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City of The Hague

City Performance Tool Report (CyPT)

City Performance Tool – June 2017

The Hague has set an ambitious target of becoming climate-neutral by 2040. Since this is 10 years ahead of both national and European Union 2050 targets, The Hague cannot rely on national or EU legislation and modernization to carry it towards its goal. The Hague must be innovative and strategic in selecting high-impact, city-level projects that leverage its position as a convener, buyer of goods and services, and decision maker.

Executive Summary

The City of The Hague is synonymous worldwide with peace and justice. Therefore it is no surprise that the city is leading The Netherlands in its aims to reduce carbon emissions, reinvent how cities deliver heat to their residents and improve local air quality. The Hague has set an ambitious target of becoming climate-neutral by 2040. Since this is 10 years ahead of both national and European Union 2050 targets, that The Hague cannot rely on national or EU legislation to provide a low-carbon energy mix, must be innovative and strategic in selecting high-impact, city-level projects that leverage its position as a convener, buyer of goods and services, and decision maker. This will position The Hague as an influential advocate and model to motivate national government to move towards carbon neutrality ahead of European Union requirements.

To achieve this ambitious goal, The Hague must maximize all available avenues to promote renewable energy and energy efficiency, as well as delivering all currently planned projects and enforcing building upgrade requirements. Siemens and The Hague have partnered in a joint study to identify the most climate-friendly and cost-efficient options through a careful analysis of existing and forecasted data. This builds on the work of Deputy Mayor for the Knowledge Economy, Education and Youth, Ingrid van Engelshoven and Deputy Mayor for Urban Development, Public Housing, Sustainability and Culture, Joris Wijsmuller, who have have been instrumental in better linking the city's economic and the environmental policies. This study will test the city team's existing plans and identify new areas for achieving emissions reductions. This joint study, initiated from the Smart City program, uncovers a possible 77% carbon reduction by 2040 through emphasizing a more renewably-sourced electricity mix.

This report comes at a time of change in The Netherlands energy policy. After gas extraction in the North Sea led to earthquakes in the Groningen area in the north-east, citizens are calling for safer energy. More broadly, stakeholders are questioning the continued use of coal in the national energy mix. Renewable energy is an obvious option for heat and/or electricity, but has its own limitations. If The Hague aims to electrify heat as well as transport, it must prepare for increasing electricity demands. A more likely path is a diversified heat mix, including geothermal, solar thermal, natural gas and electricity, distributed by heat pumps through efficient district heating networks. Increasing the proportion of renewable sources such as wind and solar will reduce the carbon intensity of heat and electricity.

Digitalization is also rapidly impacting infrastructure across energy, buildings and transport. This technological shift is allowing for new models of on-demand transport, helping facility managers monitor and optimize building performance remotely and across sites, and creating opportunities for microgrids to grow within cities where digitalization balances the electricity generation and local grid connection.

Siemens has worked with The Hague to estimate possible impacts of key technologies within an emissions model of the city. It has identified technologies with the most potential to reduce local carbon emissions in the energy, buildings (non-residential and residential) and transport sectors. It has also created scenarios that combine the most efficient technologies at specific implementation rates to determine what emissions reductions could be achieved in various time-scale. Some technologies in this analysis can be considered 'smart' or digital. The Hague can choose among specific scenarios to match the ambitiousness of its goals.

The results of the analysis have identified a number of technologies that on an individual basis have the most potential to reduce local carbon emissions in the energy, buildings (non-residential and residential) and transport sectors.

Buildings

Buildings in The Hague contribute 77% of total carbon emissions. Reducing energy demand in these buildings alongside increasing the level of renewables in the local energy mix (electricity and heat) is paramount to meeting carbon reduction targets. Efforts in The Hague are supported by the national Government of The Netherlands, which is proposing new legislation to require that non-residential buildings achieve a minimum energy performance certification of 'C.' While there are a number of commercially available technologies for non-residential buildings, the following were determined most applicable to existing building performance within The Hague.

Non-Residential Buildings

- **Demand oriented lighting (automated lighting that adjusts to natural daylight levels and room occupancy)**
- **Wall insulation**
- **Building Automation (Grade C) – building management systems that reduce the energy required to heat, cool, and circulate water)**
- **Efficient lighting – (change to more energy efficient LED lights)**

Residential Buildings

Residential buildings comprise a far larger proportion of building area than non-residential buildings, making them central to any city strategy for reducing building related emissions. The following technologies demonstrated the most potential to reduce carbon emissions within The Hague's housing stock. All of these technologies can be applied to either new or existing homes; however, cost and inconvenience will affect take-up rates in existing homes.

