launched by the Ministry of Energy, with a time horizon of 10 years. The objective was to highlight renewable energy and study how high a percentage of renewable energy a well-defined area could achieve using available technology, and (almost) without extraordinary grants. A priority in the ministry's competition was the **reduction of energy consumption across sectors, specifically heating, electricity and transportation**. Another top priority for the project was the **degree of local participation**. The business community, local authorities and local organizations had to support the proposed master plan to give it credibility. The technical solutions in the master plan were to draw primarily on available technology, but the master plan was also expected to envisage **new ways of organizing, financing and owning the proposed RE projects**.

Electricity

Over the course of 10 years (1997 – 2007) the islanders managed to be a net-exporter of electricity, generated from 11 (11MW) on-shore and 10 (23 MW) off-shore wind turbines, supplemented by biomass and solar plants.

Remarkable of the islanders, were their interest to be part of this project and their enthusiasm to invest therein. To ease implementation and secure broad public support and acceptance, the energy island project also proposed, in conjunction with the National Wind Turbine Association, an ownership scheme which would give all island citizens the chance to invest in the wind turbines. This scheme was adopted and implemented by an organization called 'Samsø Wind Energy'. All together 40 specific applications for turbine sites on local properties reached Samsø Municipality and the Aarhus County Office for Technology and Environment who conducted the area zone planning for the project.

Samsø Wind Energy began the pre-sales reservation of wind turbines shares in collaboration with the energy organization Samsø Energy and the Environment Office. These initial orders reserved two wind turbine sites for 430 shareholders. The landowners and wind turbine owners at that stage also signed an agreement to establish a fund to further other forms for renewable energy.

The first wind turbine was erected and on-line in 2000. Electricity production prices are regulated by law and include a ten year fixed price agreement which

[42] Source: 157515-200.pdf (energiakademiet.dk)

is the same for all 11 wind turbines on the island. The agreement stipulates a guaranteed price of 0.60 DKK (about 8 EUR cents) for the first 12,000 full-load running hours and after this 0.43 DKK (about 6 EUR cents) until the ten year period has expired. Each wind turbine cost about 6 million DKK (about 800,000 EUR) including the grid connection and foundation.

Figure 93: Electricity and district heating plants constructed during the first project period (1997 - 2007)

We visited Jørgen Tranberg's farm and climbed his 1 MW wind turbine. Jørgen also owns a 50% share of an off-shore wind turbine.

The off-shore wind turbines were installed specifically to "de-carbonise" the transport sector. Since there weren't technology then that could supply the transport sector's energy needs with renewable energy, the energy supply had to be offset with offshore wind turbines, producing an equivalent amount of CO_2-free energy.

Three homes installed 20m^2 of solar panels and the Samsø Energy Academy has 200 m² PV panels integrated in the roof. The main obstacle here was the lack of economic viability, and the technology appealed more to the idealistic citizen interested in self-reliance. Energy Efficiency campaigns were also part of the island project. These efforts aimed to decrease the consumption of electricity used for heating purposes by eliminating electric heaters. Other EE-efforts were in vain, the population is buying and using energy saving bulbs and A++ refrigerators and freezers and therefore is saving electricity, but the increasing use of products that use electricity negates these savings.

Transportation

During the 10-year competition timeframe, Samsø Island implemented three initiatives to lower the climate impact of the transportation sector:

1) A public transport overhaul: replacing larger buses with smaller ones in off-peak hours. More flexible bus schedules or free public transport would reduce private sector transport.

2) Reducing the energy consumption of tractors by improving driving techniques and engine specifications could reduce the energy consumption in the agriculture sector by 30%. In the summer of 2003, a demonstration project started a local production of rapeseed to supply rapeseed oil for the tractors and rapeseed feed for the animals. Unfortunately this project was not financially feasible since the rapeseed oil were subject to the same energy taxes in Denmark as diesel fuels.
3) A gradual transition to electric cars to reduce fossil fuel consumption.

Heat

The share of the total heat produced by renewable energy (RE) increased from about 25 % in 1997-1999 to about 65 % in 2005. During this same period there was a 10 % decrease in the heat consumption. There were three new district heating stations build during the project period, Nordby-Mårup (2002, 20.5 million DKK, partly grant funded), Onsbjerg (2003, 3 million DKK) and Ballen-Brundy (2004, 16.2 million DKK, partly grant-funded). The municipal council on Samsø guaranteed the mortgage loans that finance the district heating stations. Straw and wood chips for the district heating stations are produced by local farmers. The national association for energy savings 'Energisparefonden' gave a grant to heat consumers who converted from electrical heating to district heating.

In these 10 years 468 million DKK (85% from local households, companies, the municipality and the energy company) was invested to bring about the initiatives explained above to become 100% self-sufficient and have -3.5 tonnes CO_2 footprint per capita.

Samsø's conversion: Version 2.0 – Fossil-free Island by 2030

After our visit to Jørgen's farm, we visited the **Energy Academy**.

The Energy Academy was opened in 2007. Samsø Energy Academy's buildings are constructed using sustainable principles that dates back to their ancestral Viking heritage, specifically where natural ventilation are concerned. Water-saving faucets minimize water usage and rainwater-harvesting is used for flushing of toilets. Effective insulation, solar heating and a connection to the district heating network limit heating needs. Energy efficiency is achieved by A-classified equipment and low energy lamps, and supplied from 200m^2 of PV panels.

Figure 94: Samsø Energy Academy's buildings are constructed in Viking fashion

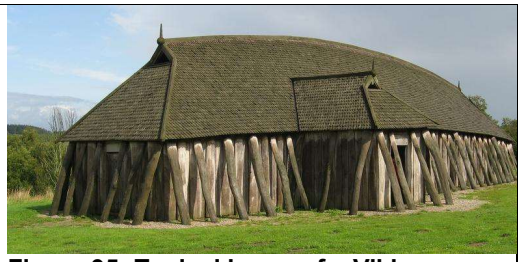


Figure 95: Typical home of a Viking.

This building is a physical gathering and meeting place for the island's various organizations. It hosts courses, meetings, seminars, and education and research exhibitions on subjects concerning energy, climate change and sustainable utilization of resources. Samsø Energy Academy has eight full-time employees. The Samsø Energy & Environmental Office, the Samsø Energy Agency, and the Samsø Energy Service are also based at Samsø Energy Academy.

Samsø Energy Academy is a project-based organization focused on the consequences of climate change. Put simply, its organizational goal is to convey knowledge about holistic cooperative processes.

Michael Kristensen from the Energy Academy who also accompanied us to Jørgen's farm presented the second phase in Samsø's conversion for even a smaller footprint on nature. This time around the Island have the ambitious goal of being fossil-free by 2030[43], with the main challenges addressed in seven objectives (refer to Figure 96). This action plan aims to reach an overall CO_2 emission reduction target of 20%.

Table 2. Overview of the actions of the master plan for Samsø – the fossil free island. Green bars indicate the time period for the planned action. Several additional specific actions will be initiated based on local efforts.

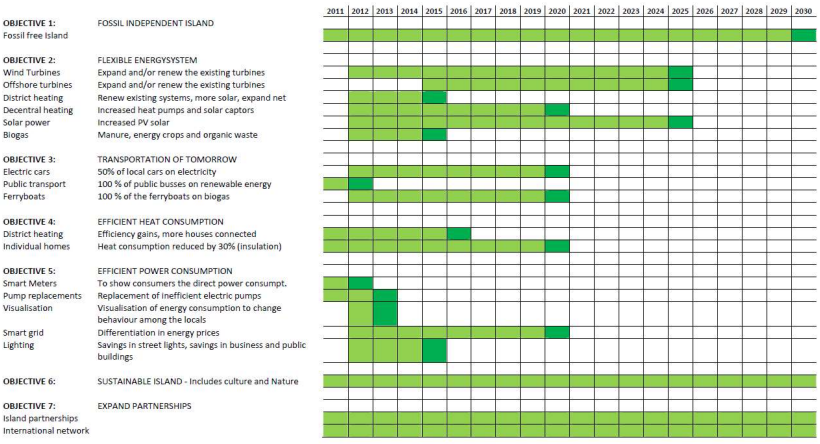


Figure 96: Action plan for reaching seven objectives to make Samsø a fossil-free island by 2030[44]

[43] 20 years earlier than the National target.
[44] Source: Sustainable Energy action plan, Island of Samsø, Final version, 17 November 2011, accessed at Samsø (covenantofmayors.eu)

Samsø island have made strides towards their ambitious goal of becoming fossil-free by 2030 by implementing the following projects already:

Samsø ferry[45]

Figure 97: The Princess Isabella, the first domestic Danish ferry to be fuelled by LNG

The Samsø ferry was the first domestic Danish ferry to be fueled by Liquefied Natural Gas (LNG) and operational since 2015. Using LNG as a fuel source is much more environmentally friendly than diesel:

- The CO_2 reduction of LNG compared to diesel is 15-20 % – depending on the methane emission caused by combustion
- The NO_x reduction is estimated to be up to 85%
- Burning LNG does not emit particles or SO_x

Additionally, specific to this ferry, the bunkering solution for the ferry is very environmentally friendly. There are no methane emissions associated with bunkering due to the so-called Mannheim Tek quick-action coupling. The ferry is allowed to have all bunkering pipes under constant gas pressure, ensuring that there is no need to flush the pipes of nitrogen gas into the atmosphere. The bunkering hose is 'parked' in the land facility after bunkering is complete, whereby LNG in the tubes is blown back into the tank by evaporation in the hose.

