SIEMENS

Copenhagen's Big Incentive

City Performance Tool – October 2015

Global Center of Competence Cities

Copenhagen has been and continues to lead cities on climate policy globally. It ranked top of Siemens' European Green City Index in 2009, and it is making great strides meeting its 2025 target for carbon neutrality. Siemens has used the CyPT and found that the City of Copenhagen is reducing emissions from nearly all of the sources where it has significant control in energy and transport. Maintaining its global leadership position will require delivering further building upgrades within its own public stock and incentivizing private building owners to take action to improve the efficiency of their buildings. The city will also have to stimulate a market shift towards cleaner vehicles and a modal shift towards low carbon public transportation. Should Copenhagen be able to pursue these recommendations then it will far outclass other cities in its scope of both ambition and success.

Executive Summary

Copenhagen is one of the world's most sustainable cities, and it is the first capital to publicly target carbon neutrality by 2025. The City of Copenhagen has delivered many of the initiatives it put forward in its 2025 Climate Plan. However, despite these successes the city still faces a number of challenges to meet its carbon neutrality target.

Siemens' Center for Competence Cities, has been working with the City of Copenhagen to identify additional actions that could be delivered by the city, its businesses and residents to help boost overall carbon savings and meet the 2025 targets. Siemens has used its City Performance Tool, the CyPT, to assess the relative benefits of implementing new technologies or technologies the city is already using at a greater scale. The aim of the report is to identify additional savings that could be obtained over the next ten years, rather than quantify the city's current measures. It focuses on those technologies that can technically be delivered in the next decade using a carbon accounting methodology that takes into consideration both direct and indirect emissions.

Our findings show:

1. Copenhagen is decoupling its CO_2e emissions so that despite a growing population and increasing building floorspace, carbon emissions are expected to decrease over the next 10 years. This is predominantly derived from greener national electricity and local heating mixes. Using our accounting standard that captures direct and indirect emissions, our model quantifies these savings as high as 12% of current annual emissions. These are savings achieved from the expansion of wind power and biomass for combined heat and power in the 2025 Climate Plan.

2. Despite these savings, the city now needs to incentivise its households and businesses and align national, regional and city-level policies to further accelerate emission reductions. The report gives examples of cities such as Melbourne, Tokyo and Oslo that have mobilised private sector investment in building technologies and alternative car technologies.

3. Beyond its current climate plan actions, the city can reduce emissions by an additional 26% through nine city wide technology investments – predominantly in the energy and building sector. Twelve percent of these savings are from further national investment in wind power, with ten percent and four percent from building and transport technologies. Total capital investment in these technologies would be around €3bn, 95% of which lie outside of the city budget.

4. The 10% savings in the building sector can be delivered if the 40 largest building owners in the city were to take action to improve the efficiency and sustainability of their commercial buildings. These owners own 30% of the city's total commercial floor space and could help the city achieve a further 10% CO_2e savings if each invested €5m per year over the next decade to retrofit their stock. This is within typical building renovation budgets.

5. The long term CO_2e and cost-saving benefits of investing in these building technologies are important, but the city should not ignore transport related emissions, which will gradually become even more important as buildings are plugged to an increasingly cleaner electricity and heating mix.

6. Copenhagen must also deal with its transport emissions today because of the long lead time to implement technologies in the sector. Although the transport sector's share of emissions is smaller today compared to the building sector, a gradual convergence will occur as wind takes over the country's electricity mix. Focusing on city wide tolling and electric car implementation can save the city 20% of its transport emissions. To achieve this, the city must align itself with the regional municipalities as Copenhagen's administrative boundaries only capture a small part of the city's built up area.

7. Copenhagen has been leading on climate policy globally. After it achieves its carbon neutral goal, it should continue working towards incorporating scope 3 indirect emissions in its accounting standard. The energy related scope 3 emissions alone are as high as 25% of direct emissions and are currently unaccounted in the city's carbon accounts

Copenhagen has been and continues to lead cities on climate policy globally. It ranked top of Siemens' European Green City Index in 2009, and it is making great strides meeting its 2025 target for carbon neutrality. Siemens has used the CyPT and found that the City of Copenhagen is reducing emissions from nearly all of the sources where it has significant control in energy and transport. Maintaining its global leadership position will require delivering further building upgrades within its own public stock and incentivizing private building owners to take action to improve the efficiency of their buildings. The city will also have to stimulate a market shift towards cleaner vehicles and a modal shift towards low carbon public transportation. Should Copenhagen be able to pursue these recommendations then it will far outclass other cities in its scope of both ambition and success.

Introducing the City Performance Tool (CyPT)

European cities stand at the forefront of sustainable development in the world. Global rankings regularly highlight their performance in terms of connectivity, mobility, and reduction of carbon emissions. Nowhere is this truer than in Copenhagen, which is often seen as the global Green leader. Cities like Copenhagen, however, are constantly striving to test the cost efficiency of their current infrastructure solutions and explore new, more effective technologies that will help them meet their environmental targets.

To help cities make informed infrastructure investment decisions, Siemens has developed the City Performance Tool (CyPT) which identifies the best energy, transport and building technologies for reducing carbon emissions and improving local air quality, and adds new jobs in the local economy.

The model takes over 350 inputs from Copenhagen's transport, energy and buildings sectors, which include the energy mix of electricity generation, transport modalities and typical energy, travel and building space demand. The model measures the impact of technologies on the CO_2 eq, PM_{10} and NO_x baselines of the city with CO_2 eq accounting performed at scopes 1, 2 and 3 levels for the building and transport sectors.

The model also tests the performance of each technology on two economic indicators. Firstly, the total capital investment and secondly the total number of gross jobs that could be created in the local economy[1].

The effects of the technologies represent proprietary data on the performance of actual Siemens products implemented by cities around the world. Importantly, they also represent non-Siemens products, allowing both Siemens and cities to compare a full spectrum of solutions from diverse technology sectors.

Starting with the city's population, energy performance, and environmental baseline, the model estimates the future impacts of technologies along the following three drivers:

1. Cleaner underlying energy mix: Shifting the energy generation mix from non-renewable to renewable energies (e.g., photovoltaic) and/or improving the efficiency of the current, fossil fuel, sources (e.g., Combined Cycle Gas Turbines).

2. Improved energy efficiency: Replacing existing technologies with more energy efficient technologies. For example replacing traditional street lighting with LED and/or demand oriented street lighting.

3. Modal shift: Modeling changes in the modal split of the city. For example by creating a new metro line, a city potentially moves passengers away from high-emitting cars and into the subway.

1.These include installation, operation, maintenance and induced local multipliers, which are calculated as full time equivalent jobs of 1760 hours. Manufacturing jobs are not accounted because some of these technologies may be produced outside the city's functional area, with no local benefits to the economy.

Data points by sector

Transport – 39%

- Annual passenger km
- Freight ton kms
- Length of road network
- Length highway network
- Bus, BRT, Street Car, Metro, Commuter / Regional Rail, Taxis, Bicycles, Cars etc.

General – 2%

- Population
- Geographic size
- Emissions target

Energy – 15%

- Electricity mix
- Heating mix
- Emissions factors for fuels

Buildings – 44%

- Square metres by building type
- Electricity demand
- Heating demand
- Cooling demand
- End use for electricity, heating and cooling
- Building envelope

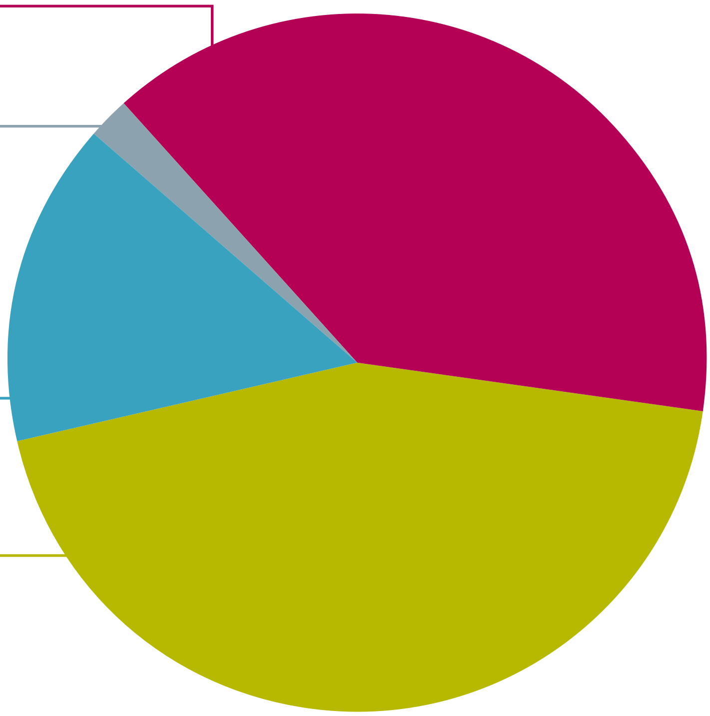


Figure 1: % of data points by sector used in the CyPT model. The model has so far been used in cities such as Munich, Vienna, London and Nanjing with each city identifying infrastructure solutions that best fit the city's energy demand and production characteristics.

The Road to Carbon Neutrality

Copenhagen stands at the forefront of sustainability, 'green growth' and quality of life. The 1973 petrol crisis acted as a wake-up call for Denmark, and sparked off a national reflection on energy production, sustainability and quality of life. As the capital city of Denmark, Copenhagen wants to lead the country on the path to a greener way to grow and be an example admired across the globe. Copenhagen's most ambitious and emblematic objective is to be a carbon-neutral city by 2025. While Copenhagen's government and Copenhageners fully embrace the ambitious target, in the next decade, the city will need to increase its efforts even more to reach their goal.