We found that insulation would generate the most total emissions reduction. However, Home Automation was the most cost-effective choice. Therefore, we have listed Home Automation as the top choice because the focus of this analysis was the new role technology can play in reducing emissions. Wall insulation is a well-stablished option, but is difficult to implement in existing buildings due to disruption.

- **Home Automation – automation of heating, cooling, lighting and ventilation**
- **Wall insulation**
- **Efficient Lighting – change to more efficient LED lights**

Transport

The transport sector within The Hague is responsible for the remaining 23% of citywide carbon emissions. The most effective technologies within The Hague are alternative fuel cars, city tolling and car sharing because cars are the largest source of emissions. Public transport is not. Delivering a tolling system that does not slow traffic flow requires camera and number plate recognition technologies, and most importantly the policy must be in place to implement such a technology.

The Hague is already reducing emissions through its Compressed Natural Gas (CNG) bus fleet and its continued promotion and expansion of public transport. These efforts complement the existing local culture of cycling and walking. Given that the city is already so active in reducing transport emissions, it has delivered or is set to deliver the 'low hanging fruit.' Our results have shown the need to boost local public transport utilization rates, particularly at the non-peak times. Since privately owned vehicles are the largest transport contributor to both carbon emissions and air pollution, further carbon reductions require limiting their use or incentivizing a change in fuel type.

- **Electric cars**
- **City (road) tolling**
- **Hydrogen cars**
- **E-car sharing**

Energy

Increasing the proportion of renewable sources in The Hague's heat and electricity mix is the single most effective way to reduce carbon emissions. This is because nearly all electricity used in buildings within The Hague comes directly from the electricity grid and most buildings utilize some form of natural gas for heating. This CyPT assessment utilizes the heat and electricity mixes of today, the expected electricity and heat mixes in 2040, and additionally tests an ideal heat mix in 2040. The key finding is that the most effective technologies will either generate cleaner power, or shift consumption from carbon based fuels to non-carbon based fuels. The three most effective technologies based on the expected electricity grid and heat mixes in 2040 include:

- **Heat pumps – air and ground source heat pumps that utilize electricity and reduce the level of natural gas needed to create heat across the city**
- **Wind generation (regional level)**
- **Photovoltaic cells**

Ideal Heat Mix in 2040

The Ideal Heat mix assumes that policy and local actions lead to a heat mix with less fossil fuels than the expected 2040 mix. The Ideal Heat mix is comprised of roughly 1/3 geothermal heat, 1/3 electric heat production through heat pumps, and 1/3 biomass heat production. The Ideal Heat mix is considered its own scenario. Simply using this mix, without any other technology changes, would reduce 2040 emissions by 984 ktonCO_2e.

Air Quality Impacts

Environmental discussions at the city level are increasingly focused on air quality as well as carbon emissions. Air quality can appear more relevant because of its more direct impact on the health of citizens. If The Hague were to prioritize air quality over its carbon emissions, the city's priorities would shift towards reducing transport related emissions over those generated by buildings.

The most effective action to improve air quality is to limit private car and truck use. In this analysis, city tolling provides the largest improvements in air quality as it directly impacts private vehicle journeys. Beyond tolling systems, further air quality improvements would require increasing the proportion of alternative fuel cars and ensuring that all new buses remain CNG or become electric or hydrogen-fueled. The Hague could also improve air quality by promoting an eCar sharing system and further expanding the existing cycling network.

The Most Cost Effective Technologies

The most cost effective technologies are, with only a few exceptions, also those that could generate the most carbon reduction. There is a notable exception within the transport sector: when focusing on cost-effectiveness, eTaxi and cycling highways rise to the top. Although eTaxis represent a small proportion of the total car fleet, they are in use far more than a privately owned car. For electric transport penetration to increase, The Hague must ensure that there are ample charging points across the city, and for broader take-up Dutch and European cities must also provide charging infrastructure. Maintaining the existing system of cycle lanes, and supplementing it with additional lanes, is also cost effective for The Hague.