In the future, the ferry will be fueled by liquefied biogas from Samsø. The planned biogas plant will be multi-functional in nature, producing biogas for transportation, and by-products that can be used as fertilizers.

From wastewater to fertilizing water- pilot scale operation[46]

The fundament for agricultural production is the availability of fresh water resources and at islands, this is a scarce resource, which is also the case for the island of Samsø. To maintain the production of fruit and vegetables, there is an increasing need to control the water circuits of the island and utilizing the resources it contains directly. The Island of Samsø, Denmark is in the forefront and aims to be a model island for a circular bio-economy. To accomplish this, there is a need to rethink wastewater treatment so it is aligned with the seasonal variation of the agricultural production.

[45] Source: Samsoe Ferry Fuelled by LNG (kosancrisplant.com)
[46] Source: Abstrats_for_2018_annual_meeting.pdf (dtu.dk)

Seems as if there is a pilot scale operation going on as part of the Ministry of Environment and Food's Environmental Technology Development and Demonstration Program (MUDP) to clean wastewater so that it can be used for irrigation purposes or sludge for biogas and fertilizer.

Electric Vehicles

To date more than 80% of municipal cars are electric vehicles. There is a case study where an intelligent/smart load management solution was installed for an EV fleet of an ambulant nursing centre. In total six charging stations have been equipped with FLEXeCHARGE Load Manager. The load management solution managed to reduce the average charging time by more than 30% in just the first few months after installation. Reduced charging times increase the utility of EVs and provide the foundation to further increase the number of charging points without costly grid extensions.

Samsø's green gholf course[47]

Samsø Golf Club was presented with The Golf Environment Prize in 2015 as proof of the great environmental effort the club had made. Already, the pilot project with micro-clover and algal fertilizer is being used on Samsø Municipality's football field and the municipality's other green areas. Micro-clover save a lot of nitrogen, inhibits weeds and requires less water. Water is recycled on the gholf course. Electricity and solar cells power the green mower and gholf carts. Sheep are used to graze the field. Biodiversity are improved and golfers and visitors are greeted by hare and deer.

SMILE – Smart grid[48]

A smart grid pilot project is being carried out at Ballen Harbour and Ballen Ferry Port. This was our last stop on Samsø island. The project stakeholders is a consortium consisting of 19 partners from Italy, Scotland, Portugal, Denmark, The Netherlands and Greece. Samsø Energy Academy is the coordinator for the Samsø partners.

The technological solution employed at the marina entails the integration of battery technology, the use of electrical power for heating and fueling, hydroelectric pumping, EVs, electric loading of ships, a unified demand management and algorithms that can predict consumption and needs.[49]

[47] Source: Green Golfclub on Samsø » Energiakademiet
[48] Source: SMILE (smart grid) » Energiakademiet
[49] There are several sources researching the demand management and algorithms for the Ballen Marina in Samsø. Refer for instance to PowerPoint Presentation (smartenergysystems.eu) for a quick summary thereof.

The microgrid comprise solar power (first time in my life that I saw vertically installed PV panels – On the harbour wall, 60kWp) and battery energy storage (49kW, 237kWh) with an intelligent energy storage inverter and smart energy management software supplying 340 charging points which can support up to 10 000 boats per year at the Ballen Marina. Whenever the boats dock power supply is enabled at the sockets after payment is made via a website / app (cpay.dk) where you have an option for smart charging where you pay a reduced fee if you allow the software to control when and at what rate to charge your boat. The speed of charging is controlled by the user's input of his planned departure time.

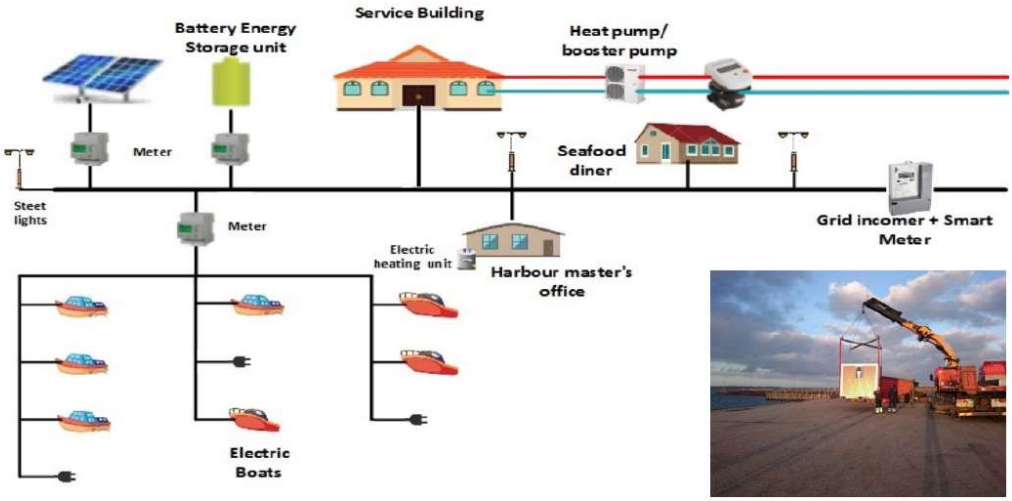


Figure 98: The microgrid layout incorporating PV and BESS to power the marina.

Figure 99: The battery energy storage system is housed in the red building with rooftop PV and a boat charging station is visible to the left-hand side.

Figure 100: Vertically installed PV plant on the harbour wall

Figure 101: Close-up of the charging station sockets. Note the QR code that provides easy access to the internet to enable charging with user interface of choosing charging times and payment options.

9.6.2.Horsens bioenergy Biogas plant[50]

In our last week, we had a site visit to Horsens Bioenergi Biogas plant. The plant was built by Bigadon A/S in late 2013 and came into operation in 2014. The plant was constructed for 73.3 million DKK and costs about 12.7 million DKK to maintain and operate per annum. The plant comprise an area of 15 000 m^2 and can handle 240 000 tonnes of feedstock per year. The plant produces 13 million Nm^3 biogas/year and 8 million Nm^3 methane/year. The estimated energy sales of biogas sold to the gas network is 67 GWh.

One of the key considerations for this plant was Horsens Municipality's requirements for assessing visual impact. The visual impact must be assessed in accordance to visibility and contrast which has given rise to its peculiar inverted dome like shape with the digesters visible behind it.

[50] Source: Home - Horsens Bioenergy - Horsens Bioenergy (horsensbioenergi.dk)

Figure 102: Horsens Bioenergi biogas plant

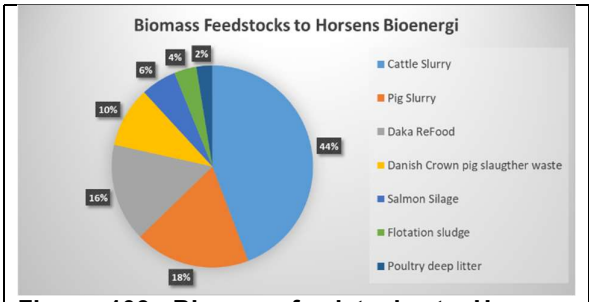


Figure 103: Biomass feedstocks to Horsens Bioenergi

Horsens Bioenergi's co-digestion plant produces biogas from several feedstocks (refer to Figure 103). The plant has 33 suppliers of manure all within a 15km radius from the plant, and Danish Crown pig slaughter-house, one of Europe's largest pig slaughterhouse groups, just 1km away. Daka ReFood, a pre-treatment plant for food waste, was constructed in 2016. The plant can handle 55 000 tonnes per annum of food waste from supermarkets, food producers, and canteens. The plant has the ability to sort the packaging from the food waste and was a first of its kind in Denmark. The Daka ReFood pre-treatment plant delivers the food waste to the bio-digesters, where it is mixed with the existing biomass.[51]

The plant was built with a receiving tank, pasteurization tanks, two digesters/reactor tanks of 8 000 m^3, two covered storage tanks with gas collection of 1 500 m^3 and the upgrading facility.[52]

The feedstocks are received and mixed into the plant's receiving tank and mixing tank. A biological air cleaning system connected to both the receiving and mixing tank prevents odour nuisances. Hereafter the biomass is heated to 70°C and treated in the plant's pasteurization tanks. In here pathogens and weed seeds are eradicated, and at the same time the EU's hygiene requirements are observed.

