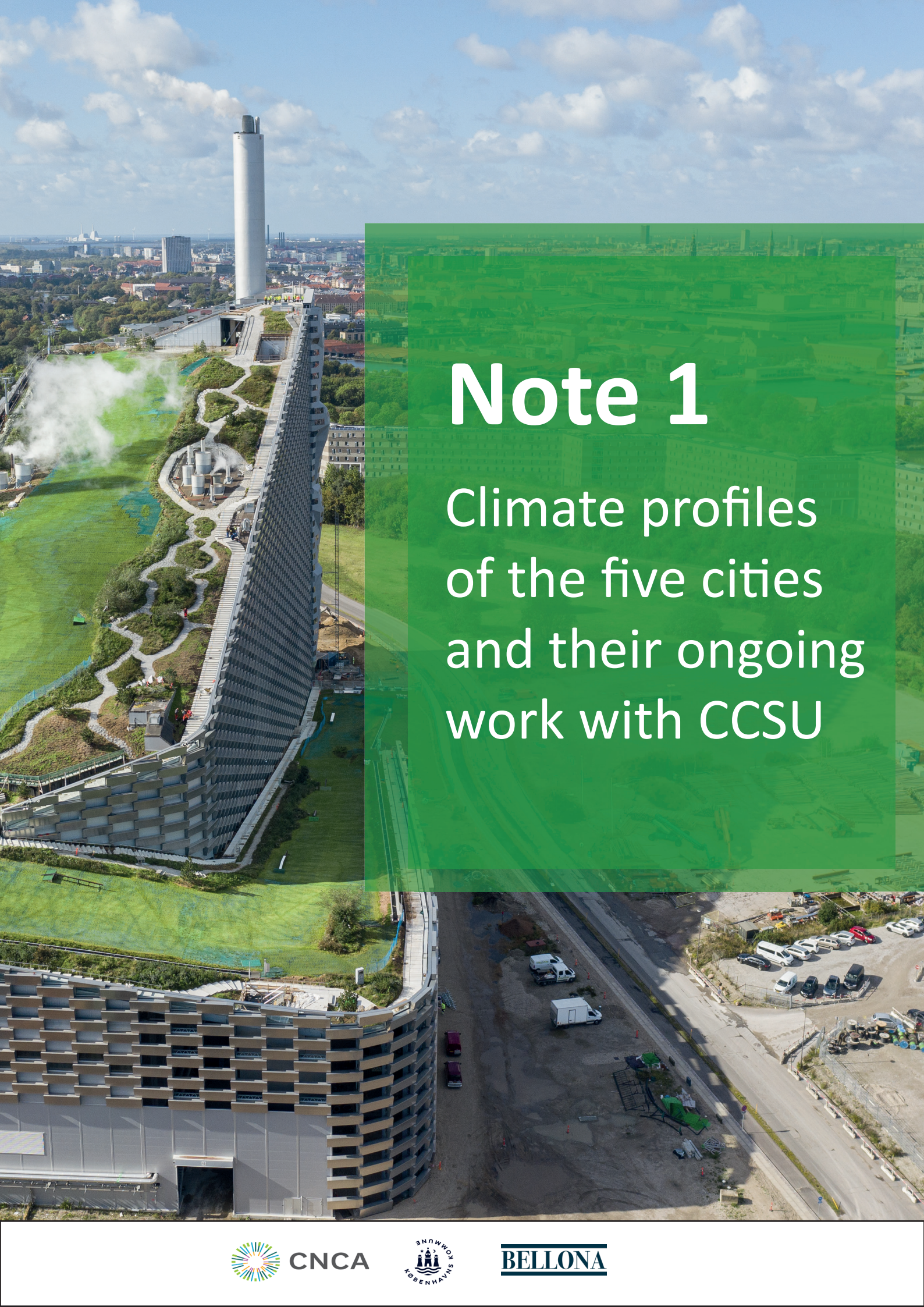




Note 1

Climate profiles
of the five cities
and their ongoing
work with CCSU



CNCA



BELLONA

Climate profiles of the five cities and their ongoing work on CCSU

The cities of Amsterdam, Copenhagen, Helsinki, Oslo and Stockholm all have very ambitious climate goals, and are committed to finding new solutions to tackle the climate challenges and to create sustainable cities. Besides these climate commitments, the 5 cities have several commonalities. The cities are all capitals, are similar in sizes with populations below 1 million, and all experience continual population growth. The cities are located in climatic zones with cold winters, which requires an intensified heat consumption during months of winter. In terms of the cities' climatic footprint, they have similar energy systems with local CO₂ emitting point sources from industries such as district heating and waste incinerations, making the CCSU technologies a relevant means to reduce the emissions released from these point sources. The CCSU technologies are in these cities acknowledged as an important measure to obtain sustainable and low-carbon cities in the near future.

The City of Amsterdam

Amsterdam has set ambitious goals to reduce their CO₂ emissions by 95 % by 2050, and 55 % by 2030 compared to 1990 levels. The 2030 target is a reduction of 3.2 million tons over a 12-year period. The city is moreover planning to completely phase out of the use of natural gas by 2040.

Amsterdam is currently emitting 4.5 million tons annually compared to 3 million tons in 1990. The largest emissions in Amsterdam derives from the electricity sector (51%), while the remaining emissions stem from the energy used in the built environment (28%), industry and harbour (11 %), and mobility (9 %) and from the Amsterdam city council (1%). To achieve carbon-neutrality, Amsterdam is therefore highly focused on transforming their energy systems, and to stop the use of fossil fuels. Amsterdam

moreover intends to move towards being a circular economy by 2050, where recycling of waste and renewable resource is used for products and buildings. Despite an increased production of renewable energies in Amsterdam, and a decreasing energy consumption per capita, the population has been growing with around 10.000 new residents per year, making the level of CO₂ emissions unchanged since 2012.

Amsterdam's work with CCSU