The city will still have direct emissions (scope 1) inside their city border which will have to be offset from renewable energy production – predominantly from its new wind power investments. The city plans to produce more power than it consumes and hence become a net-exporter of power, with a large share of renewable to offset the remaining transport emissions that the city cannot reduce in the space of ten years.

Copenhagen's achievements

In comparison to 1990, Copenhagen's greenhouse gas (GHG) emissions per capita decreased by 40%, from 7.31 tonnes of CO_2 eq in 1990 to 4.38 tonnes of CO_2 eq today. As figure 2 shows, the predominant driver for these savings has been the greening of its electricity generation. At the same time, the Gross Value Added (GVA) per capita – which measures the contribution of each individual producer and industry to the economy – kept increasing. This demonstrates, in action, Copenhagen's successful commitment to the idea of Green Growth or Green Economy – as developed by the OECD, UNEP, the World Bank and the Green Growth Institute. Copenhagen's relationship to sustainable development is genuinely positive: going greener is an opportunity for Copenhagen's economy, it is not perceived as an economic and/or financial burden.

Copenhagen's approach to sustainable development offers equilibrium between economic awareness and a very deep

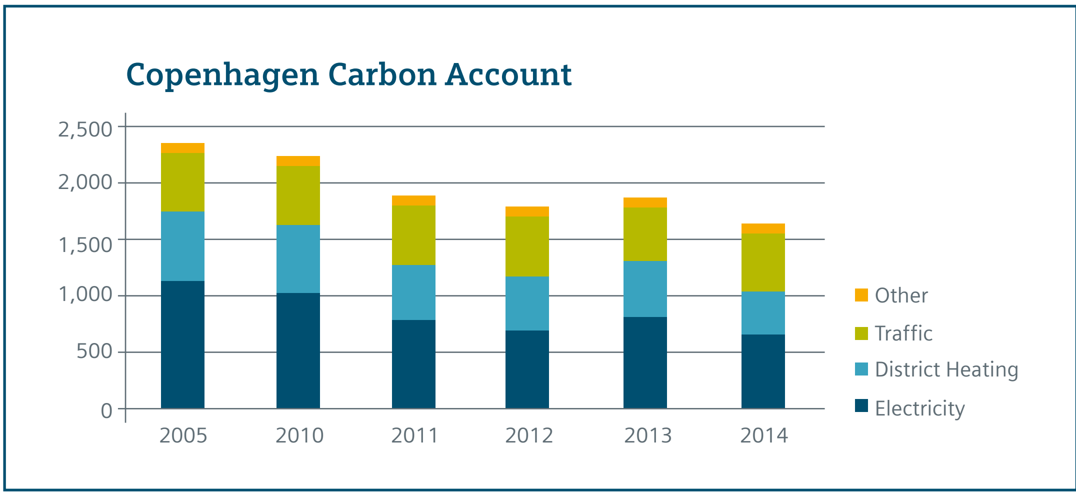


Figure 2: Progress in Copenhagen's mitigation in the last decade

Photo: Metroselskabet/Peter Sørensen

understanding of Copenhageners needs and desires. Thus, while Copenhagen evaluates that *"every person who chooses cycling contributes a net profit for society of DKK 1.22 per trip (€ 0.16). Taking a car results in a net loss for society of DKK 1.13 per trip (€ 0.15)"*, the city is also very aware that Copenhageners *"choose the bicycle because it is the easiest and fastest way to circulate around the city. If the share of cyclists is to be further increased, the bicycle must be made to be the easiest and fastest for even more people than today."*

Reflecting these achievements, Copenhagen achieved the highest ranking in Siemens' *European Green City Index*. The index, while highlighting Copenhagen's good overall performance, also underlines the improvements the city can aim at. Thus, while it is ranked joint first in the category 'Environmental Governance', it does not reach the top position in any of the individual categories: while it is ranked second in 'Energy' and third in 'Transport', Copenhagen only achieves the fifth position in 'Air Quality' and 'Water'; it ranks seventh in Europe on 'Waste and Land use'. This is representative of Copenhagen's progress towards greenhouse gas savings and sustainable development: while it stands as the European leader on that subject, Copenhagen should not rest on its laurels as much is left to achieve its target to be the next carbon-neutral city.

Copenhagen distinguishes itself by the major efforts the city made towards improving its consumption of water per capita and its policy towards energy production – most especially heat consumption. Equally, in terms of heating efficiency, over the years Copenhagen has developed a policy leading to the city going from 32% of district heating penetration in the city in 1970 to more than 98% of the heating consumption being provided by district heating today. This puts Copenhagen in a unique position because it owns its energy company and is therefore able to bring emissions to zero without the need to mobilize other stakeholders. The City of Copenhagen evaluates CHP levels of efficiency to reach 94%. Copenhagen has embarked on a heavy decarbonization programme for its district network moving away from gas into wood pellets and ultimately burning biomass. The city plans to build a wood fired CHP of 115-350 MW within the next ten years.

In the transport sector, the city is currently building two new metro lines that according to our calculations will reduce transport emissions by nearly 5% and build over 30km of new cycle highways, which will result in a further 2.5% CO_{2e} reductions.

Finally, in the energy sector, the city is further investing in wind power adding 100 new wind turbines with a total capacity of 360 MW both inside and outside of its administrative boundaries at a total cost of €750m. In total, across sectors, Copenhagen's Climate Plan brings together investments of around €3.5bn up to 2025, yet the city argues that the wider social benefits will be greater through energy efficiencies and reductions of fossil fuel imports.

Copenhagen's Baseline

In order to calculate Copenhagen's energy and emissions footprint, Siemens looked at the way travel, electricity and heating demand is structured in the city as well as the make-up of the energy supply that feeds this demand. Changes in the energy and emissions footprints of Copenhagen are predominantly driven by population growth, which will be considerable in the city over the next decade.

Copenhagen

Area: 86.25 km^2

Population: 570,000

Built up area: N/A

With a population of 570,172 in 2015, we have calculated Copenhagen's CO_2 eq baseline to be 2.403 kt CO_2e (with transport contributing 20% and buildings contributing 80%) as shown in figure 3. According to the CyPT calculations this city total will decrease by 11% to 2136 kt CO_2e in 2025 and even further by 37% to 1507 kt CO_2e in 2050[2]. This is an important achievement for a city undergoing high population growth and is attributable to the city's reliance on cleaner electricity and heating. Unlike other cities that the Siemens CyPT team has worked in, this city will achieve emission reductions mainly by greening its heating mix and relying on a cleaner national electricity mix. Any further technology impacts will simply accelerate this overall trend.

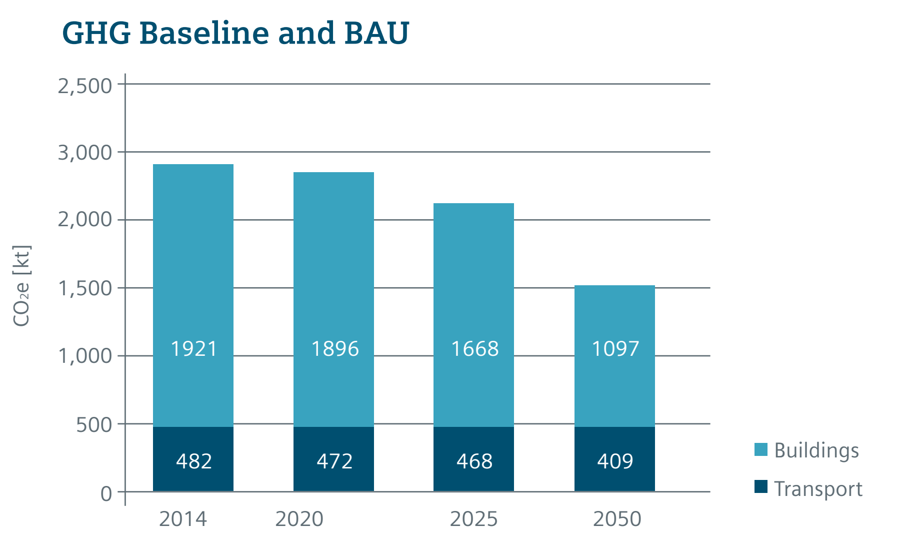


Figure 3: Sectoral distribution of emissions in Copenhagen using the CyPT accounting methodology

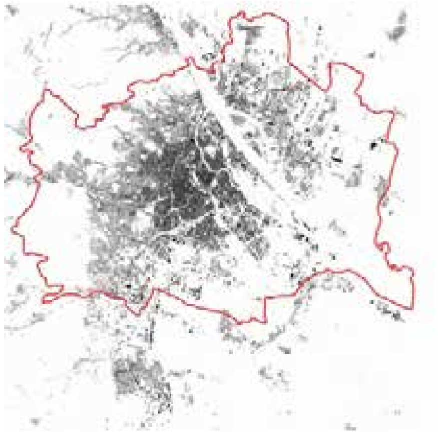
2.Our baseline is some 55% higher than Copenhagen's official baseline. This is because the CyPT model takes into consideration some scope 3 indirect emissions, such as electricity production and distribution, that Copenhagen's accounting method omits. A full analysis of the different accounting methods is given in Appendix II.