Scenarios

The basis of this report is the calculation of emissions savings. Any attempt to meet the carbon reductions requires addressing all three key sectors, and Siemens and The Hague have developed a projected emissions baseline for 2040 and four active scenarios for testing technologies. These scenarios build up in intensity from implementing only the currently mandated building technologies (3% annual implementation rate [AIR]), to supplementing these technologies with some of the already planned transport technologies, such as low emission buses and new tram vehicles. This means that if The Hague enforces building performance mandates, and delivers its planned transport changes, it could reduce emissions in 2040 by 26%. While positive, this is not enough for The Hague to meet its carbon reduction target. The Hague would need to implement additional building and transport technologies, and utilize cleaner electricity and heat mixes, to reduce emissions by the 77% figure mentioned above. This would bring The Hague would be very close to meeting the national 2050 target 10 years ahead of time. However, higher implementation rates and more renewable energy – whether from the ground, wind or sun – would be required to achieve full carbon neutrality.

The city of The Hague cannot directly change the national grid mix or legislation requiring connections to the natural gas network for heat. However, together with other Dutch cities, The Hague can lobby for improvements and support city-scale energy initiatives, for example a solar powered microgrid and geothermal district heating. If the national grid mix were to be 100% renewable, then The Hague's emissions would drop by a further 58% to 264 ktCO_2. This may seem still high, given that the electricity grid mix is 100% renewable, but there will still be Scope 3 emissions linked to the production and maintenance of the generation plants. This number would come closer to zero if the heat mix were also to be generated from fully renewable sources, as 34% of The Hague's total emissions today come from building heat.

Timing: A Delivery Roadmap

A key output of this study is to provide The Hague with a high-level roadmap for rolling out its programs and any newly identified concepts. Within the very short term, 2 to 5 years, The Hague can only reasonably deliver what is already within its existing strategies and funding pipeline. However, The Hague must be planning how it will deliver the bigger results through a greater use of geothermal heat, constructing district heating systems, electricity storage and carbon capture.

The Hague could begin addressing both building and transport emissions by starting with improvements to its own building stock and vehicle fleets. The Hague should have its buildings' energy performance assessed and the most beneficial technologies should be implemented and the energy savings results publicized. The Hague could also deliver the first of the active scenarios in this study by enforcing local legislation that stipulates all energy efficiency projects in non-residential buildings with a short repayment period (3 – 6.5 years) should be delivered. Should the proposed required energy efficiency grade 'C' be legislated, this could also generate initial savings. When city's CNG vehicles will be replaced in the short-term, the city could insist that the replacements are low emission, alternative fuel vehicles.

In the medium to long-term, The Hague can start to amend building codes to require more insulation and home automation for new builds. The city can consider programs to incentivize take-up in both areas among the existing stock. In transport, eCar uptake has the largest potential impact on both carbon emissions and air quality. The Hague can offer incentives for people and businesses that choose eCars. In the longer term, The Hague will need to partner with local utilities, the grid operater, and potentially create its own renewably sourced energy for heat and electricity. The planning for these longer term ambitions will need to start immediately, as upgrading the grid and building new generation facilities will take time.

This report is intended to outline the key results of the CyPT analysis and to contextualize these results in a way that is helpful to policy makers. The report is structured as follows:

- The Hague, its City Vision and emissions targets
- Introduction to the CyPT tool
- Creating an emissions baseline for The Hague
- Developing technology and implementation scenarios
- Specific technology results (CO_2, PM_{10} and NOx)
- Conclusions