Over the past few years CCSU has been part of the political debate. Storing captured carbon under the sea would take away the incentive to transform production processes based on fossil fuels, towards more sustainable production processes based on renewable energy. Using captured carbon as a raw material for new products is perceived as a more circular and sustainable practice. However, the application of these techniques is yet limited.

Despite the concerns, CCS is generally considered an unavoidable technology, if the Netherlands are to achieve its domestic goals of reducing emissions for the short and middle term. In 2013, the Minister of Economic Affairs signed the Energy Agreement for Sustainable Growth, including the development of a vision on CCS reinforcing the Dutch commitment to CCS, and stating that CCS is unavoidable if wanting to transform the entire energy sector sustainably. One of the important areas for carbon capture is the North Sea Channel District and the extended harbour area in Amsterdam. Decarbonisation is currently part of national strategies and subsidy program. Projects including carbon utilisation for circular industrial purposes, and CO₂ infrastructure has been considered in terms of extending the current OCAP pipeline from the harbour of Rotterdam towards the harbour of Amsterdam, passing along the greenhouses in 'Westland'

City	Populaton	Largest emission sources	Current Emission	Emissions reduction goals
Amsterdam	860.124 (2018)	Energy	4.5 million tons/year	55 % by 2030, 95 % by 2050
Copenhagen	602.481 (2017)	Energy		100 % by 2025
Helsinki	631.965 (2016)	Heating		100 % by 2035
Oslo	672.061 (2017)	Transport	1.4 million tons/year	95 % by 2030
Stockholm	962.154 (2017)	Transport	2.7 million tons/year	100 % by 2040

area, where carbon is used for the growth of fruit and vegetable plants. Also, a new pipeline is considered as an underground connection to empty gas fields in the North Sea, as a possible site to store carbon. A feasibility study is being conducted at AEB Amsterdam, Amsterdam's largest waste-to-energy facility, as CCS could reduce emissions at this point source with about 450,000 ton per year. A facility where the city of Amsterdam is the only shareholder, and hence defines the conditions under which the incinerator can operate in the future. At this moment AEB and the huge steel producing factory 'Tata-steel' are seen as the first possible candidates for CCSU, however other point sources of CO₂ that might be part of a CCSU system are still to be identified. Studies is moreover conducted at the port of Amsterdam, a city owned entity, to investigate the opportunities for introducing CCSU, as well as to investigate possible economic benefits. Utilization of CO₂ in greenhouses (during summer) is part of the feasibility study that is being conducted by AEB Amsterdam.