Munich

Area: 310.4 km^2

Population: 1.4 million

Built up area: 177 km^2



Vienna

Area: 414.6 km^2

Population: 1.8 million

Built up area: 146.8 km^2

Our projections in the figure above highlight another phenomenon driven by the city's cleaner energy mix. A slow convergence is occurring between transport and building related emissions. Currently transport emissions make up 20% of city wide emissions in our model. This will increase to 22% by 2025 and to 27% by 2050 as Copenhagen's buildings will increasingly be connected to greener and greener energy. The following sections will discuss the sector based baselines in further detail.

Transport

The modal split of transportation in 2015 relies mostly on cars and city trains when one looks at passenger kilometers rather than number of trips travelled. Cars represent 42% of passenger kilometers while city trains account for 27% of journeys. Altogether, public transports (city, regional and interregional trains, subway, tram, bus and bus rapid transit) account for 42% of the journeys in Copenhagen. Cycling and walking respectively account for 10% and 7% of the modal split, or 7% altogether[3]. The personal transportation demand for Copenhagen is 4,700 million person / km per year.

It is important to note that the large passenger kilometers attributed to private cars is predominantly due to trips originating from the outer municipalities surrounding Copenhagen. The diagram above shows a quick comparison on the challenges that Copenhagen faces in regulating such traffic flows compared to cities like Vienna and Munich whose administrative boundaries (shown in red) cover the majority of the built up areas in the city. In other words, no matter how progressive Copenhagen is with its de-motorization policies, unless a metropolitan consensus is achieved on reducing car use into the city, the transport related transport emissions will remain a big obstacle to the city's ambitions.

3. Cycling and walking figures are significantly lower if measured by passenger kms rather than number of trips

Copenhagen's Baseline

In order to calculate Copenhagen's energy and emissions footprint, Siemens looked at the way travel, electricity and heating demand is structured in the city as well as the make-up of the energy supply that feeds this demand. Changes in the energy and emissions footprints of Copenhagen are predominantly driven by population growth, which will be considerable in the city over the next decade.

Electricity

The electricity mix of Denmark relies heavily on wind power, as it already represents 35% of the electricity mix and according to national projections will increase to 55% in 2025. Nuclear, coal and heavy fuel oil represent 33%, while renewable energies account for 60% of Copenhagen's energy electricity mix. The breakdown of renewable energies is 2.0% for photovoltaic energies, 10% from hydro, 8% from biomass, 0.5% from biogas and 5% from waste.

It is because of the dynamics of this electricity mix that Copenhagen can achieve carbon neutrality. As long as Copenhagen is a net exporter of locally produced green electricity, the city can offset its actual emissions. This is shown in figure 5 below. The city's CHP network basically produces enough heat for the city and co-generates electricity that is fed into the national grid that is cleaner than the national mix.

Looking forward, the heating mix of the city will improve further in the next ten years replacing coal, gas and oil with

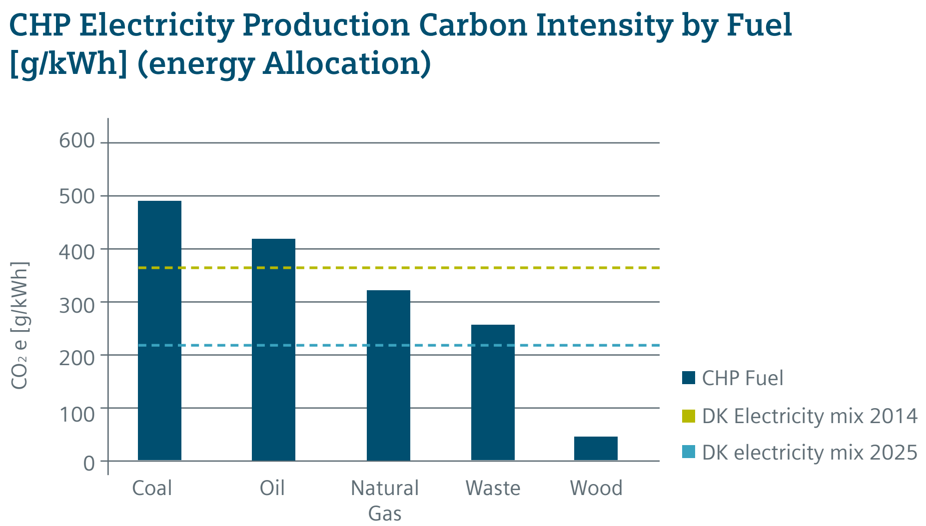


Figure 5: Copenhagen's CHP electricity production carbon intensity by fuel type. The city can offset its direct emissions as long as the carbon intensity is below the Danish national mix

biomass, waste and wood pellets. Although this is good for citywide emissions, this mix will have to compete with Denmark's very own improving electricity mix. Once the national energy mix is carbon neutral, Copenhagen will not be able to offset its emissions and will have to look to other countries to sell its excess energy.

Copenhagen is by all means the European Champion for green growth and sustainable development. Copenhagen's attitude towards these issues has been both proactive and successful. The level of penetration of district heating and overall in household energy consumption, as well as the amount of journeys made using bicycles offer a positive vision of the city's achievements. Yet, Copenhagen's ambitious targets to be a carbon-neutral city by 2025 remain very ambitious and challenging. The CyPT could play a crucial role in further boosting mitigation over the next decade, as it could reveal some high impact technologies that may have not been fully exploited.

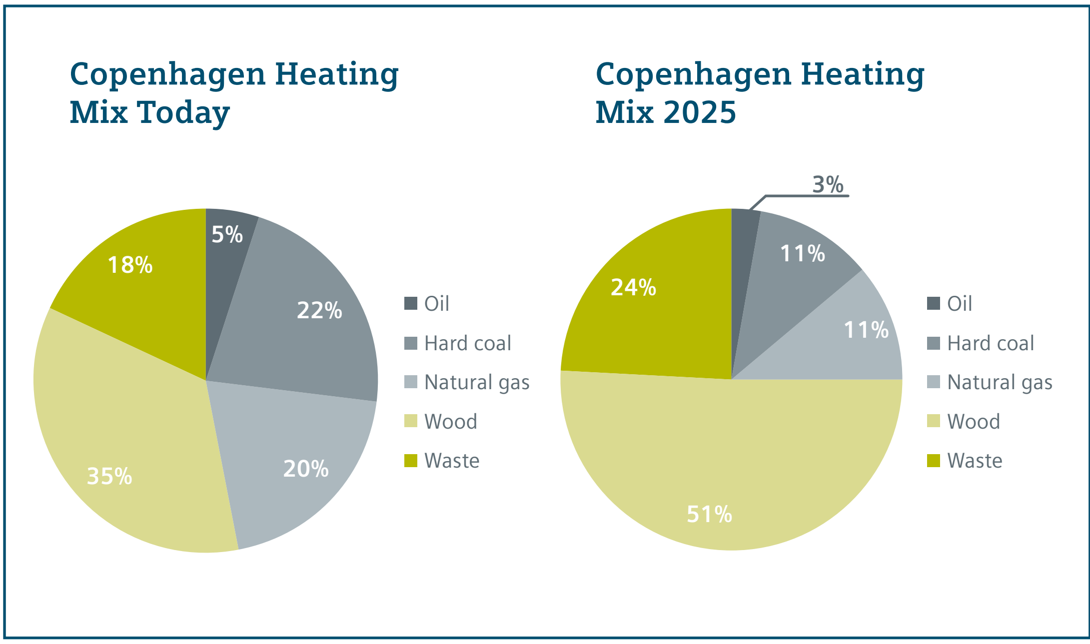


Figure 6: Copenhagen is increasingly decarbonizing its heating mix

Technology Choices

Siemens worked with the City of Copenhagen's climate team to determine realistic implementation levels for the technologies that the city could deliver in order to meet its targets. We took the city's 2012 Climate Plan and 2014 Climate Projects as base documents to model the infrastructure solutions that have already been budgeted in the city. The implementation of these energy and transport technologies was then increased and some 'out of plan' technologies introduced in a so called 'Climate Plus' bundle of technologies. Because of limited data on the state of the city's real estate stock, building technologies were modeled separately on the holdings of the city's 40 largest building owners.

Copenhagen's achievements

This bundle of technologies increased the implementation rate of technologies currently in the climate plan and introduced new solutions outside of the city's current initiatives such as congestion charging and on-shore harbor power supply. The model assumes that an extra metro line can be built in the city over the next ten years and that the best environmental alternative car technology will make up 10% of the car share in the city.

Technology	Implementation rate by 2025	Unit
Hybrid electric buses	50%[4]	Share of fleet
Electric buses	50%	Share of fleet
Metro – new lines	3	Lines
Tram – new lines	3	Lines
Intelligent traffic light management	100%	Share of traffic lights
Change Cng to "Compressed Natural Gas (CNG)	10%	Share of car fleet
Electric cars	10%	Share of car fleet
Hydrogen cars	10%	Share of car fleet
Hybrid electric cars	10%	Share of car fleet
Plug-in hybrid electric cars	10%	Share of car fleet
Electric taxis	10%	Share of car fleet
Electric car sharing	2	Cars / 1000 inhabitants
Intermodal traffic management	85%	Share of users
Bike sharing	5	Bikes/1000 inhabitants
Car – eco-driver training and consumption awareness	50%	Share of drivers trained
Metro – reduced headway	90	Seconds
Buses – new cng vehicles	50%	Share of fleet
Metro – regenerative braking	100%	Lines
Smart street lighting	100%	Share of street lights
Cycle highway	7	Km/100.000 Inhabitants
Freight train – electrification	100%	Share of railway network
Car & motorcycle – city tolling	20%	Road traffic reduction
Wind	65%	Share of energy
Photovoltaic (PV)	5%	Share of energy
Combined cycle gas turbine	5%	Share of energy
Network optimization	70%	Grid covered
Smart grid for monitoring and control	70%	Grid covered
Power system automation	70%	Grid covered

Investment level:

- *National*
- *Private Sector*
- *Municipal*

40 Building Owners

Copenhagen's forty largest building owners control over 30% of the city's entire commercial stock and 10% of the residential stock. We modelled the impact of energy saving building technologies if they retrofitted their entire commercial stock. We assumed that any new-built property will meet the highest standards and that a ten year implementation period will provide enough time for the technologies to be installed.