The digesters are heated by a heat exchanger system, where the pasteurized biomass is simultaneously cooled down to the process temperature in the subsequent digestion step. Additional heat is produced by a gas boiler. Biogas

[51] Source: We optimize biogasification - Daka ReFood
[52] Source: https://www.biogasgoglobal.com/Admin/Public/DWSDownload.aspx?File=%2fFiles%2fFiles%2fBiogas-Go-Global%2fDatasheet-HorsensMXfinal.pdf

is produced from organic waste, which is biodegraded using bacteria in an anaerobic environment. The process is accelerated by maintaining a temperature of either 38°C (mesophilic) or 52°C (thermophilic) in the plant's biodigesters - in Horsens Bioenergi's plant, the depletion is mesophilic. For 25 days the biomass solids are transformed in a microbial / oxygen-free environment into biogas comprising 60-70% methane gas and 30-40% carbon dioxide.

The biogas is discharged from the reactor tanks to a so-called water scrubbing upgrade plant, which purifies the carbon dioxide and collects hydrogen sulfide and water vapor.

The methane gas is then pressurized to 4 bar and discharged onto Ørsted's natural gas network 1.6 km from the plant.

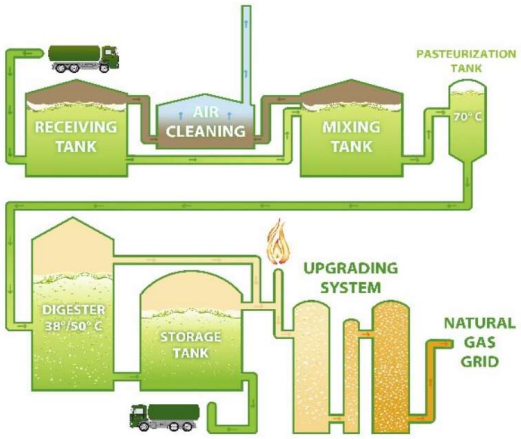


Figure 104: The production of biogas and the system/processes at Horsens Bioenergi

Horsens Bioenergi's trucks transport the slurry from the local farmers to the plant and returns it after degassing. The digestate is used as fertilizer on farm land.

The plant was extended in 2016 with a third 8000m^3 digester[53] and an ammine scrubber as a second upgrading facility. Malmberg is the manufacturer of the first water scrubbing upgrade plant (a COMPACT ® GR14 machine)[54] and Ammongas provided the ammine scrubber.

Figure 105: The Malmberg water scrubber upgrading plant

Figure 106: The ammine scrubber upgrading plant

Lessons learnt:

- Biogas plants should be close to their feedstock. Some of the trucks makes between 75 – 95 runs between the supplier and the plant, causing

[53] Source: Horsens Bioenergi - Bigadan
[54] Source: Read about Horsens Biogas plant with a Malmberg COMPACT upgrading machine

nearly 3 – 4 % more traffic load to the nearest road. Closer to the feedstock reduces travel time, increase safety for truck drivers, reduces road maintenance and ensures reduced CO_2 emissions.

- Get the feedstock mixture correct. The team learnt from experience that too much of a good thing is not so good, e.g. when too much of the Norwegion salmon fish waste caused a significant reduction in gas production shortly before the Christmas of 2014.
- Reliable suppliers of feedstock. Horsens Bioenergi has a good relationship with their suppliers and although they are not paying for the feedstock they are providing degassed slurry (with more phosphor, less ammonia, methane and nitrous oxide) with several benefits to the suppliers at no cost.
- Good technology. The plant keeps expanding and employing the latest technology (e.g. Daka ReFood, Ammine Scrubber)
- Good relationship with the municipality and community, as seen from their visual impact considerations and keeping their odour emissions as little as possible.[55]

9.7. Climate resilient Cities

9.7.1. Copenhagen City walk

On Monday, 4 October, our first day out of the hotel after isolation, we did a City walk from the hotel, to Nørreport station, and continue to Kgs Nytorv Station, from where we took the metro to Copenhagen Central. On the way the aim was to observe and discuss a number of climate and environment related features such as biking infrastructure (refer to section 9.4), flood control measures as well as climate adaptation measures at Nørreport station. Nørreport station is Copenhagen's busiest metro station, covering 10 500m^2 urban space with 2500 parking lots for bicycles accommodated in recessed bicycle 'beds', redesigned and upgraded in 2015. The access points to the station is also known for its green roofs and house a few solar panels.

We also walked past Sankt Annae Square and the Skuespilshuset. Skuespilhuset's meaningful technical solutions reduced its overall energy consumption by nearly 40%, through initiatives like using seawater for cooling and repurposing excess heat from the building's users and lighting.[56]

[55] Horsens Bioenergi plant aims to keep OML levels less than 10 LE. OML stands for Operationelle Metrologiske Luftkvalitetsmodel (A operational meteorological air quality model).
[56] Source: Skuespilhuset - Danish Architecture Center - DAC

Figure 107: Nørreport station from the air

The metro is designed for climate change[57]

Climate-change induced events that impacts the metro the most include cloudbursts, storms, lighting strikes and storm surges. If the metro system is flooded, worst-case implications include breakdown and material damage. For example, if saltwater reaches any of the technical installations, this could lead to prolonged downtime and significant financial losses. The aim is for the Metro to be completely dry. The authorities has therefore included a climate change adaptation strategy from the onset of planning and design. The metro system is designed on the basis of a 2000-year cloudburst event; i.e. an event which has a 5% likelihood of occurring within the lifespan of the metro (100 years). Changing climate change models and scenarios should always be at the forefront of consideration: the mean water level forecasts have gone, for example, from 48cm at the time of designing the first metro, to 1m at the time of designing the Nordhavn branch. This requires a height change of where to place platforms and shafts. The City of Copenhagen allows for 10cm of water at ground level in the event of a cloudburst. Recently they have also started to take the wave effect caused by traffic into account. The bus traffic at Nørreport station caused a wave effect during the cloudburst of 2011 and caused more water to accumulate around metro entrances than had been anticipated. They therefore had to improve the pumping capacity to rid the stations from stormwater. Risk analyses of cloudbursts and storms are conducted for the entire metro system, but there are specific assessments done for each individual installation.

Some specific climate change adaptation solutions implemented at the metro entails:

- The layout of streets around the underground stations is designed so that the stormwater will run away from the stairwells.

[57] Source: The Metro has been designed for climate change (klimatilpasning.dk)

- Where the metro descends from above ground to an underground tunnel, a drainage grate is established across the tracks on the way down into the tunnel. Stormwater can be accumulated here and pumped away before reaching the tunnels. If excess water reaches the tunnel it is led away to retention wells and pump wells.
- Underground stations have been secured against backflow from the City's stormwater network.
- Storm-surge gates have been established at Frederiksberg, Nørreport and Kongens Nytorv stations to safeguard the direct underground access to shopping centres or the electrified railways of Greater Copenhagen.
- Technician rooms are fitted with watertight outer doors, and some even have an extra 30cm-high doorstep.
- All electrical and mechanical installations are watertight.
- For long stretches above ground, drains have been established to lead water away from the tracks towards the stormwater system.
- Trees have been removed that pose a risk to tracks.
- Gabion walls have been built along exposed above-ground stretches.

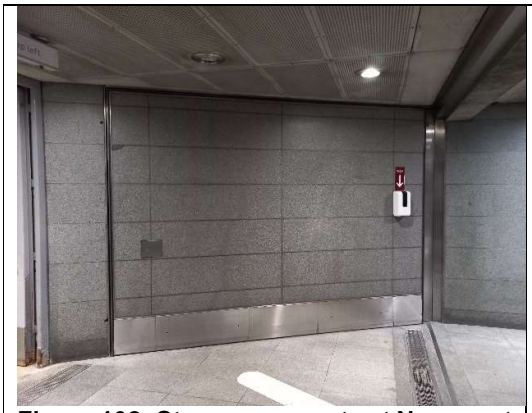


Figure 108: Storm-surge gate at Nørreport station

Figure 109: At some stations (here at Kongens Nytorv) an extra step has been established in front of the metro access way

Some cloudburst adaptation plans also included creating a by-pass subsurface stormwater tunnel diverting the water away from the high-lying areas towards the waterfront preventing water to affect the railway system (refer to Figure 110).

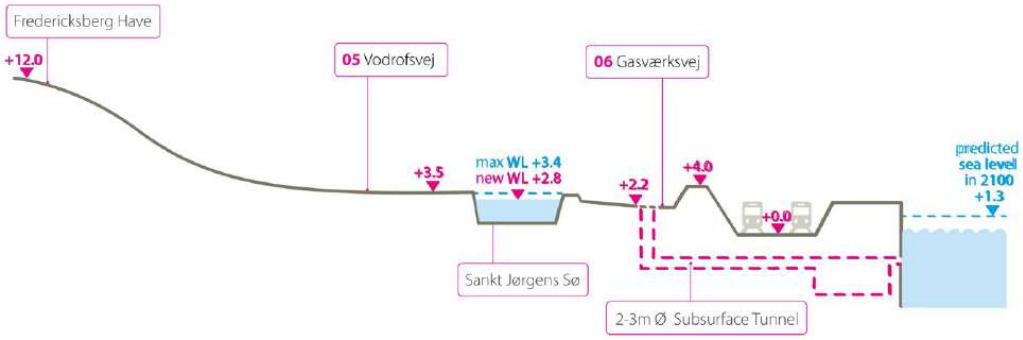


Figure 110: Concept design of a by-pass sub-surface stormwater tunnel diverting excess water from Sankt Joergens Lake to the waterfront without affecting the railway system.