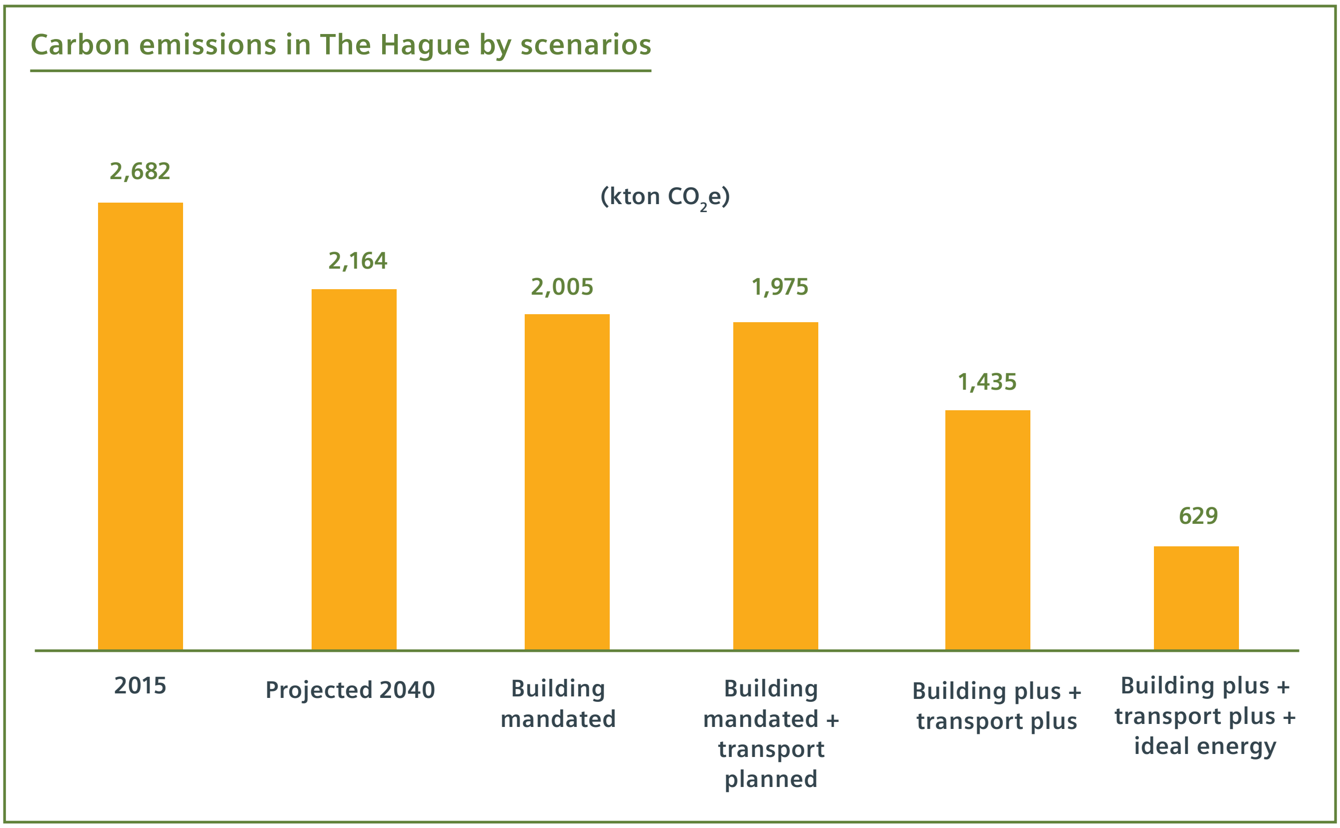


Chart 1: Carbon Emissions in The Hague by Scenarios

Introduction

The Hague: Its City Vision and Emission Reduction Targets

The Hague is a global city, renowned for promoting peace and justice, and is home to The Netherlands' national ministries. More than 150 international organizations are based within its international quarter, including the Institute for Global Justice, Europol, the International Criminal Court and the UN Climate Fund. The city's international reputation is further strengthened by the more than 300 international companies in the region.

Building on The Hague's global reputation, the city aims to provide a five star quality of life. Quality of life is directly linked to issues such as air quality and comfortable, efficient transportation. Residents want The Hague to live up to its reputation for social justice by being a leader in tackling global climate change. The Hague has set a target of reaching climate neutrality by 2040,10 years ahead of the European Union's 2050 aim.

In order to meet its climate target, The Hague has put forward an energy vision that includes increases in renewable energy within its local electricity, heat and transport networks and improvements in the energy efficiency of its buildings. The importance to The Hague of reaching its climate neutrality target is the reason that the city engaged with the environmental consultancy firm, CE Delft, to work backwards from 2040 and identify the policies and actions needed to reach the targets. Delft's 'Back (Casting) study' has delivered some tough messages and points to a need for the city to dramatically step-up its actions in order to deliver change within its own estate and fleets, and to reach out to the private sector to address energy generation, building energy use and transportation. The study also identifies The Hague's dependence upon the European Union and national government for delivering on its aims to reduce the carbon intensity of the grid. The report cites that about half of emissions are directly linked to policies outside the jurisdiction of the city and that part of the city's possible success will be in riding on the tailwind of these policies. The report also highlights how the city can

decrease transport-related emissions with tools like city tolling, and by encouraging widespread building retrofit.