Technology	Implementation rate by 2025	Unit
Wall insulation[5]	100%	Stock covered
Glazing	100%	Stock covered
Efficient lighting technology	100%	Stock covered
Home Energy Monitoring	100%	Stock covered
Home Automation	100%	Stock covered
Building Envelope	100%	Stock covered
Wall insulation	100%	Stock covered
Glazing	100%	Stock covered
Efficient lighting technology	100%	Stock covered
Demand oriented lighting	100%	Stock covered
Building Efficiency Monitoring (BEM)	100%	Stock covered
Building Performance Optimization (BPO)	100%	Stock covered
Demand controlled ventilation	100%	Stock covered
Heat recovery	100%	Stock covered
Building Envelope	100%	Stock covered
Room Automation, Building Automation and Control Systems (BACS), Class C[6]	100%	Stock covered
Room Automation, Building Automation and Control Systems (BACS), Class B[6]	100%	Stock covered
Room Automation, Building Automation and Control Systems (BACS), Class A[6]	100%	Stock covered
Efficient Motors	100%	Stock covered
Room Automation, HVAC	100%	Stock covered
Room Automation, HVAC+lighting	100%	Stock covered
Room Automation, HVAC+blind	100%	Stock covered
Building Remote Monitoring (BRM)	100%	Stock covered

Residential

Non-residential

4. Technologies are modelled on an individual basis for comparison basis. We are not assuming that all the technologies can be simultaneously implemented together. 5. ibid 6. Class A, B and C refers to Energy Performance Class for Building Automation and Control Systems (BACS) as described in EN 15232.

Results

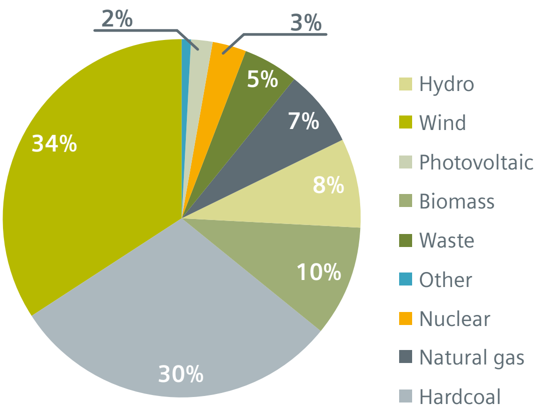
Energy

In our model, wind energy at the national and local level remains the most important mitigation strategy for Copenhagen. This will be partly led by the national government and from the city's current investments in wind. In our study, we increased uptake of wind energy from 55% to 65% resulting in over 11% citywide CO_2e savings.

How quickly Denmark's electricity mix decarbonizes will have a direct impact on three aspects of the city's mitigation strategies.

1. The cleaner the national mix, the less important energy saving building technologies will become in the long term – in terms of CO_2e savings only. This is because these buildings will be plugged to an increasingly cleaner supply. In the medium term, up to 2025, buildings related emissions will decrease from 80% to 78% of city wide emissions. By 2050, these will further decrease to 73%.
2. Copenhagen is removing gas and coal from its CHP mix and replacing it with biomass and wood pellets at a very fast pace. However, in terms of scope 3 emissions, this mix remains more carbon intensive than the increasingly dominant national wind mix. In the long term, Copenhagen may have to look outside of Denmark to offset its direct emissions.
3. Cleaning up the national electricity mix, increases the incentive to electrify transportation, but decreases the carbon attractiveness of promoting non-motorized modes such as cycling.

Denmark's Electricy Mix Today



Denmark's Projected Electricy Mix 2025

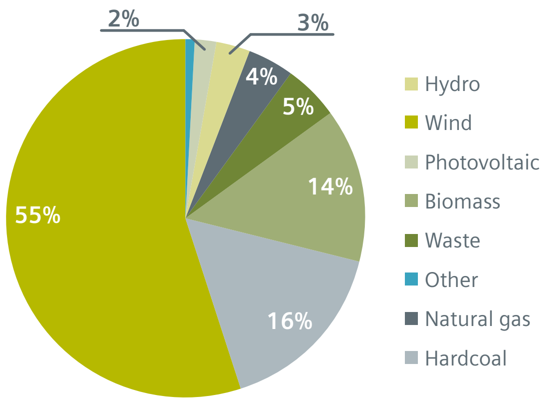


Figure 7: The Danish electricity mix is projected to have a 55% share of wind generation

The national wind mix will therefore play a pivotal role in the city's mitigation strategies. In the short run, the city will continue to focus on cleaning up its CHP mix and on its building emissions that make up the vast majority of CO_2 eq levels. In the long run, the city will have to look to the transport sector as the national wind mix will diminish the impact of buildings.

Our results also show that although wind delivers the largest savings, it is combined cycle gas turbines that are the most cost effective way at reducing CO_2 eq levels. Our results show that combined cycle gas turbines can save 2.2kg of CO_2 eq for every 1€ of capital investment versus the 1.5kg from wind energy. This is predominantly due to efficiency differences between the systems. Copenhagen will need to install roughly 3 times more capacity in variable wind energy to cover the same amount of capacity, compared to a combined cycle gas turbine working non stop. From a pure cost perspective it will make sense for the city to diversify the generation mix by having wind at the core and topping up with more cost effective solutions such as combined cycle gas turbines.

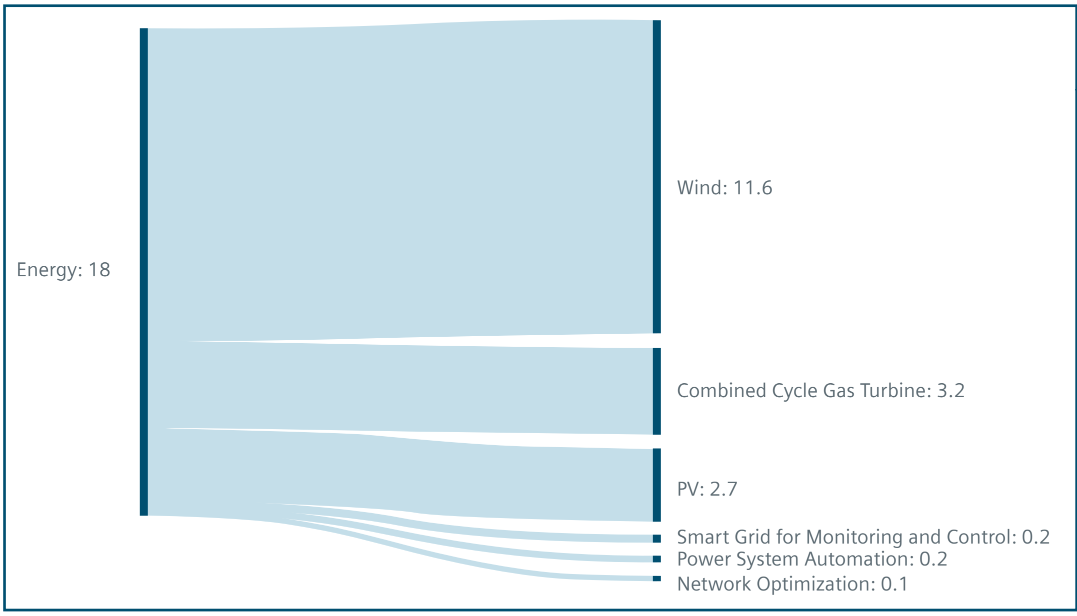


Figure 8: % savings by technology relative to energy related emissions in the city. All figures relate to %. Total savings amount to 18% of city wide emissions.

Results

The building technologies modelled in this study include monitoring services where advice is given on how energy savings can be made in buildings to room automation solutions where both lights and climate are controlled in building zones based on user behavior. The majority of these building technologies have pay back periods of around five years, well inside the city's ten year mitigation target but ultimately the city will need to devise a mechanism to make the investments worthwhile. The classical owner-tenant split incentives dilemma where one stakeholder pays for the benefits of others may be averted through some of the city's current programmes.

Copenhagen is currently launching an energy service market where private firms take on the risk of guaranteeing energy savings in return for a fee paid by the landlords or tenants.

Box 1 to the right gives a number of other examples of how cities such as Melbourne, Chicago and Tokyo incentivized their commercial building owners to retrofit their stock. Getting financial incentives as in Melbourne or a cap and trade scheme as in Tokyo that required immediate market action provided a clear motivation for the sector to act.

Box 1

Melbourne – Sustainable Buildings Program

As Australia's fastest growing city, Melbourne has consistently embedded sustainability into its long-term development plans to ensure economically and environmentally responsible growth. In 2003, the City of Melbourne set an ambitious goal for the municipality of zero net emissions by 2020. To reach this goal, the City of Melbourne has therefore designed the 1200 Buildings Program to encourage the retrofitting of 1,200 commercial buildings – approximately 70% of the city's commercial building stock responsible for nearly 50% of Melbourne's CO_2e emissions. Although the program is voluntary, it provides building owners with significant incentives to retrofit their properties. Once a building has committed to improving energy efficiency by 38%, it has access to tailored advice for retrofitting; marketing activities and campaigns; and government-furnished financial incentives, including the program's key component, Environmental Upgrade Agreements (EUA). Based on similar legislation in other major cities around the world, the EUA is a finance mechanism developed to remove a number of barriers preventing building owners from accessing finance to improve buildings' energy and water efficiency.