Figure 111 illustrates the subterranean storage basin that was constructed for the Aarhus River project (presented to us during the Aarhus Vand presentation while still in isolation). Although not in Copenhagen, this figure is included here as an example of the sheer size of retention / pump wells that forms part of the Danish stormwater adaptation plans.

Figure 111: Subterranean storage basins constructed for the Aarhus River project

Green Roofs[58]

The City walk was concluded at the SE Bank buildings (separated by / surrounded by The City Dune) and the National Archives, both of which featured in the "green roofs" publication of the City of Copenhagen, and just opposite our Wake-up Hotel.

Green roofs are roofs covered with vegetation such as stonecrops, mosses, perennials, shrubs or trees. The choice of vegetation determines the thickness and thereby the weight of the green roof as well as the required maintenance. There are several benefits to green roofs, such as increasing biodiversity, preventing rainwater run-off, reducing the heat island effect and increasing the functionality of buildings and cities. Since 2010 green roofs are mandated in most new local plans of the City of Copenhagen.

SE Bank & Pension, a Swedish bank, wanted to establish a Scandinavian presence in Copenhagen. They are the owner of an urban space between their headquarters and an office space rented out. The client wanted the urban space to become a green and welcoming urban space tying the headquarter, surrounding area, the harbor and the rest of Copenhagen together. The urban space that was designed and implemented became known as The City Dune and was Copenhagen's first fully acclimatized urban space. It is renowned for the fact that although it is a privately owned property it is fully accessible by the general public. It showcases how private corporations and municipalities can cooperate in creating open and accessible urban space of high value to the public. The City Dune covers an area of 7300 m^2 and was designed and implemented from 2005 – 2010 at a cost of EUR 4.85 million.[59]

[58] Source: green_roofs_copenhagen.pdf (klimatilpasning.dk)
[59] Source: The City Dune Copenhagen, Urban Space - e-architect

The key drivers from the client indicated that the urban space should include recreational spots for employees and guests, full accessibility for the walking impaired, provide the client with a distinctive urban brand, and most importantly, had to be fully sustainable and 100% acclimatized wrt rainwater handling. Currently, The City Dune is quite a favourite spot for skate-board enthusiasts due to the gradual slope rising 7 meters to the highline ending at the rooftop garden of the National Archive.

The City Dune is made of folded white concrete, inspired by the sand dunes of Northern Denmark and the snow dunes of the Scandinavian winter. The concrete has a non-skid and water-repellent surface. The large white surfaces creates a cooler microclimate during the warm periods of the year by reflecting as much of the incoming heat radiation as possible.[59]

Figure 112: The SE Bank & Pension headquarters with the City Dune meandering to the green rooftop of the National Archives

The primary purpose of the National Archives' roof garden is to provide a pedestrian passage and cycle path (900m long) for the public, which links Bernstorffsgade and SEB Bank's new registered office to the north with Tivoli Hotel and Congress Centre to the south. The secondary aim is to create a quiet garden close to the Port of Copenhagen and the Central station where people can sit down, relax, read a book or just enjoy the sun, peace, and the sight and scent of the plants. The visual design aimed to minimize hard surfaces and used a wide range of different plant species (40 different plant varieties). The weight load on the deck has presented a major challenge with regard to project design. The external insulation of the roof structure has required a minimum load of 250 kg/m^2 and a maximum load of 580 kg/m^2. These weight requirements governed the choice of vegetation types on the structure.

The technical design leads all precipitation water through the growth media and the reservoir plates before excess water reaches the drainage system. It is

estimated that around 60-70% of the precipitation in the area is retained annually, and hence reducing the impact on the stormwater system.[60]

Figure 113: The National Archive's rooftop garden

9.7.2. Visit to Aarhus Municipality

Our first excursion in Aarhus was a visit to Aarhus Municipality where we had a presentation on their Climate Action Plan. The theme of their action plan is “Go Green with Aarhus” and was expressed very similar to our “Let’s Act” climate action campaign.

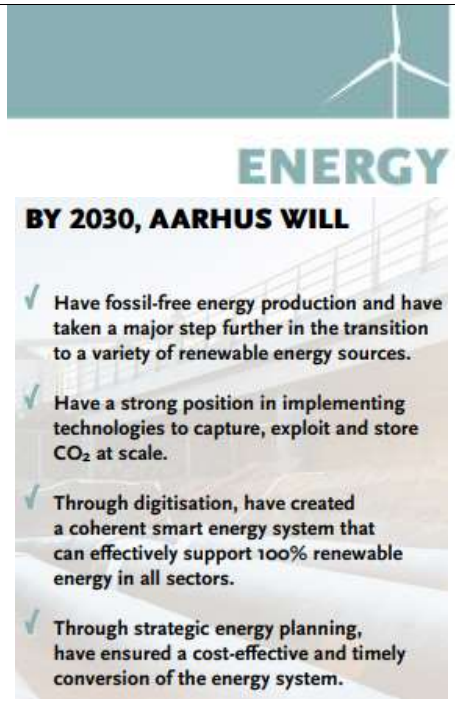
Figure 114: Theme of Aarhus Municipality's most recent CCAP

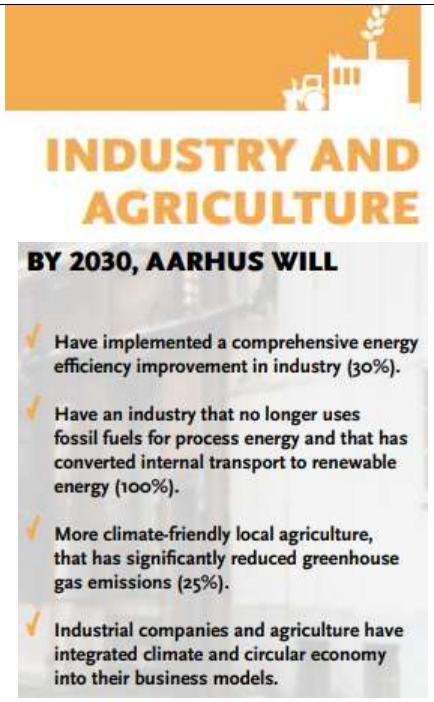
Figure 115: City of Cape Town's Let's Act climate action campaign slogan

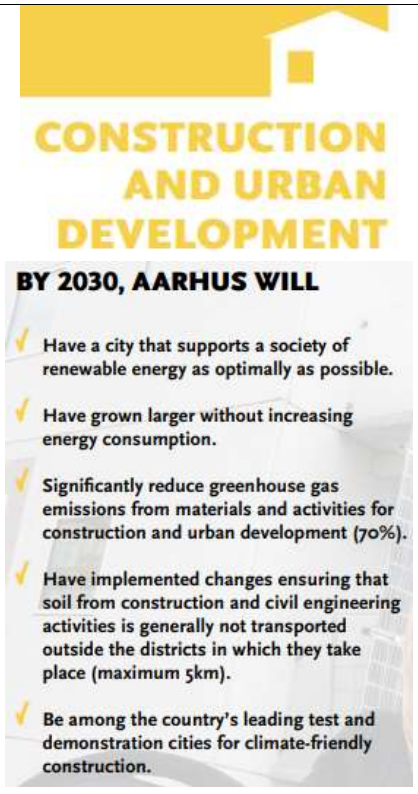
Aarhus Municipality has the vision of becoming carbon neutral by 2030 and fossil-free by 2050. Aarhus has come a long way and managed to reduce their emissions by 50% in the time period from 2009 – 2018. Their current climate

[60] Source: Copenhagen. Green roof, the Danish State Archives - About the idea - Water Sensitive Urban Design in Denmark (wsud-denmark.com)