The Hague has taken a holistic approach to urban development, and is creating partnerships between the municipality and the city's five main stakeholder groups: residents, businesses, visitors, students and international institutions. Siemens has built on these recent efforts by collaborating with The Hague, using its City Performance Tool (CyPT) to analyze data specific to The Hague and The Netherlands on energy usage, journey habits, population forecasts and local energy mixes. The analysis identified the scale of actions required, the most impactful technology options, the technology implementation levels and timing necessary to meet its 2040 target for climate neutrality. The collaboration aims to use the city's own data and Siemens' knowledge of technology to develop a technology roadmap for The Hague to reach carbon neutrality.

The Hague has taken a holistic approach to program delivery, and it is creating joint partnerships between the municipality and the city's five main stakeholder groups: residents, businesses, visitors, students and international institutions. The CyPT analysis is intended to further The Hague's aims by identifying the scale of actions required, the most impactful technology options, the technology implementation levels and timing necessary to meet its 2040 target for climate neutrality.

Introducing the City Performance Tool

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 greenhouse gas emissions. Cities like The Hague 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.

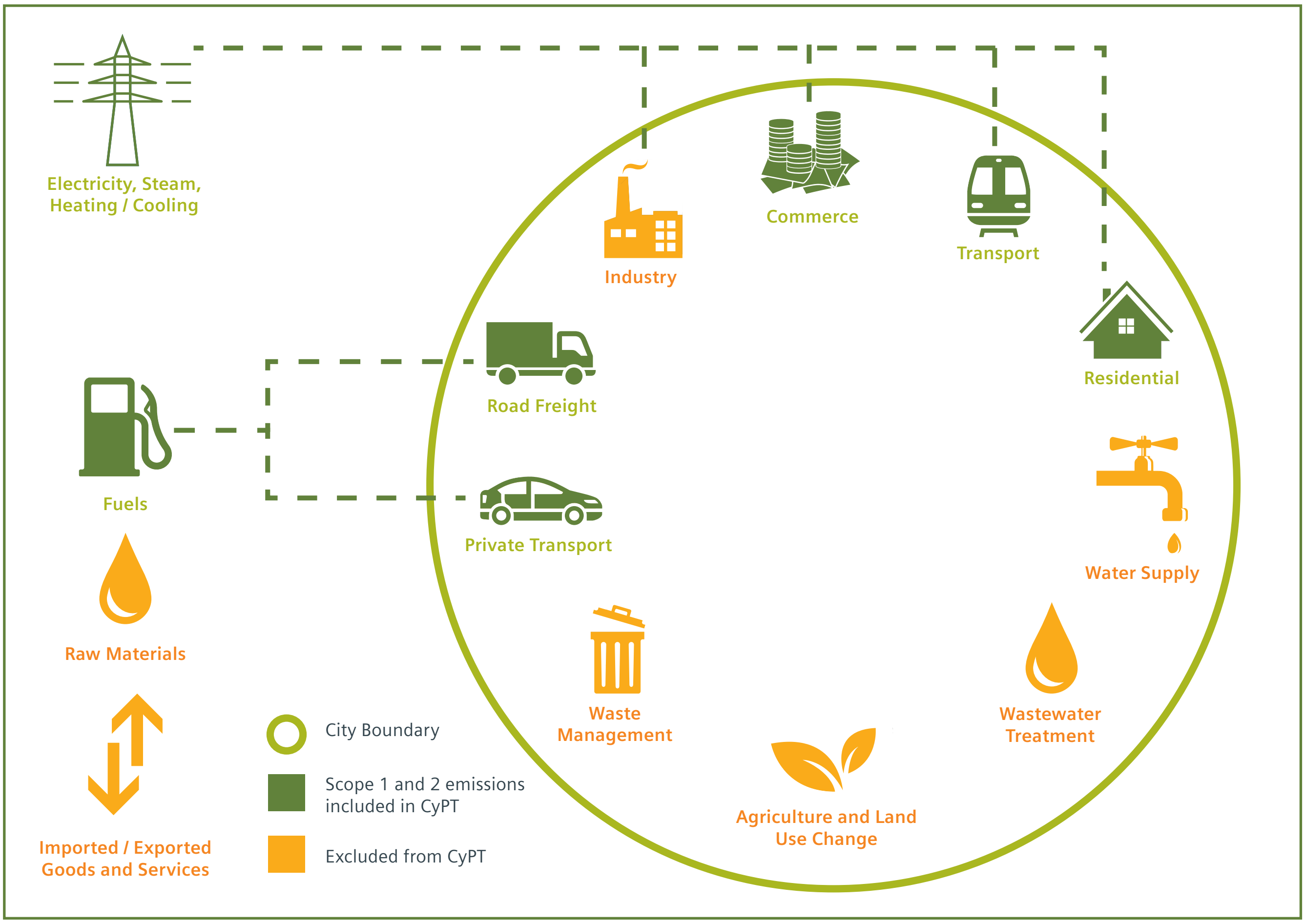
To help cities make informed infrastructure investment decisions, Siemens has developed the City Performance Tool (CyPT) that identifies which technologies from the transport, building and energy sectors best fit a city's baseline in order to mitigate CO_2eq emissions, improve air quality and add new jobs in the local economy.