Since its inception in 2010, the 1200 Buildings program has supported 10% of the building sector retrofit.

Approximately 56 signatories (representing 5% of total buildings) have committed to promoting their efforts in retrofitting, and five buildings have used EUAs to access finance to retrofit, generating $5.6 million of investment and aiming to save 5,660 tons of carbon emissions and $491,000 in energy costs per year. If the 1200 Buildings program is successful, it will enable commercial buildings to improve their efficiency by approximately 38%, which would lead to the elimination of 383,000 tons of CO_2e each year. The program would also lead to a reduction in potable water use in the commercial sector by 5 giga liters – an important goal for a city with scare water resources and at risk from the impacts of climate change.

Retrofit Chicago – The Commercial Buildings Initiative

The City of Chicago has some of the most iconic buildings which showcase the city's strength in global business and innovative architecture. The Commercial Buildings Initiative is one of three components of Retrofit Chicago, a coordinated, cross-sector plan to bring energy efficiency improvements to municipal, commercial, and residential buildings throughout the city. Structured as a voluntary leadership effort, Chicago's Commercial Buildings Initiative aims to increase energy efficiency in commercial buildings larger than 200,000 square feet. By reducing energy use by at least 20% within 5 years, participants support the City of Chicago's private sector's commitment to increasing asset value, reducing operating costs, creating jobs, and lowering greenhouse gas emissions. In joining the program, participating buildings also commit to begin energy efficiency work within 6 months, track progress and share efficiency successes with the public, as well as serve as ambassadors to other buildings interested in increasing energy efficiency.

When the program was launched in 2012, 14 buildings covering 14 million square feet of office and hospitality space joined the Commercial Buildings Initiative. This number has increased to 32 buildings and 28 million square feet since then. Program partners develop a participant value proposition that focuses on increased building asset value through reduced operating expenses and improved tenant attraction and retention. By providing technical support, access to financial incentives, public recognition, expedited permits and fee waivers, and peer-to-peer engagement and best practice sharing, the Commercial Buildings Initiative is achieving great economic and environmental benefits for the City of Chicago.

Tokyo – Cap-and-Trade Program

In 2006 Tokyo announced its aim to cut emissions by 25% from 2000 levels by 2020. As part of the strategy to achieve this goal, the Tokyo Metropolitan Government (TMG) focuses to reduce emissions from the city's new and existing building stock, implementing a cap-and-trade program for existing large commercial, government, and industrial buildings.

Results

Buildings

If Copenhagen's forty largest building owners collectively retrofitted their commercial stock over the next decade, the city could reduce its citywide emissions by 10%. The six commercial building technologies listed in figure 10 below require an average investment of €50m Euros, per owner, over the next decade in order to improve the energy efficiency of their stock.

From the selected technologies, we picked six cutting edge commercial building technologies to reach total savings of around 10% of city wide emissions. These are listed in the table opposite (figure 9) with savings attributable to the stock of these 40 building owners alone.

Building automation remains the most important technology with just under 4% city wide emission savings. Building Automation and Control System (BACS) are building technologies that can be installed to existing or new buildings. An Energy Class A building corresponds to a high energy performance BACS, which include room automation with automatic demand control, scheduled maintenance, energy monitoring and sustainable energy optimization.

Box 1 (cont.)

Launched in 2010, the Tokyo cap-and-trade program is the world's first urban cap-and-trade program.

The cap-and-trade system sets out that buildings over a certain size to take action in reducing its emissions. The cap is fixed for reducing GHG emissions at 6% for the first compliance period (FY2010-FY2014) and 15% for the second compliance period (FY2015-FY2019). If a building reduces emissions beyond the cap, then it is eligible to sell "credits" to buildings unable to match those targets. Thus, a market for GHG emissions is established, which produces the market-allocated distribution of a government-set level of emissions. In its first year of the program, 1,159 participating buildings in Tokyo exceeded expectations and reduced emissions by a total of 13%. Of the participating commercial buildings, 93% have now met the first compliance factor, and more than 70% have already surpassed the target for 2019. Because of the market mechanism the cap-and-trade program provides greater emissions reductions at a reduced cost to all participants. Moreover, energy efficiency efforts are now addressed jointly by tenants and building owners, which has led to greater public awareness of climate change issues.

The full set of building technologies are compared in the diagram on the opposite page.

Lever	% Reductions CO_2e	kg CO_2 eq savings / CAPEX	Total jobs
Building Efficiency Monitoring (BEM)	0.7%	1.3	900
Building Performance Optimization (BPO)	2%	5	400
Heat recovery	1.3%	0.1	2,600
Building Automation, BACS A	4%	0.1	5,400
Room Automation, HVAC+blind	1%	0	8,000
Building Remote Monitoring (BRM)	1%	2	1,400

Figure 9: Shortlisted smart technologies providing the largest savings

Results

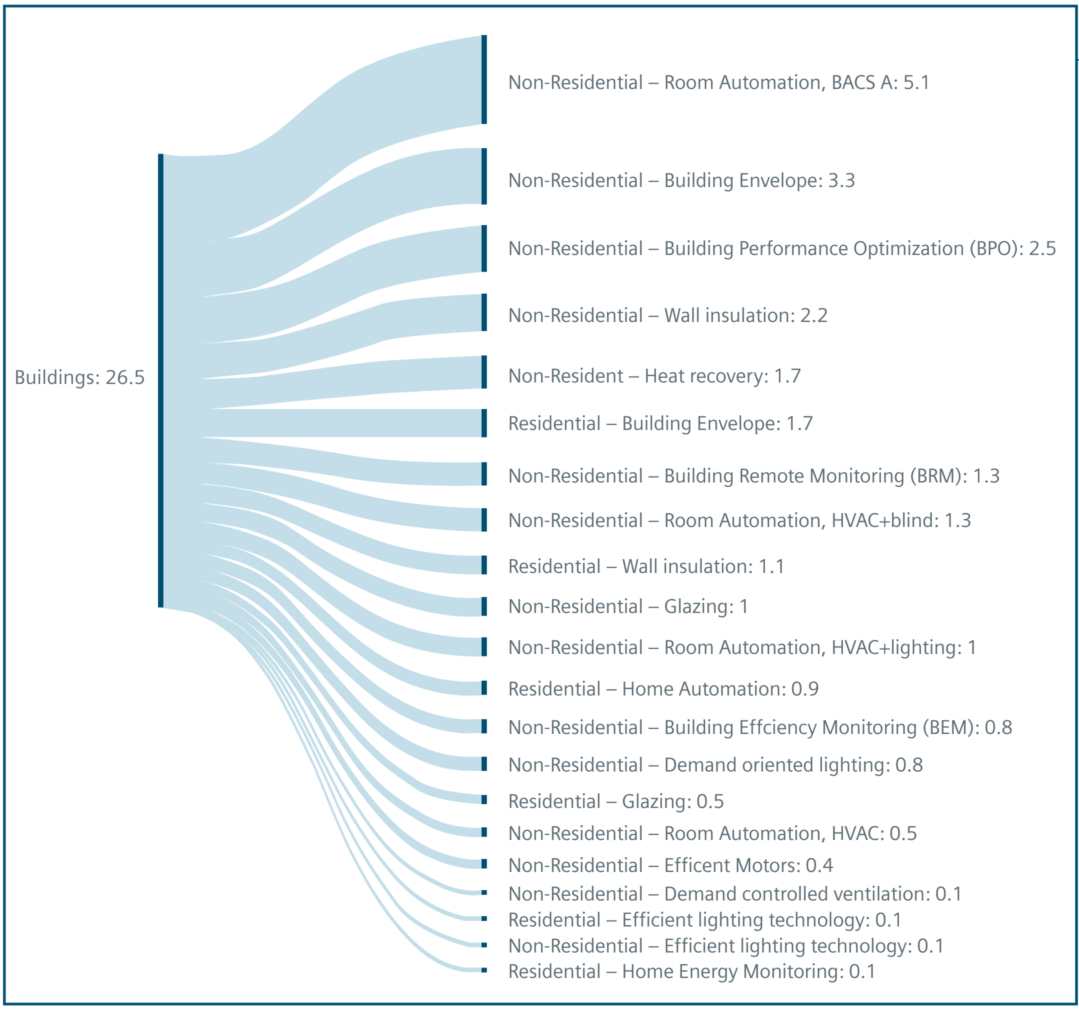


Figure 10: savings by technology relative to building related emissions in the city. All figures relate to %

Results

Transport

In contrast to the high impact wind and building technologies, the transport related technologies in the CyPT are predominantly influenced by city investments. It is however, the technologies that deal directly with the city's private car usage that provide the greatest emission reductions. City tolling remains the high impact lever with over 12% savings of overall transport related GHG emissions sector based emission reductions, assuming that the toll will be set at a level, where 20% less private vehicle km are reached in the city.

Due to Copenhagen's low share of alternative car technologies, electric cars provide over 5 % CO_2 eq sector savings with an implementation rate of 10% of total car shares. Although, Copenhagen has found it difficult to incentivize households to switch cars despite an extensive investment in charging infrastructure, the city can look to some international cities as precedents as shown in box 2 to the right.