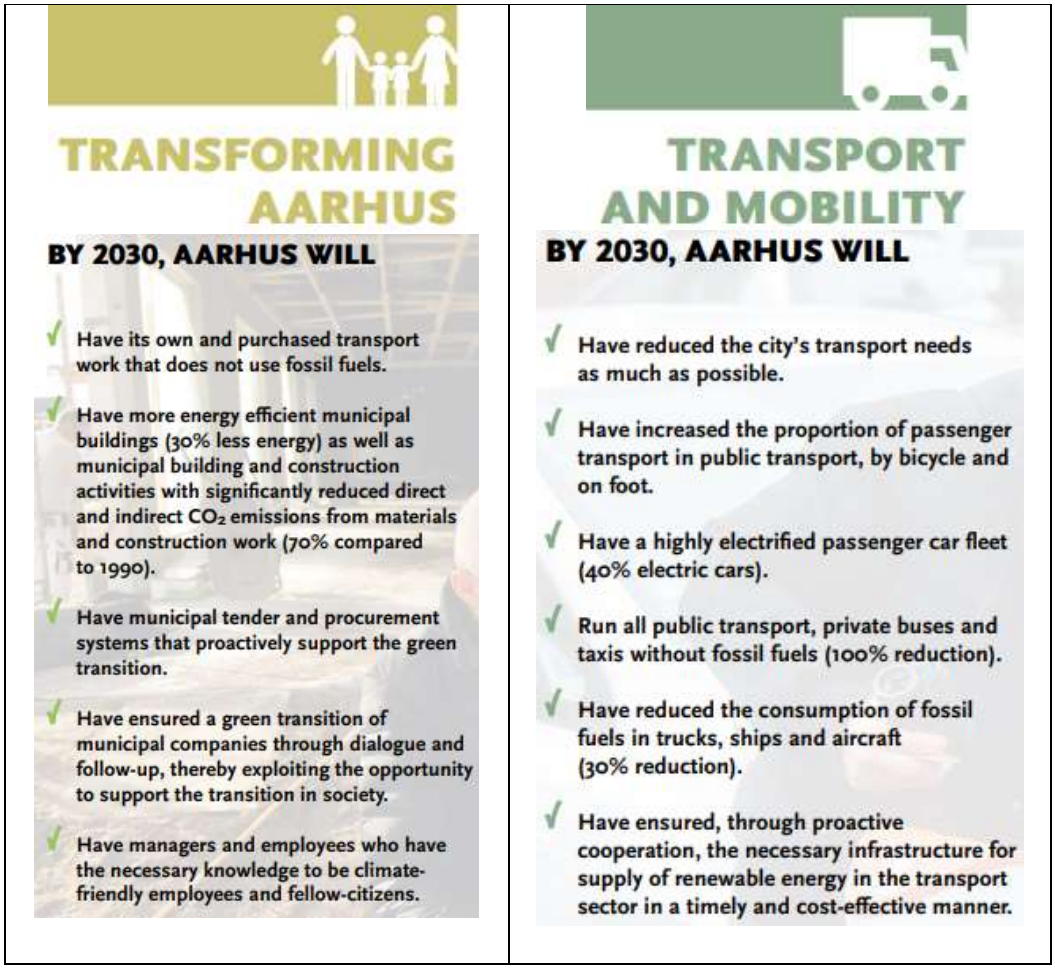
action (2021 – 2024) has six focus areas and 57 initiatives aligned to the Climate Strategy of 2030. The goals of the Climate strategy are given below for each of the six focus areas.[61]







[61] Source: Green Transition in Aarhus (gogreenwithaarhus.dk)



Aarhus Municipality has a number of international relations and projects in which they share know-how and technical solutions. One such international relationship is with the City of Tshwane to focus on sustainable city development.

9.7.3. Green organisations – the Niras example

We visited two of Niras offices, the one in Allerød near Copenhagen and the one in Aarhus. I have already touched on the examples of the offices' illustrating / demonstrating their commitment to the sustainable development goals (refer to section 9.3) and their participation in the Bike-to-work campaign (refer to section 9.4). Both offices also have PV solar installations to off-set electricity consumption, the one in Allerød also have a green roof.

The offices support (where possible) the movement of "**Wild on purpose**". "Wild on purpose" is a non-profit association, around since 2017, aimed at sharing a "holistic and inclusive perspective on nature, which emphasize a wilder and more diverse nature". Efforts are tailored to improve biodiversity the natural way specifically around the workplaces of both municipalities and institutions. It is beneficial for plants, animals and humans, contributing to well-being and life

quality. The association is known for its knowledge sharing of for example design, outdoor facilities, plants and gardening.[62]

The offices are very pro waste minimization and re-use/recycling. All rooms are fitted with light sensors to check for occupancy and adjusting lights in accordance to natural lighting entering through the windows. They apply hot-desk principles, and makes use of products with the **EU Ecolabel or Nordic Swan promoting green manufacturing practices**.

Printing paper, printer toner cartridges, batteries, Glass, metal cans, and other waste streams from the kitchen is sorted on site and recycled. Staff have a "put and take" room where you can bring items you no longer use or need for someone else's utililty.

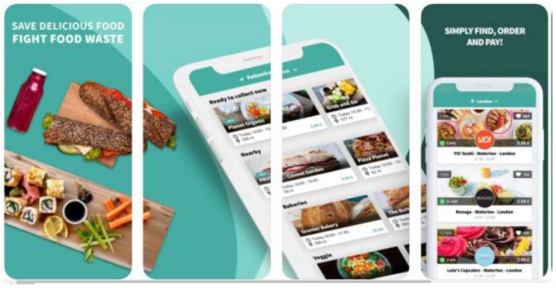


Figure 116: "Too Good to Go" mobile application for Niras employees

Food at the offices include a vegetarian option, 30 – 60% of all meals comprise organic food and food or organic waste is pulped and send to a biogas facility. They have a **"Too Good to Go" mobile application** where the canteen informs staff which food is leftover after the lunchtime serving that might be purchased for dinner. This application aims to reduce any food waste. **Residual coffee-grounds** from the coffee machines are used in **eco-friendly and cruelty-free skincare.**

At the Allerød offices we were fortunate to visit the **Niras Green Tech hub**, which only opened a month before. The Green Tech hub provides 5000m^2 of office space, storage and production facilities to start-ups. The Hub was created to provide a vibrant and innovative environment for entrepreneurs with access to Niras' many experts specialising in sustainability within different industries such as food, beverage, building, energy and infrastructure. The Green Tech hub provides an opportunity for sparring, co-development and collaboration with Niras to assist start-ups with building their prototypes, company structure, setting up production and presenting their products to relevant Niras clients.[63]

[62] Source: KMD is 'going wild' - Read the article
[63] Source: NIRAS Green Tech Hub

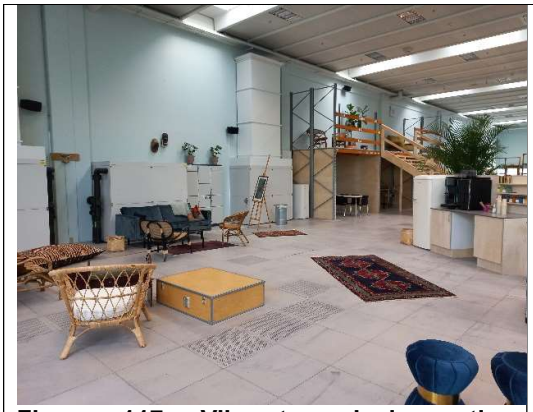


Figure 117: Vibrant and innovative environment for start-ups. The facility can accommodate 100 residents.

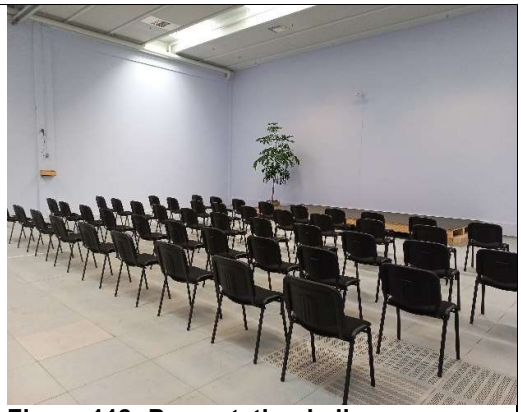


Figure 118: Presentation hall

Figure 119: Production hall

Figure 120: Cph Farmhouse is one of the resident's whose projects we viewed. They explore sustainable ways of producing high quality micro-greens, herbs and lettuce in vertical farming and horticulture.

9.7.4.Aarhus City walk

This City walk had a bigger focus on waste management although elements of stormwater management was also covered.

Waste management[64] in Aarhus are quite unique and originated from the need to improve the working environment for waste collectors. Waste collectors suffered from attrition due to heavy lifts and poor access conditions, so it now became mandatory to use wheeled waste containers and ensure flat passage ways without stairs and bumps.

[64] Source: Affald_Case_Aarhus_web_15.01.13.pdf (ecoinnovation.dk)

Figure 121: Above ground receptors for refuse in the new Aarhus system

Since 2008 more than 5,000 waste containers have been removed from pavements and courtyards along with some 100 igloos for waste paper and glass. Instead, around 800 4m^3 underground containers have been established for collection of refuse, paper, glass, and batteries.

The system was designed by architects, using a german product but tailoring it to the preferences of Aarhus residents. The above ground receptor were made rounder and a lot of work went into the handle, making it pleasant to touch. A discrete colour were chosen to blend with the cityscape.

Crane trucks are utilized to lift the containers out of the underground chambers and emptying it. Containers are weighed every time they are emptied to enhance optimal planning for collection routes and frequency of collection. This ensures that vehicles rarely meet half-empty containers to the benefit of residents and the climate.