The CyPT model includes the performance of over 70 technologies, allowing the City of The Hague to compare a variety of technologies and city investment projects that would ordinarily fall into management silos like transport and buildings, and never be compared against each other in a quantified manner.

The CyPT model takes over 350 inputs from The Hague's transport, energy and buildings sectors, which include the energy mix of electricity generation, transport modalities and typical energy, travel and building space demand. We refer to this as a city's energy DNA, which we split into transport and buildings energy demand (residential and commercial). How high the energy demand is and how it is split between the transport and buildings energy demand (residential and commercial). The total energy demand, and its split between the transport and buildings sectors, depends both on how people use transport and buildings, and how the city generates its electricity and heating.

After calculating the DNA, we estimate the CO_2eq emissions and other air quality measures. For The Hague, the CyPT is looking specifically at carbon reduction. The model measures the impact of technologies on the CO_2eq baselines of the city, with CO_2eq accounting at Scopes 1 and 3 levels for the building and transport sectors (Figure 1). This involves consideration of both direct emissions within the city boundaries, such as urban vehicle emissions, as well as indirect emissions from the consumption of electricity and heat produced outside the city.

The model also models the impact of each technology on two economic indicators: the total capital investment needed to deliver the technologies, and the gross number of jobs that could be created in the local economy. These include installation, operation and maintenance jobs, which are calculated as full time equivalent jobs of 1760 hours per year. Manufacturing jobs are not considered because some of these technologies may be produced outside the city's functional area, with no local benefits to the economy.



Scope 1, 2, & 3 emissions captured in this study. Icons are for indicative purposes only

Starting with the city's population, energy performance, and emissions 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., photovoltaics) and/or improving the efficiency of the current, fossil fuel, sources (e.g., Combined Cycle Gas Turbines).

2. Improved energy efficiency in buildings and transport: Replacing existing technologies with more energy efficient technologies (e.g. replacing traditional street lighting with LED and/or demand oriented street lighting).

3. Modal shift in transportation: Modeling changes in the modal split of the city (e.g. creating a new metro line to passengers away from high-emitting cars into mass transport)

The CyPT model has been used in cities such as Copenhagen, San Francisco, Vienna, London, Mexico City and Nanjing, with each city identifying infrastructure solutions that best fit their specific energy demand and production characteristics. Each of the CyPT cities are using their results in a different way. In some cases, CyPT results have become the backbone of their climate action plan, in some it answered the city's questions about the data they should collect in the future, and in others the results are being shared across city departments to better align and focus policy.

The following diagram illustrates the type of data collected in each sector and the sectors that have the most specific data points.