Oslo

Norway has emerged as the world's largest electric cars market with over 11% of market share. With just 5.1 million people, Norway accounts for a third of all European electric car sales, with Oslo having the highest concentration across the country. There are several national level incentives that promote electric cars in Norway. All-electric cars are exempt from all non-recurring vehicle fees, including purchase taxes, which are extremely high for ordinary cars, and consumers benefit from 25% VAT on purchase. This incentive makes the price for electric vehicles very competitive with petrol and diesel fueled cars, which can be relatively expensive in Norway due to high tax regime. Electric vehicles are also exempt from the annual road tax, all public parking fees, as well as road and ferry toll payments. Moreover, electric car drivers are allowed to use dedicated bus lanes, which speeds up journey times; cost less to insure and local governments subsidize the installation of charging points in private homes. These incentives are in effect until 2018 or until the 50,000 EV target is achieved.

Box 2

Rotterdam

The Rotterdam Electric programme, launched by the City of Rotterdam in 2012, intends to support and accelerate the development of the electric mobility market. Several incentives have been put in place such as the provision of sufficient network of charging stations in across Rotterdam. Owners of an electric vehicle parked on private property (such as a driveway or garage) can apply for a grant towards the purchase of the equipment for an electric charging station, up to a maximum of € 1000 per station. If green energy is used to charge the vehicle, the municipality will reimburse the energy costs for the first year that the charging station is in use, up to a total of € 450. Owners of an electric vehicle who cannot park on their own property, can apply to the City of Rotterdam to have a public charging station provided. The municipality will install this charging station in a car park or on the street in the applicant's vicinity. If this charging station is placed in a paid parking zone, the applicant will receive the cost of the parking permit for the first year, up to a maximum of € 678. The city of Rotterdam is also offering business buyers €2,500 scrappage incentives which, together with other state-funded subsidies, can bring the price of a e-NV200 Visia Flex down to just €4,950. The same discount opportunities can bring the price of a new Nissan LEAF down from €24,110 to just €7,450, which make electric vehicles substantially cheaper than conventional cars.

San Francisco

The City of San Francisco boasts more electric vehicles per capita of chargers-per-electric than any other city in the U.S. To address the predicament of finding available charging stations across the city, which is still one of the main reasons globally many car drivers shy away from purchasing an electric vehicle, the City of San Francisco incentivizes people by facilitating chargers for the private sector, so that whoever wants to install one can do so without bureaucratic hurdles, while also benefiting from state-level grants and a streamlined permitting process. In addition, the state of California recently passed a building code mandating that a certain portion of new construction come pre-wired for electric vehicle chargers. San Francisco is also working on its own code, which will be see even stricter building rules that favor electric mobility. Moreover, the city installed three off-the-grid solar-powered charging station, which allow electric vehicle owners to pull up and charge their cars for free.

Results

Congestion charging is a very simple technology to implement at a minimal cost to the city. In fact it is the most cost effective way of reducing CO_2 eq in the city as is shown in the figure 11. Although City Tolling provides less total savings than combined cycle gas turbines room automation and wind energy levers (as shown in green), the savings per € of investment are by far the highest at around 11kg of CO_2 eq saved for every 1€ of capital investment.

Cost efficiency of selected technologies

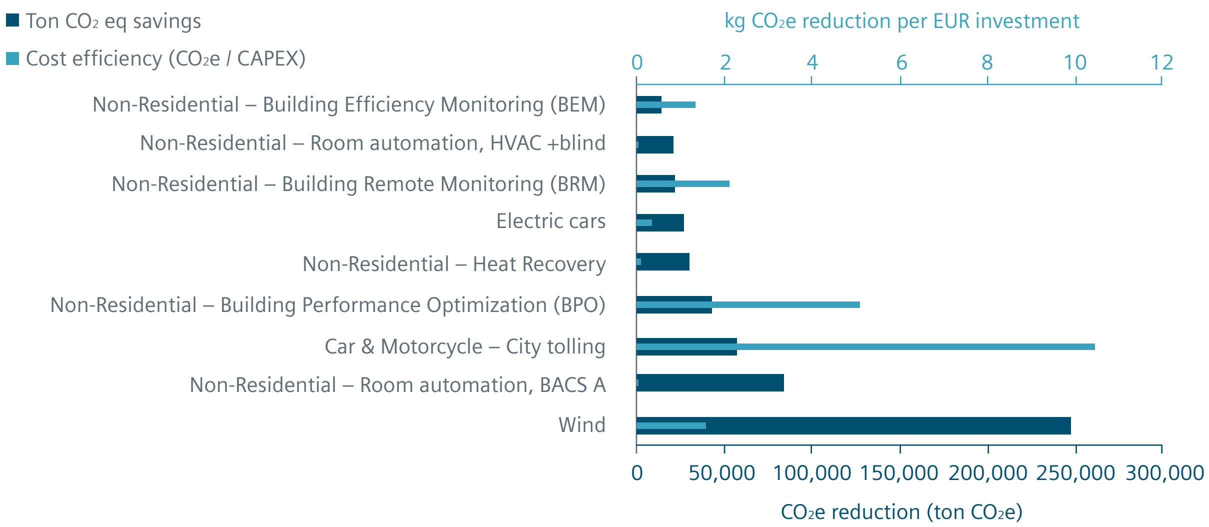


Figure 11: Comparing the cost effectiveness of selected technologies

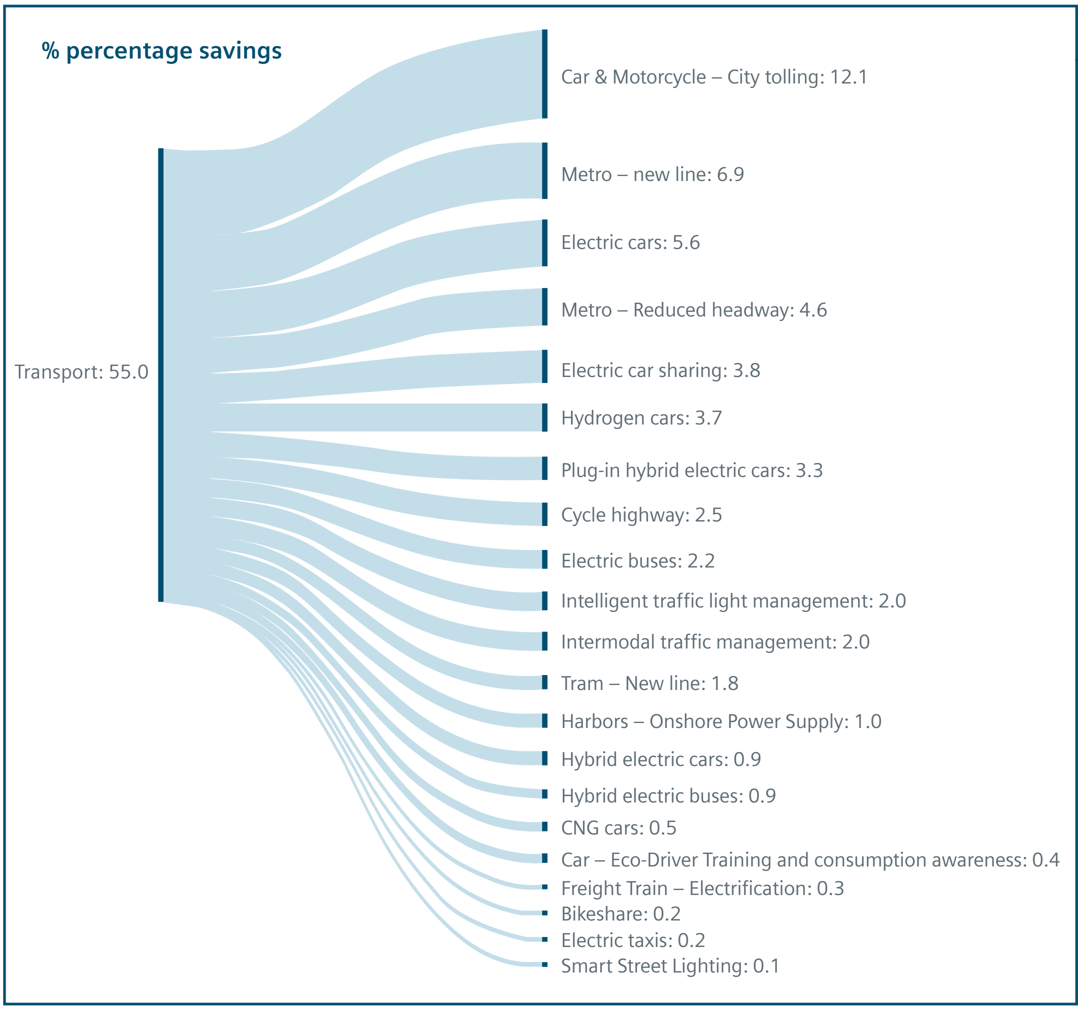


Figure 12: savings by technology relative to transport related emissions in the city. All figures relate to %

Conclusion

This report has shown that the most significant CO_2e mitigation technologies in the City Performance Tool lie outside Copenhagen's public budgeting programme. These include national investments in wind, private investments in building retrofitting and household and business investment in alternative cars. This is not to say that the city cannot take action on its emissions but that its role has to shift increasingly away from a direct investment one to an incentivizing one.

Perhaps the greatest drivers of Copenhagen's emissions reductions are its push to decarbonize its district heating network and its reliance on an increasingly greener national electricity mix. We modelled over 12% CO_2e reductions from these initiatives alone. If Denmark's share of wind power is increased by a further 10% of its 2025 target, the city will gain a further 11% emission reductions.