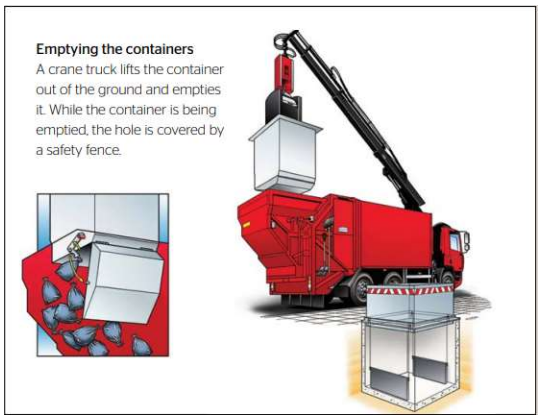


Figure 122: Waste collection in the new Aarhus system

The new system has a much more appealing appearance, resulting in less littering and less vandalism due to its more robust design. Odour nuisances are mitigated due to better hygience, since the containers remain cooler during the summer, thereby also solving the vermin crisis. Residents experience a smoother collection process and can enjoy more space in their courtyards.

Figure 123: The "Free Fridge" food waste section at the Reuse recycling centre

On our walk we also visited the **Reuse recycling centre** which were similar to the ones we have visited in Copenhagen (Solrødgård Climate and Environmental Park and Borgervænget Genbrugsstation (the Citizen's recycling station) during the Østerbro Climate-resilient neighbourhood) with the exception that it also had a **section for food waste** where dumpster divers share food they have found in containers outside of supermarkets.

Figure 124: The automatic car park at Dokk1 City library. Here a vehicle is retrieved from elevator cabin 20.

From Reuse recycling centre we continued the walk to the **City's library, Dokk1**. Both design and technical solutions are focused on sustainable initiatives.[65] The goal is to reduce energy consumption - both in the construction phase and the operational phase. The building meets the Danish class 2015 low energy requirements and boasts a 2432 m^2 solar installation. Seawater is used to cool the building. One of the most extraordinary features of this library is however its **automatic car park**, currently the biggest in Denmark, creating space for 1000 cars in the City centre. Vehicle owners can now drive their cars into one of the 20 elevator cabins at the facility and park it on the elevator platform. The elevator will then transport the vehicle down below ground level to a vacant parking shelf. When the vehicle is needed, one only needs to insert the parking ticket into a machine and the elevator system will collect the vehicle and return it to you in 2 - 3 minutes.[66]

From Dokk1 we visited the **sluice[67] at the Aarhus river outlet next to Dokk1**. Construction started January 2013 and lasted up to end of 2015, with construction cost totaling 46 million DKK. It is expected that a traditional solution with underground retention basins would have cost ten times more. The implemented solution serves two purposes:

1) Four sluice gates / flood gates will protect the city against intruding seawater during high sea levels. The sea level in the harbour can hereby rise up to 2.5 meters above normal water level without flooding the city. The sluice closes automatically when the water level is 1.4 meters above normal water level.
2) Six powerful pumps (18 000 litres per second) will pump water away from the river into the sea during cloudbursts.

Figure 125: One of the four sluice gates at Aarhus river outlet.

[65] Source: English | Dokk1
[66] Source: Privat- og erhvervsabonnement til parkering i Aarhus (dokk1-parkering.dk)
[67] Source: Sluice prepares Aarhus for more water (stateofgreen.com)

Figure 126: Temporary tree that residents can donate money for its eventual planting.

The last item on this City walk that I found quite interesting was a fake tree in one of the streets. Residents can submit a **request** to the Municipality of where they would like to see **a tree** planted. The Municipality will erect a fake tree/ temporary tree at the location requested and perform traffic impact studies (for vehicles and NMT) while at the same time, residents can vote and donate money towards planting the tree by merely scanning a QR code on the temporary tree. If sufficient money were collected by the general public and there is no technical objections to the tree being planted, the municipality indeed plants the tree.

9.8. Presentations

Throughout the learning programme there were several presentations which are mentioned below with key takeaways from each.

9.8.1. Financing climate / green projects and practices

Presentation on several financial mechanisms and funds available to finance climate change adaptation, mitigation, and/or resilience projects. Applying for financial aid may be a laborious but worthwhile endeavour if carefully researched and can present opportunities in a fiscally constrained context. Africa, and South Africa in particular, is ideally positioned to tap into these financial resources being a non-Annex I country eligible for the $100 billion a year climate finance funding deal committed by Annex I countries (as agreed to at COP15).

9.8.2. Disaster Risk Management

Presentation on the definitions of disaster, hazard, risk, vulnerability, disaster types, disaster risk reduction, community-based DRR, and examples from work done by the Red Cross, DRR actions, or solutions. According to the strict definitions of a disaster and hazard, there is no such thing as a natural disaster but rather natural hazards which can lead to disasters given a high vulnerability. The advice is, therefore, to assess all known hazards, identify the vulnerabilities and mitigate them as far as reasonably practicable in all sector planning.

9.8.3. Climate Change Mitigation

This presentation was given at the Niras office in Allerød and centred around the resources and technologies available for renewable energy, energy efficiency in Buildings, Industry and Transport as well as improving energy conservation.

In order for an organisation or country to determine their best climate action plan, one needs to understand what activities/sectors are the biggest culprits. 73% of greenhouse gas emissions stems from energy usage by the sectors of Transportation, Electricity and heat, buildings, other fuel combustion, manufacturing and construction and fugitive emissions (refer to Figure 127).

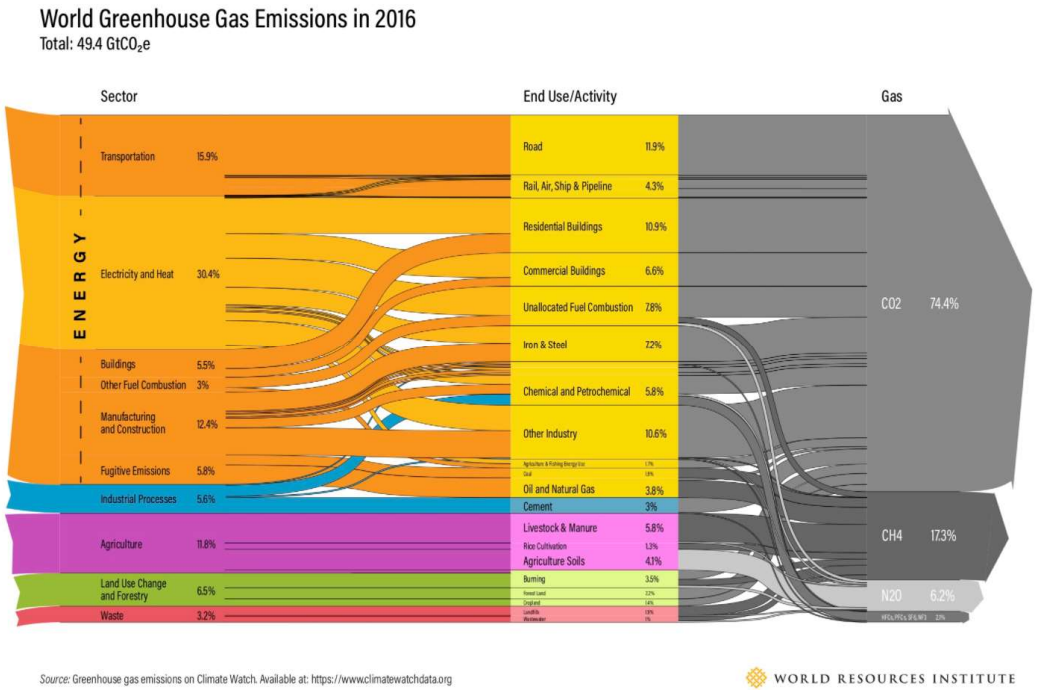


Figure 127: World greenhouse gas emissions in 2016 subdivided into sectors, end use or activity and the gas emission caused.

The presentation illustrated the need for an organization/country to be acutely aware of the types of resources to their availability and the potential feedstock/fuel available to harness that resources (e.g. making use of wind and solar maps).

The presentation highlighted the difficulty for a developing country to decouple energy growth and economic growth in comparison with developed countries. Denmark has succeeded in this and has had a very stable gross energy consumption amidst high GDP growth ensuring a decline in the gross energy consumption per unit of GDP.