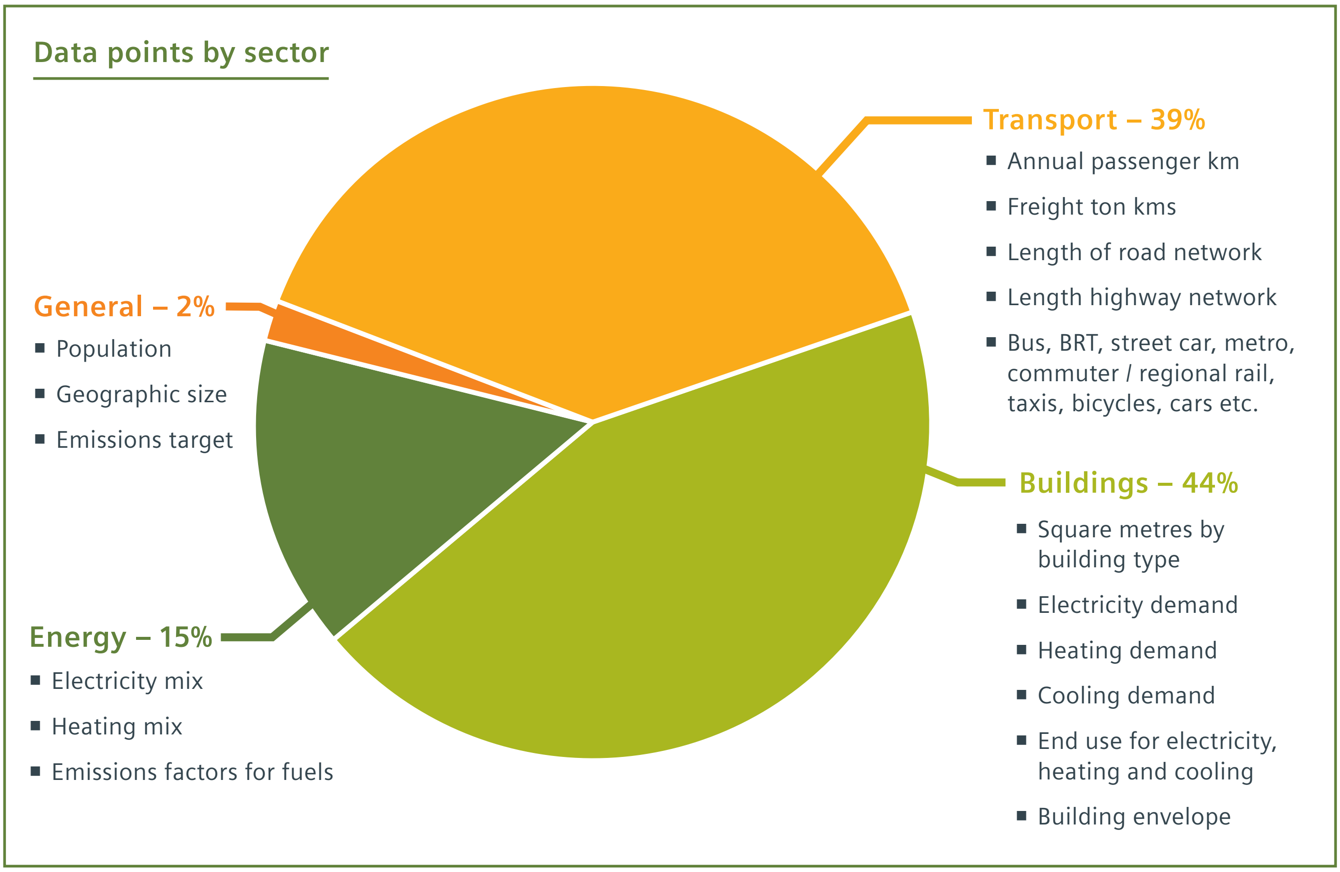


Chart 2: % of data points used in the CyPT model.

The Hague Today – CyPT Baseline (2015)

We first create an emissions baseline for today. This baseline is projected into the future, to assess the impact of technologies and model emissions scenarios for 2040, The Hague's target for carbon neutrality. The most important data points in the baseline are the fuel mixes for both heat and electricity and the modal share for transport.

Siemens has estimated that the 2015 emissions baseline for The Hague's buildings and transport sectors totals 2.6MT of CO_2. Most carbon emissions, 77%, are generated by the buildings sector. The proportion of emissions linked to buildings in The Hague is very close to that of most of the other Northern European CyPT cities, which are around 75%. Transport accounts for the remaining 23%, generated through passenger and freight transport moving around the city (see Chart 3).