In terms of public and political awareness, CCSU has been introduced in the public and political climate debate by including the technologies in Amsterdam's recent *Climate Neutral 2050 Roadmap*.

The City of Copenhagen

In 2009, while the COP15 was held in Copenhagen, the City Council set an ambitious vision to become carbon neutral by 2025. This led to the development of CPH2025 Climate Plan approved by the City Council in 2012, setting the overall frame towards 2025 and also working as the first implementation period. Within the CPH2025 climate plan the following themes are included energy consumption and production, mobility and the city administrations own emissions. Despite an expected growth in population by 20 % in the next decade, Copenhagen aims to achieve a green transition while continuously enabling growth, development and increased quality of life with the reduction of CO₂ emissions.

The annual CO₂ mapping showed in 2017 that the emissions were reduced by 42 %. Cutting emissions on energy consumption is considered the cheapest way, and despite that the reductions in energy consumption is expected to account for only 7 % of the total needed CO₂ reductions, there is a focus on energy savings. Production of energy is currently the largest source of CO₂ emissions in the city, and it is therefore vital to replace coal, oil and natural gas with renewable energy sources. Therefore, efforts to reduce emissions from this sector is expected to represent 80 % of the total reductions towards 2025 and are already underway with a new biomass fuelled combined heat and power plant opening in 2019, and a number of wind turbines are expected soon. The majority of CO₂ emissions derive from road traffic, why transforming the infrastructure for transportation purposes is an important component in cutting emissions in this sector. By 2025, the goal is to have at least 75 % of all transportation done by foot, bike or by public transport.

Copenhagen's work with CCSU

Copenhagen have conducted a mid-term evaluation of the city's climate plan in 2018, which revealed that with the implementation of current measures a gap of 200.000 tons CO₂ would occur in terms of reaching the 2025 targets. CCS and CCU was in the evaluation thus suggested as a new initiative to reach the goals set in the city's climate plan. The city is hence currently investigating the possibilities for carbon capture, storage or utilisation in products such as e-fuels, which is considered to contribute to reducing fossil fuels in the transport sector. The goal is that CCS/CCU will contribute to reach the goal of carbon neutrality in 2025.

Copenhagen is currently collaborating with the local waste-to-energy plant, ARC, exploring the opportunities of implementing a carbon capture facility at their plant, and further the screening of the technical possibilities for capture, storage and utilisation. The goal is to capture the CO₂ that derives from the fossil fraction in the facility, which is approx. 165.000 tons CO₂ per year.

In Denmark national legislations are however currently making it impossible to implement storage solutions. Studies on the formations suited for storage has however been conducted, yet no actual practice with underground storage of CO₂ has been carried out in Denmark. In recent years CCS and CCU has been gaining momentum in the political arena, and the last climate proposal established by the Danish government suggested to earmark 100 million DKK to technological and natural solutions for carbon capture. The focus of CCS and especially BECCS has also increased in Danish media in the recent year, as a consequence of IPCC latest report calling for more impactful measures.

The city is in dialogue with a number of relevant stakeholders including universities, energy utilities, businesses and the Geological Survey of Denmark and Greenland. A next step is to further work with Danish stakeholders to mature a CCS project and develop more knowledge related to a specific project.

The City of Helsinki

Helsinki's climate goal is to achieve carbon-neutrality by 2035. Becoming carbon-neutral in Helsinki requires a reduction of emissions by at least 80 % compared to 1990 levels. The last 20 % of the needed reduction is planned to include compensation initiatives, such as increasing the number of carbon sinks outside the city and by trading emissions. Progress has already been achieved, and Helsinki's level of emissions were in 2018 27 % less compared to 1990 despite a growing population in the city. The reduction is approximately 45 % less per capita.