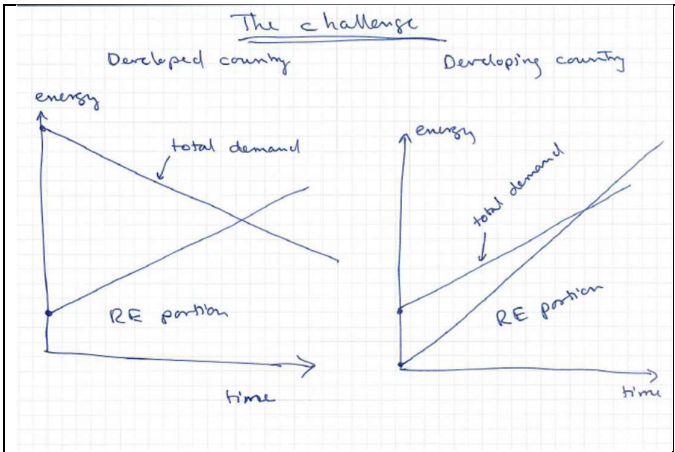


Figure 128: The challenge of decoupling energy demand from economic growth

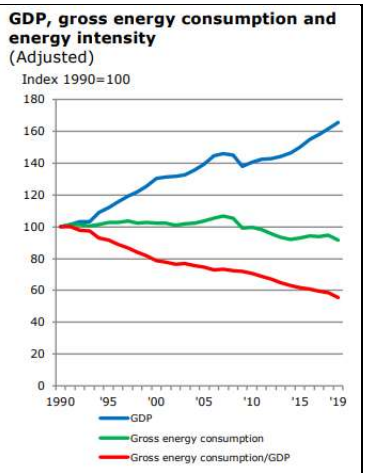


Figure 129: The Danish case study for decoupling energy consumption from economic growth

9.8.4. Climate change adaptation

Presentation with an introduction to Climate change, the United Nations Framework Convention on Climate change (UNFCCC) and Conference of the Parties (COP), Intergovernmental Panel on Climate Change (IPCC), and the latest 6th Assessment report, the Paris Agreement, the carbon and methane cycle to understand the sources and the sinks of these greenhouse gases and the difference and linkages between adaptation and mitigation as responses to Climate change. Several climate change adaptation measures were presented with the focus on **Sustainable Urban Drainage Systems (SUDS)** and **Climate-Smart Agriculture (CSA)** to protect **Ecosystem services (ES)**. Adaptation measures that maintain and restore are called **Ecosystem-Based Adaptation (EBA)**. As far as CSA was concerned, the presentation provided information on **Silvo-arable and Silvo-pastoral agroforestry, conservation farming, Permaculture,** and **biochar charcoal**. The **Urban Heat Island effect** was introduced and increased trees, green roofs and urban farming were suggested as adaptation measures.

9.8.5. Climate scenarios and projections

This was probably the most eye-opening presentation on climate change and what to expect from the climate future. It was presented by Jens Hesselbjerg Christensen, one of the review editors for IPCC's 6th AR. The presentation indicated the contribution of workgroup I (The Physical Science Basis) to the 6th AR. It was really a "hopeful doomsday" presentation summarized as follows:

- "The Paris agreement goals are not impossible to meet, but it requires very big changes in how we use fossil fuels, net zero around 2050 – a formidable transition into a sustainable future"
- "Even with Paris agreement goals reached, there will be significant climate change in the next hundred years (and beyond)
- "Sea level will continue to rise for many centuries and significant increases can no longer be ruled out"

This time around there were a greater focus on regional conditions and change with the introduction of the Interactive Atlas. The Atlas is "an online tool that

complements the WG I Report by providing flexible spatial and temporal analyses of past, observed and projected climate change information."[68] The presentation included a demonstration on the Interactive Atlas. Cape Town falls within the West Southern Africa (WSAF) reference region.

9.8.6. Green Student Movement

This is a movement with a mandate to initiate system change (change in institutions, structures and rules), incite political action on all levels (every policy should be seen as a climate policy, or a policy that can assist/contribute towards improve climate change) and build a community centered around action. The presentation discussed **Climate justice** as one of the main topics and introduced the carbon map. The **carbon map** compares countries of the world relative to each other by changing the footprint of each country to express the footprint or impact that country have for different indicators. Indicators includes size, population, wealth, CO_2 emissions from oil, gas and coal extractions, CO_2 emissions from fossil fuel use and people most at risk from floods, droughts or extreme weather temperature.

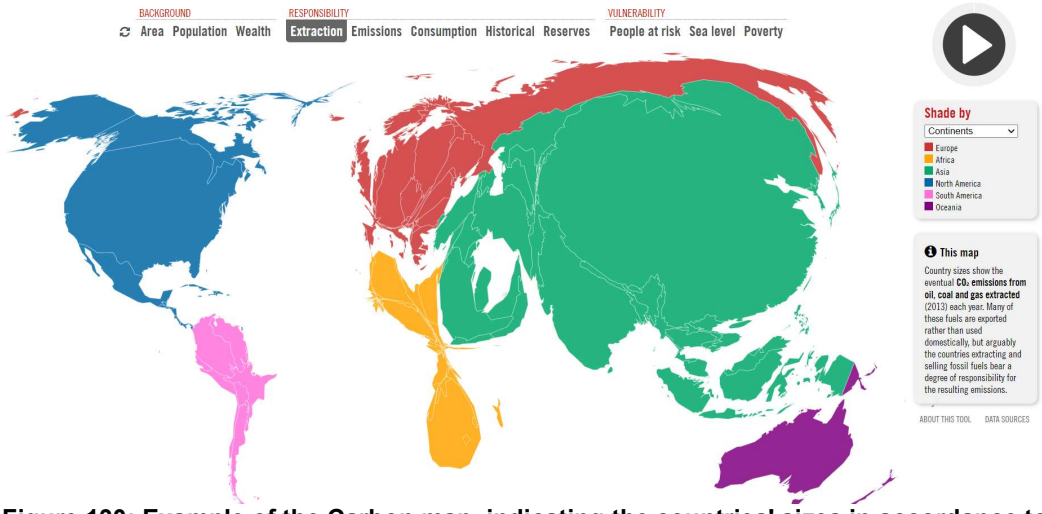


Figure 130: Example of the Carbon map, indicating the countries' sizes in accordance to CO_2 emissions from coal, gas and oil extraction

The Green Student Movement arranges marches to create awareness around Climate change. The Green Student Movement also recently provided four demands to the 98 municipalities of Denmark. All municipalities are to:

1) Apply an in-house carbon tax of DKK850. This item has to do with green procurement. E.g. Electric vehicles are more expensive than fossil fuel powered vehicles, but if a carbon tax are imposed on the fossil fuel equivalent vehicle, municipalities might be more likely to procure the more-expensive-but-better-for-the-environment vehicle.
2) Start local climate citizen assemblies aided by experts and with real influence on municipal climate policy
3) Make bigger and more cohesive nature areas to secure biodiversity
4) Secure green jobs for a just transition.

[68] Source: IPCC_AR6_WGI_Full_Report_smaller.pdf

9.8.7. Green buildings / Sustainability in buildings

This presentation was about sustainable buildings, and considered topics such as

- Danish building codes driving energy savings, building sector innovation and optimization during renovation,
- life cycle design and cost covering social inclusionary design, using up-cycled building material and considering operating cost after construction and occupancy and
- The Danish green building certification.

Denmark is very progressive in producing building codes that enforces energy consumption savings in buildings. This is understandable considering that 35% of energy consumption in Denmark is used for heating and hot water in buildings. The implementation of the building codes these days have however managed to **reduce energy consumption in new buildings to 17.2%** in comparison to those built in 1995 (refer to Figure 131 and Figure 132). The maximum energy demand limit is on the total amount of supplied energy for heating, ventilation, cooling and domestic hot water.

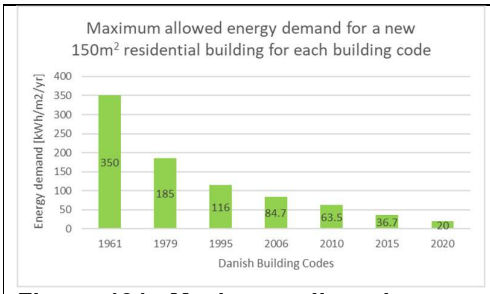


Figure 131: Maximum allowed energy demand for a residential building according to the codes from 1961 onwards.[69]

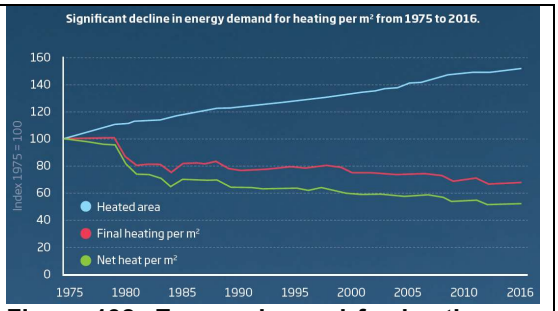


Figure 132: Energy demand for heating per sqm from a 1975 base year[70]

Denmark has an aging building stock with historically higher energy consumption rates. The code therefore also contains regulations regarding the energy performance of building components that are renovated or replaced (such as the replacement of a window, ventilation system or roof). The implementation of energy savings measures in Denmark is generally only cost-efficient when carried out with maintenance work or other changes. Applying the code to renovations ensure that the energy saving measures are made when economically feasible for residents.

Technological developments in the building sector prompts regular revisions of the code. Before any changes are made however, industry is widely consulted to determine realistic and ambitious changes. The changes are announced several years before they come into force so that industry can develop new solutions and invest in the necessary production apparatus. The **building codes** are therefore in itself an **impetus for innovation in the building sector**.

[69] Source: tool_ee_byg_web.pdf (ens.dk)
[70] Source: Energy renovation of buildings | State of Green

In addition to an entire chapter dedicated to energy consumption of buildings, the building codes also have chapters for Lifts, energy supply systems adjacent to buildings, light and view of the surroundings, thermal indoor climate and installations for heating and cooling systems, and ventilation that can impact the overall energy consumption of the building. As was highlighted in the presentation, it is important to take all of these metrics into account during the design stage of a new building or a renovated building to reach the optimum energy consumption for the best occupancy comfort. The cost of design changes increases exponentially with time later on in the life cycle of a building.