In the short term, Copenhagen must incentivise its largest building owners to retrofit their building stock. We have focused on the commercial holdings of the city's largest building owners and modelled the impact of six sensor based energy based technologies that provided nearly

10% citywide CO_2e savings. There are numerous international city-led initiatives that Copenhagen can emulate to incentivise the largest building owners. This can take a light incentive approach such as reduced business rates to a more regulatory approach such as Tokyo's cap and trade. The capital investment needed to achieve this change is €5m per building owner, per annum, for ten years.

The greatest transport related savings are related to alternative car technologies and an overall reduction in car use through city tolling. Although the savings are moderate today because of the transport sector's low share in overall emissions, these will increasingly become more important as Copenhagen's building emissions will drop because of cleaner electricity and heating mixes.

Copenhagen's big incentive identified technologies outside of the city's current climate plan. It is a combined strategy to get additional CO_2e savings by tackling building emissions in the private sector whilst putting the necessary national and regional regulatory framework to limit car use and switch to alternative cars.

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Appendix I

Full results are indicated in the table below with the nine shortlisted citywide technologies to achieve the 25% gap indicated in green. These were picked in terms of their overall savings as well as their technical deliverability in the ten year period to 2025. Because the majority of the city's emissions are in the building sector, wind energy delivers the largest savings for the city. Similarly, the energy saving building technologies from the city's largest owners collectively provide 10% city wide CO_2 eq savings.

Lever	% Reductions CO_2 eq	kg CO_2 eq savings / CAPEX	% Reductions PM_{10}	% Reductions NO_X	Total jobs
Residential – Wall insulation	0.9%	0.2	1.5%	1.1%	1,300
Residential – Glazing	0.4%	0.1	0.7%	0.5%	1,100
Residential – Efficient lighting technology	0.1%	0.2	0.0%	0.1%	0
Residential – Home Energy Monitoring	0.1%	0.1	0.0%	0.1%	20
Residential – Home Automation	0.7%	0.4	1.0%	0.9%	60
Residential – Building Envelope	1.3%	0.1	2.2%	1.6%	2,500
Non-Residential – Wall insulation	1.7%	0.3	2.9%	2.2%	2,000
Non-Residential – Glazing	0.8%	0	1.3%	1.0%	5,800
Non-Residential – Efficient lighting technology	0.1%	0	0.0%	0.1%	1,700
Non-Residential – Demand oriented lighting	0.6%	0.2	0.3%	0.8%	1,100
Non-Residential – Building Efficiency Monitoring (BEM)	0.7%	1.3	0.7%	0.9%	900
Non-Residential – Building Performance Optimization (BPO)	2%	5	2.2%	2.6%	400
Non-Residential – Demand controlled ventilation	0.1%	0.1	0.1%	0.1%	50
Non-Residential – Heat recovery	1.3%	0.1	2.2%	1.7%	2,600
Non-Residential – Building Envelope	2.6%	0.1	4.2%	3.2%	8,000
Non-Residential – Room Automation, BACS A	4%	0.1	4.3%	5.1%	5,400
Non-Residential – Efficient Motors	0.3%	1.3	0.4%	0.4%	26
Non-Residential – Room Automation, HVAC	0.4%	0	0.6%	0.5%	3,000
Non-Residential – Room Automation, HVAC+lighting	0.8%	0	1.0%	1.0%	5,800
Non-Residential – Room Automation, HVAC+blind	1%	0	1.3%	1.3%	7,900
Non-Residential – Building Remote Monitoring (BRM)	1%	2.1	1.2%	1.4%	1,405
Hybrid electric buses	0.20%	0.4	2.0%	3.1%	0
Electric buses	0.5%	0.1	4.1%	8.6%	10
Metro – new lines	1.5%	0	4.4%	5.7%	87,000
Tram – new lines					
Intelligent traffic light management	0.5%	1.9	2.1%	1.7%	200
CNG cars	0.1%	0	3.1%	3.6%	700

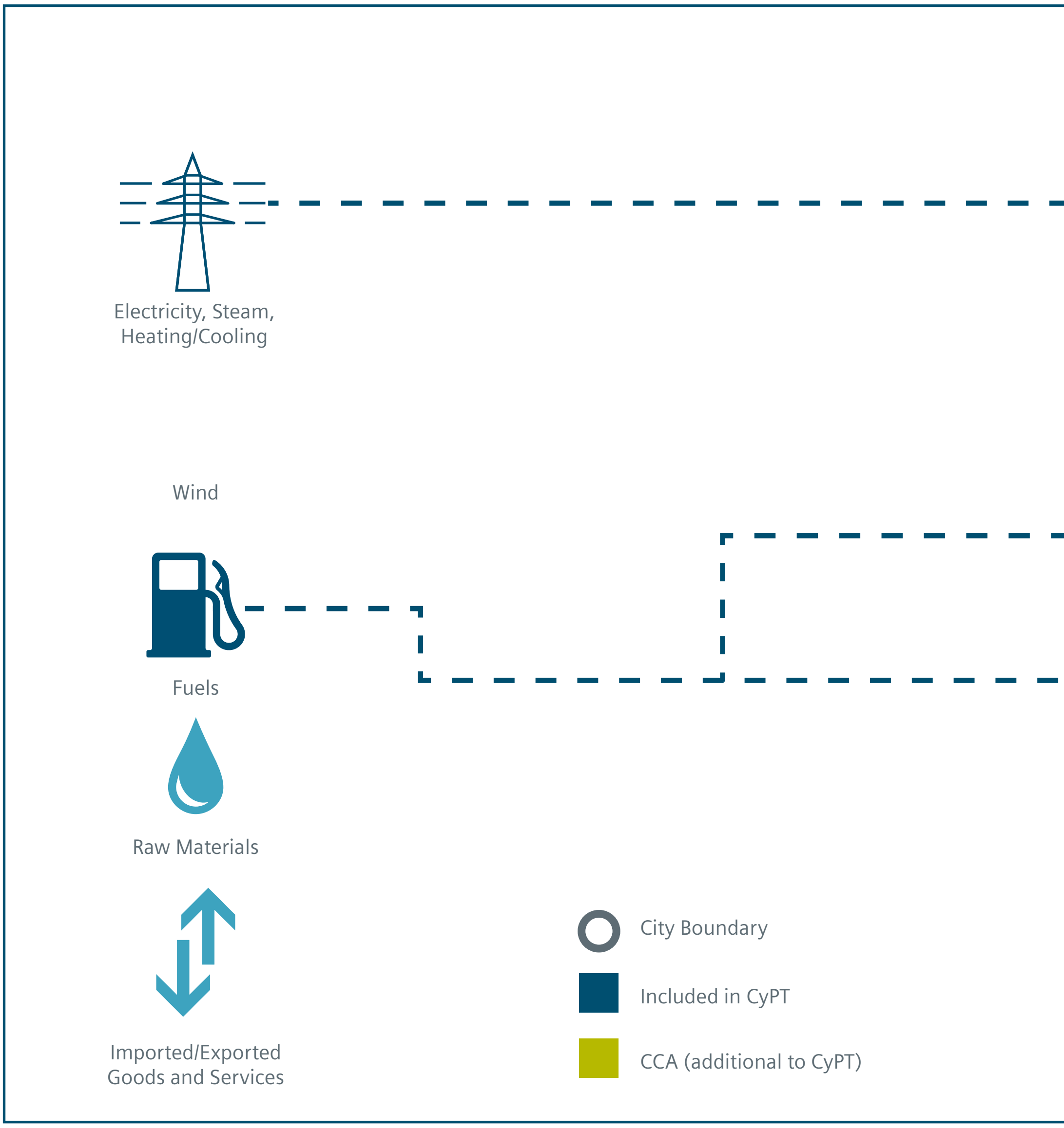
Lever	% Reductions CO_2e	kg CO_2 eq savings / CAPEX	% Reductions PM_{10}	% Reductions NO_X	Total jobs
Electric cars	1.2%	0.4	3.7%	3.5%	500
Hydrogen cars	0.8%	0	2.5%	2.1%	1,300
Hybrid electric cars	0.20%	0.1	2.3%	1.2%	0
Plug-in hybrid electric cars	0.7%	0.1	3.0%	2.4%	90
Electric taxis	0%	0.1	0.1%	0.1%	20
Electric car sharing	0.8%	0.3	2.9%	2.3%	2,700
Intermodal traffic management	0.4%	3.1	2.0%	1.2%	20
Bikeshare	0%	0.1	0.2%	0.1%	400
Car – Eco-Driver Training	0.1%	1.6	0.4%	0.2%	41
Metro – Reduced headway	1%	0	2.9%	3.8%	3,500
Metro – Regenerative braking	0.00%	0.2	0.0%	0.0%	2
Smart Street Lighting	0%	0	0.0%	0.1%	200
Cycle highway	0.6%	1.1	2.4%	1.6%	200
Freight Train – Electrification	0.1%	0	0.9%	1.9%	300
Car & Motorcycle – City tolling	2.7%	10.5	11.4%	5.5%	40
Harbors – Onshore Power Supply	0.2%	0.6	-0.2%	6.7%	100
Wind	11.5%	1.6	2.0%	8.1%	400
PV	2.8%	0.5	-0.2%	1.8%	1,500
Combined Cycle Gas Turbine	3.2%	2.3	1.1%	2.7%	500
Network Optimization	0.1%	0.5	0.1%	0.1%	200
Smart Grid for Monitoring and Control	0.2%	1	0.1%	0.2%	40
Power System Automation	0.2%	0.400	0.1%	0.1%	180