Most of the energy produced in Helsinki is based on fossil fuels causing large CO₂ emissions. Heating of buildings is moreover a large contributor to emissions with the

majority of fuels used being natural gas and coal. The largest contribution to Helsinki's greenhouse gas emissions derives from heating with 56 %, followed by traffic on 24 % with half of these emissions caused by cars, and electricity with 15 %, while waste management, industry and machinery and agriculture accounts for the last 5 % of the emissions.

Helsinki's work with CCSU

Helsinki is aiming to become carbon neutral by 2035, why CCS is considered a possible method to reaching these goals. Helsinki is studying all emission reductions and compensating options, but with CCS being one of the solutions particularly in the energy production.

Currently, there has been no active programmes or incentives for introducing CCS, and the technology has not been very present in the political agenda. Despite the minor attention given to CCS technologies in the past, an increasing attention has been present in the last 2 years with the IPCC calling for further action to stay within the 1.5-degree temperature rise.

Helsinki has some interesting point sources for carbon capture, with the city-owned energy company, Helen, having large heat and power plants in the city area. These key emission sources are thus of interest when assessing the possibilities for applying CCS. The possibilities for combining CCS with the use of bio energy (BECCS) is moreover considered as a mean to provide negative emissions in the production of energy.

In Finland the storage capacity for carbon is very limited, Helsinki is however exploring both the opportunity of storing and using the captured carbon. Helsinki is moreover planning to conduct further studies on the estimated potentials of capturing, storing and using carbon in a local and regional context.

The City of Oslo

Oslo has ambitious climate goals and strives to lead the transformation of a greener and more inclusive society, with a goal of reducing direct greenhouse gas emissions by 36% by 2020 and 95 % by 2030. A goal and transformation, which requires readjustments in both the use of energy and transport. In Oslo, emissions have increased by 25 % since 1990, and the goal of converting from fossil energy to using renewable energy and transforming into a sustainable city, thus requires a strategy with impactful measures. Oslo has the world's highest proportion of electric cars, a cycle-based waste management system, and an expanding green commercial sector. The use of fossil heating oil in buildings currently accounts for 17% of the emissions. The use of heating oil in buildings is banned from 2020. Despite Oslo having increased the use of public transport and non-emitting means of transport, the transport sector still accounts for 61% of the emissions in Oslo, of which around half are attributable to the transport of people, and half to goods transport and

construction activities. The transport sectors will thus require the most determined efforts moving forward. Emissions from waste incineration represents about 200.000 tons CO₂ per year in Oslo, or about 20 % of the total emissions, in addition to the approx. 200.000 tons of biogenic CO₂. To date, it is very difficult to reduce most of these emissions through other measures, and CCS is therefore seen as the solution in this context.

Oslo's work with CCSU

CCS has had a relatively long history in Norway, and currently two established CCS facilities is running (Snøhvit and Sleipner), while it is the plan to establish at least one more facility in the coming years. Oslo are hence in an advanced position in terms of Norway's CCS experience and know-how.

To reach the city's ambitious goals, Oslo's largest CO₂ point source – the waste incineration plant at Klemetsrud – must be emission free by 2030. Oslo's City Council has therefore decided to participate in the national CCS commitment that aims to have at least one full-scale CCS project by 2024, which could potentially be the Klemetsrud plant. The plant has been tested with CO₂ capture technologies, and it was found that 90 % of the about 400.000 tons CO₂ emitted at the plant could be captured. In October 2018 the government moreover granted funding to commence a Front-End-Engineering-Design (FEED) study at the Klemetsrud plant in 2019. Since 58 % of the yearly waste burnt at Klemetsrud derives from biomass, a CCS project would guarantee negative emissions, and it has been deemed extremely difficult for Oslo to reach its 2030 target without CCS being fitted on this plant. An investment decision is expected in 2020/21, with potential operation from 2023/24.