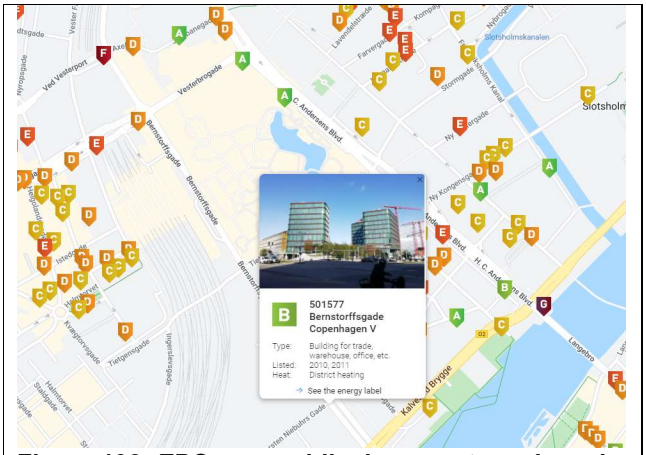


Figure 133: EPCs are public documents and can be accessed from [Demo Map Addresses | Dea (sparenergi.dk)](). For example, the SEB Bank and Pension building has a B-rating.

It is **mandatory to have a valid Energy Performance Certificate (EPC) in Denmark** before a sale or rent contract is signed. Large public buildings must always have a valid EPC, even if the owner or the tenant has not changed. The Danish Energy Agency (DEA) is responsible for implementing the EPC as well as the daily operations, supervision, quality assurance and future development of the scheme. The EPC documents rate buildings on an energy efficiency scale ranging from A (high energy efficiency) to G (low energy efficiency). The EPC assigns an energy rating and lists cost-effective measures for improving the building's energy performance. The validity of the EPC is 10 years. Research has shown that Danish purchasers are willing to pay a **premium house price** for a higher energy rating (as high as DKK 44 000 for a difference between a C-label and a D-label).

In addition to the EPCs, Denmark also has a **certification** for sustainable buildings, which was launched by the Green Building Council Denmark (DK-GBC) in 2012. They adapted the German system **DGNB** (Deutsche Gesellschaft für Nachhaltiges Bauen) focusing on the triple bottom line of sustainability. The DGNB framework operates a hierarchy of criteria organized in six qualities. The Environmental, Economical and Social quality all contribute 22.5% towards the certification, whereas Technical, Process and Site quality contribute 15%, 12.5%, 5% respectively. The DGNB system rates buildings by using performance indices for the items in each of the quality criteria. The platinum certificate is the most prestigious award issued by DGNB for a total index performance score of 80% or more, thereafter Gold (65%), Silver (≥ 50%), and lastly Bronze (≥ 35%).[71]

[71] Source: DGNB-Criteria-Set-Buildings-In-Use-Version-2020.pdf

Figure 134: The six DGBN quality criteria and the items considered for each quality.[72]

10. ANNEXURES

10.1 Annexure A: Additional links/internet resources

FOR FURTHER DETAILS, CONTACT:

DATE	28/03/2022		
NAME	Ina Nel	CONTACT NUMBER	072 412 2194
E-MAIL ADDRESS	ina.nel@capetown.gov.za		
DIRECTORATE	Energy	FILE REF NO	
SIGNATURE :	Ina Nel Digitally signed by Ina Nel Date: 2022.03.28 01:30:31 +02'00'		

Edgar Capes Digitally signed by Edgar Capes DN: cn=Edgar Capes, o=City of Cape Town, ou=Electricity Generation & Distribution, email=edgar.capes@capetown.gov.za, c=ZA Date: 2022.03.28 10:49:27 +02'00'

EXECUTIVE DIRECTOR [COMPULSORY TO INSERT NAME]		COMMENT:	Leslie John Rencontre Digitally signed by Leslie John Rencontre Date: 2022.03.28 18:05:14 +02'00'
The ED's signature represents support for report content and confirms POPIA compliance.		Contents of report noted. Should be shared at Energy PC and then with relevant departments who are impacted by the practices reported on in this report	
SIGNATURE:	Digitally signed by Kadri Nassiep Date: 2022.03.30 22:28:41 +02'00'		
NAME	KM Nassiep		
DATE	30 March 2022		

[72] Source: DGNB criteria for new buildings [137]. In brackets for the main pillars... | Download Scientific Diagram (researchgate.net)

MANAGER: INTERNATIONAL RELATIONS

DR. DENVER VAN SCHALKWYK

DATE Denver Van Schalkwyk Digitally signed by Denver Van Schalkwyk Date: 2022.04.01 14:55:29 +02'00'

COMMENT:

Digitally signed by Jason Sam Liebenberg
Date: 2022.04.11 07:03:39 +02'00'

☐ REPORT COMPLIANT WITH THE PROVISIONS OF COUNCIL'S DELEGATIONS, POLICIES, BY-LAWS, AND ALL LEGISLATION RELATING TO THE MATTER UNDER CONSIDERATION.

LEGAL COMPLIANCE

☐ NON-COMPLIANT

COMMENT:

NAME

TEL

DATE

For information

Digitally signed by Lungelo Mbandazayo
Date: 2022.04.12 14:57:04 +02'00'

CITY MANAGER

☒ SUPPORTED FOR ONWARD SUBMISSION TO:

MAYCO ☒

RELEVANT SECTION 79 OR 80 COMMITTEE ☒

☐ NOT SUPPORTED

DATE

☐ REFERRED BACK

COMMENT:

Annexure A: Additional links/internet resources

More information / Informative links on NMT

1. Transport (kk.dk) – Information on transport in the City of Copenhagen.
2. Welcome to Cycling Embassy of Denmark - Cycling Embassy of Denmark (cyclingsolutions.info)
3. Publications cycling in Denmark (cyclingsolutions.info) – access to publications such as Denmark's national bicycle strategy, Sustainable Urban Transportation, CPH 2025 Climate Plan, Good, Better, Best – The City of Copenhagen's Bicycle Strategy 2011 - 2025
4. Mobility & Cycling | Urban development (kk.dk) – access to Good, Better, Best – The City of Copenhagen's Bicycle Strategy 2011 – 2025 and the Bicycle accounts – facts about cycling in Copenhagen
5. Copenhagen - The Best Cycling City in the World | Urban development (kk.dk) – access to publication "Focus on Cycling: Copenhagen guidelines for the design of road projects"
6. Cycle superhighways - Supercykelstier
7. Bycycklen | Activities | VisitCopenhagen & City bike | City Bike (bycyklen.dk)

More information / Informative links on CSA

1. Ecosystem services video
2. Ecosystem services, adaptation, and DRR video
3. Climate-Smart Agriculture video
4. Agroforestry video
5. About Agroforestry – The Agroforestry Research Trust
6. Conservation farming video
7. Permaculture Principles: thinking tools for an era of change
8. Permakultur Danmark | Welcome to the Permaculture Association of Denmark! (permakultur-danmark.dk)
9. Permaculture principles video
10. Home - www.frichs-pyrolysis.dk
11. Biochar project video
12. Ithaka Institute - Kon-Tiki (ithaka-institut.org)
13. Focus on Sustainable Soils - Biochar for Sustainable Soils
14. Food and agricultural organization of the United Nations E-learning
15. Climate-smart agriculture 101
16. Climate-Smart Agriculture | Food and Agriculture Organization of the United Nations (fao.org)
17. Climate-Smart Agriculture Sourcebook (fao.org)

More information / Informative links on SUDS

1. Sustainable-Urban-Drainage-Systems.pdf (stateofgreen.com)
2. Susdrain - The community for sustainable drainage
3. WSUD systems in Denmark - Water Sensitive Urban Design in Denmark (wsud-denmark.com)
4. HOFOR_mulighedskatalog_version 1A_rev 3.indd (regnruten.dk)

CITY OF CAPE TOWN
ISIXEKO SASEKAPA
STAD KAAPSTAD

ENERGY DIRECTORATE
Susan Knox-Mosdell
Principal Professional Officer (Legal)

C: +27 83 462 0816
E: susan.mosdell@capetown.gov.za

28 March 2022

Ina Nel
Energy Generation and Distribution

Dear Ina

POPIA COMPLIANCE : MAYCO REPORT : FEEDBACK ON THE INTERNATIONAL/OUTSIDE THE BORDERS OF THE RSA TRIP UNDERTAKEN FROM 27 SEPTEMBER 2021 TO 22 OCTOBER 2021 TO ATTEND THE CLIMATE CHANGE: ADAPTATION, MITIGATION AND RESILIENCE LEARNING PROGRAMME IN DENMARK

It is hereby confirmed that the aforementioned report is compliant with the Protection of Personal Information Act since you as the data subject have given consent to the processing of your personal information in the report.

Yours faithfully

Susan Knox-Mosdell
PPO: Legal and Policy
POPIA Steward: Energy