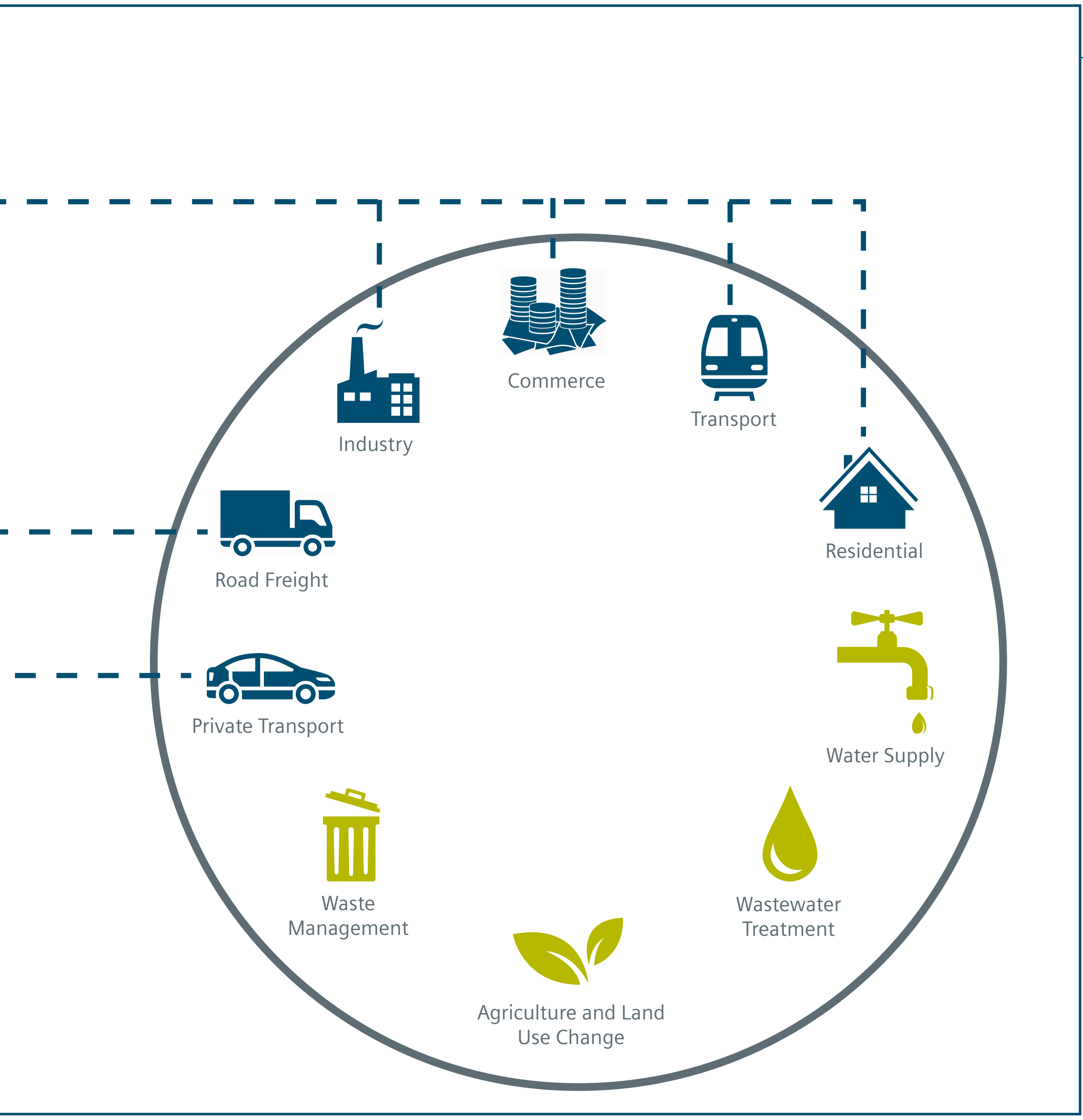
Shortlisted technologies that can be added up into a comprehensive technology strategy for Copenhagen

Appendix II

The following section compares the different accounting methodologies used in Copenhagen's Carbon Account (CCA) and the in CyPT model. Copenhagen's accounts are much wider than the CyPT's, covering additional sectors such as industry, water supply, waste and waste water treatment. We are confident however that the CyPT does capture 95% of the emissions which are predominantly derived from the buildings and transport sectors.

The main difference lies in the CyPT's accounting of indirect scope 3 emissions outside of the city's boundaries and the allocation for district heating. This is mainly composed of energy production and distribution as shown in the figure below.





Including scope 3 emissions has a significant impact on the building sector and to a lesser degree on the transport related emissions.

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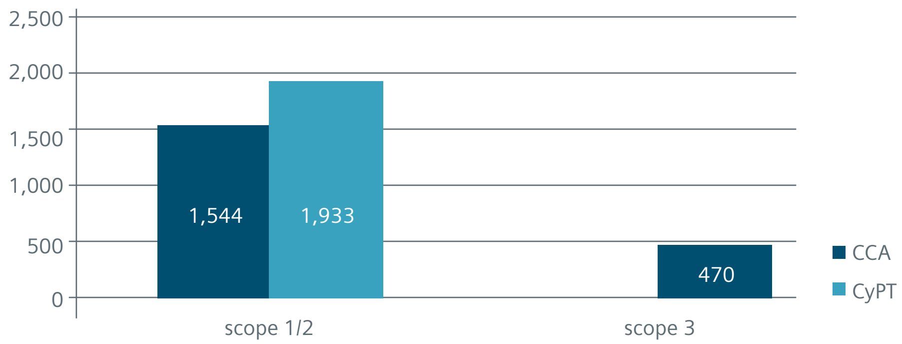
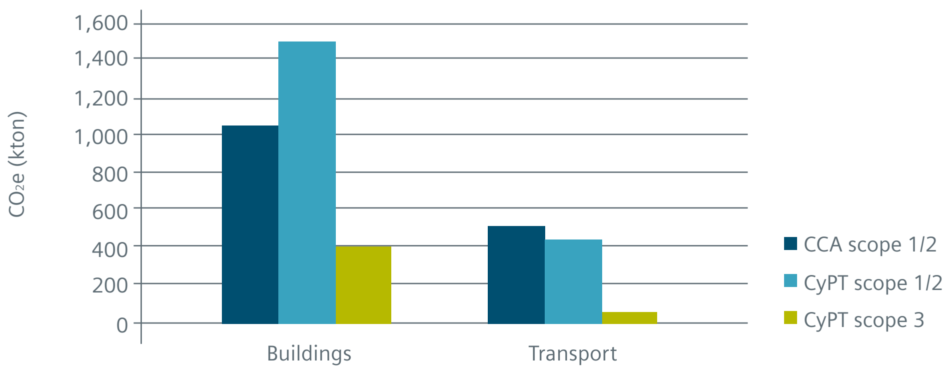
Baseline 2014 comparison – by scope



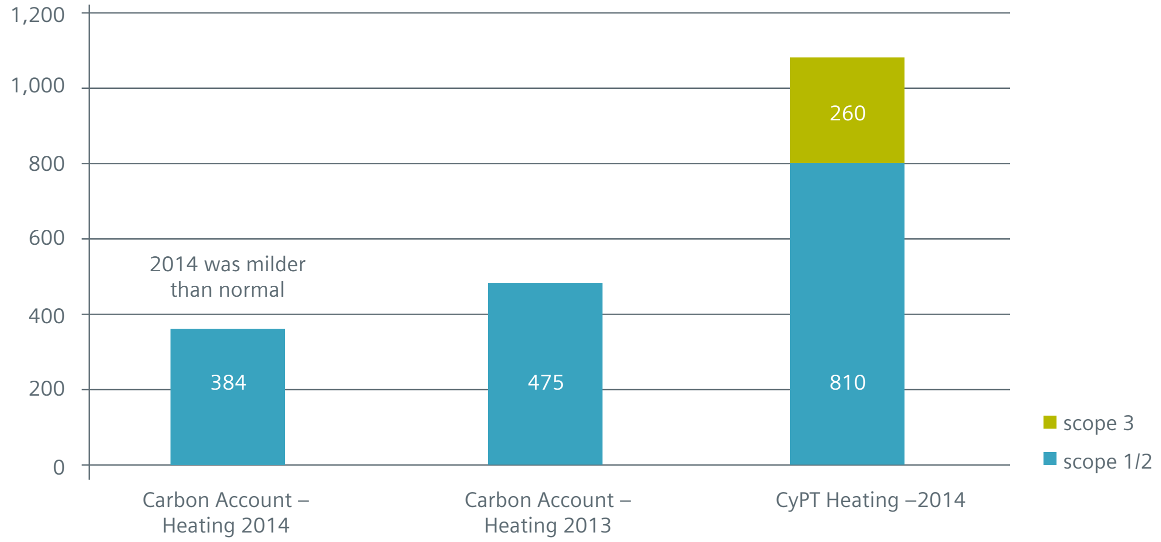
Even without the scope 3 emissions, there is a discrepancy of about 390 kton.

Baseline 2014 comparison – by sector



The discrepancy is largely due to the building sector, and it shows to be in the district heating.

District Heating comparison – by scope



CyPT has different heating emissions (compared to cities own accounting) due the different allocation and scope difference method for combined heat and power plants. This suggests that building levers reducing CO_2e by saving heat will overestimate their potential absolute savings when compared with the Copenhagen allocation method. One should have this in mind when comparing savings across sectors in this report as transport and energy will appear more conservative than the buildings ones.

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