Equinor, Shell and Total are responsible for planning storage facilities, and have found storage sites holding capacity for 1.3 million tons of CO₂ per year for 25 years (total 32.5 million tons). Equinor is currently operating storage reservoirs, where more than 20 million tons of CO₂ to date has been stored from Sleipner and Snøhvit, giving Equinor more than 20 years of experience with CCS methods.

With the planning of a new full-scale project the focus and interest in CCS has increased, and the technologies has been part of the political and public debate for a long time. Norway has moreover improved its abilities of enabling CCS projects, with policy announcements supporting the technology, and the Norwegian government in January 2019 granting permission for CO₂ storage in the Troll field in the North Sea. A key element in introducing a full-scale carbon capture project in Norway, the permit marks an important milestone for Norway's climate agenda (Gassnova, 2019). Public perception of CCS is likewise relatively positive with various University groups and NGOs being active in the CCS arena.

The City of Stockholm

The city of Stockholm has a climate goal to be fossil-fuel free by 2040, and to reduce CO₂ emissions to 2.2 tons per capita by 2020. In 2018 the total CO₂ emissions in Stockholm amounted to 2.110.000 tons, with transport accounting for 48 %, energy use in buildings accounting for 32 %, and the use of gas and electricity representing 20 %. Stockholm has made significant progress and have since 1990 decreased their emissions by around 40 %, despite a high population growth, yet there is an urgent need to intensify the work, if the ambitious climate goals are to be achieved. Fossil fuels are currently accounting for approx. 25 % of the total energy use in Stockholm, accounted as kWh. Converted to carbon emissions it is 2.3 tons CO₂ per capita in 2017.

Since 1996 Stockholm has had action plans for climate reductions, the latest is from 2016-2019, and for the moment a new climate action plan is being developed for 2020-2023, which covers all direct energy use in the city, parts of the consumption and CCS/BECCS. However, the most challenging CO₂ contributor lies in the transport sector.

In 2040, it is expected that the remaining fossil fuels will derive from aviation and shipping industries as well as from the energy sector, where fossil-based plastic waste are combusted. Although the goal is to be fossil-fuel free by 2040, the residual fossil energy used per capita in 2040 is expected to correspond to 0.4 tons. The plan is however to develop carbon sinks to compensate for the continued emissions in the transport and energy sector.

Stockholm's work with CCSU

With the recent reports from IPCC expressing the need for CCS and BECCS as a necessary solution to reverse the effects of climate change, an increasingly political interest has arisen in Sweden in recent years, and the Swedish Government has ordered an investigation of how negative emissions can be achieved. The investigation shall be delivered by January 2020 at the latest.

In the city of Stockholm, several CO₂ emitting heat and power plants are located, and these could potentially fit as suitable point sources for BECCS. In the city's 2019 budget, CCS and biochar production are declared as proper measures for reversing climate change. The city council shall therefore investigate the city's ability to become a climate positive city with negative emissions, and therefore especially BECCS is considered as an interesting measure. The total potential for BECCS in connection to combined heat and power plants in the Stockholm region is estimated to about 1.300.000 tons CO₂ per year, and the potential of BECCS in one CHP-plant (using biomass) is estimated to about 800.000 ton per year. In the coming year a new climate plan will be developed, in which BECCS will be described as a possible measure and why BECCS will be further investigated.

In the city's financial 2019 budget, carbon capture in combination with biomass is declared a promising measure to reverse climate change. BECCS implemented on several different point sources in Stockholm has an estimated potential for emissions reductions of 1.300.000 tonnes of CO₂ per year. The local utility district heating company Stockholm Exergi, owned partly by the city, has begun planning a BECCS project that could be operating in 2024/25. In December 2019 Stockholm Exergi started Sweden's first test facility that captures carbon dioxide from biocogeneration. However, Sweden is not seen to have storage possibilities and the plan is therefore to send the CO₂ to Norway.