Carbon emissions by sector – The Hague, 2015

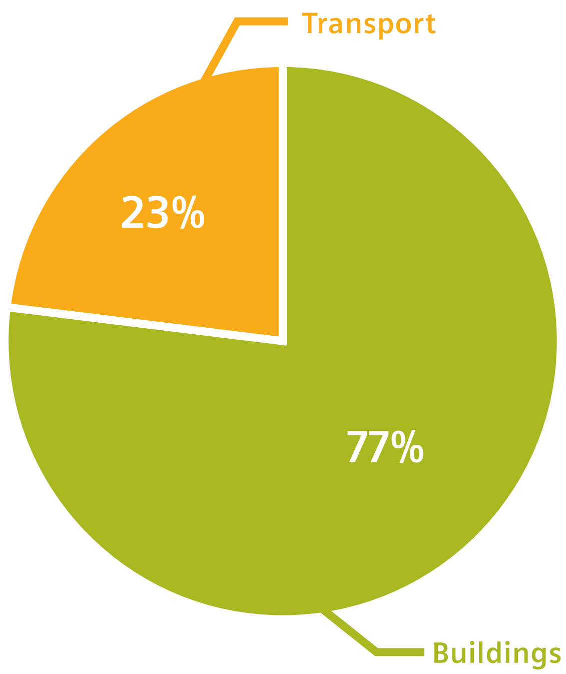


Chart 3: Carbon emissions by sector 2015

CyPT and The Hague's Carbon Scanner

The City Performance Tool has estimated that The Hague's total carbon emissions for buildings and transport in 2015 are 2.6MT. This estimation far exceeds an internal calculation of carbon emissions using The Hague's Carbon Scanner, which calculated total emissions around 1.5MT. Siemens and The Hague reviewed this analysis and determined that the same technologies performed the best using either baseline, but that the degree of savings depended upon the calculation method.

It is critical to have an agreed-upon baseline, and Siemens and The Hague further analyzed the data and methodologies to understand the differences in approach. The review identified several ways in which the two systems calculated baselines differently, including:

- The CyPT considers all three emissions scopes (1-3), whereas The Hague's carbon scanner accounts for only emissions occurring within the city: Scopes 1 & 2. Accounting for only Scopes 1 & 2 is normal in city carbon accounting, but inclusion of Scope 3 emissions related to sourcing and transportation of fuels is also important. For example, biomass sourced from overseas will have a different carbon intensity than biomass sourced locally. Reflecting this difference helps in selecting the least carbon intensive options.
- The CyPT considers the carbon equivalent impact of a wider range of greenhouse gasses.
- Differences in emissions factors used in the CyPT versus the Carbon Scanner. Generally speaking, the CyPT uses higher emissions factors for local electricity and heat.
- Data discrepancies that derive from different source numbers across different departments.

Both the City of The Hague and Siemens acknowledge these differences, and will base further discussions upon the relative impact of technologies, as opposed to the final amount of carbon savings.

Determining The Hague's Starting Position

Not all data is equal when estimating carbon and air quality emissions and reductions linked to technology. What sits behind the CyPT model is an estimation on energy used, and the source of that energy is integral to the achieved results.

The following diagrams represent some of the key data that will impact all scenario results, including the electricity and heating fuel mixes for today and in 2040, the modal share of local transport (based upon actual km travelled as opposed to journeys taken), and the specific sources of emissions today across the city.

Electricity and Heat Mixes in 2015

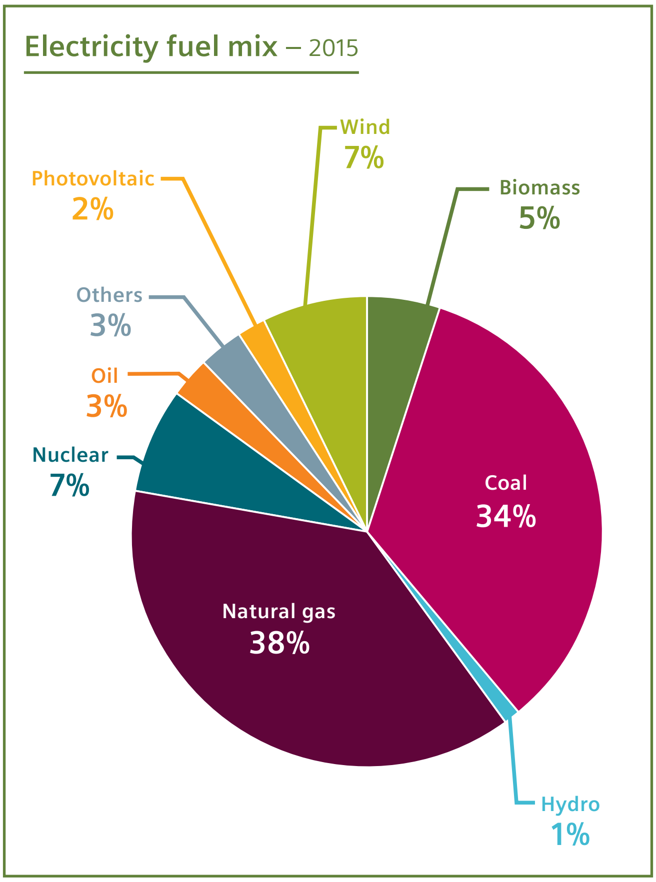


Chart 4: Electricity Fuel Mix 2015

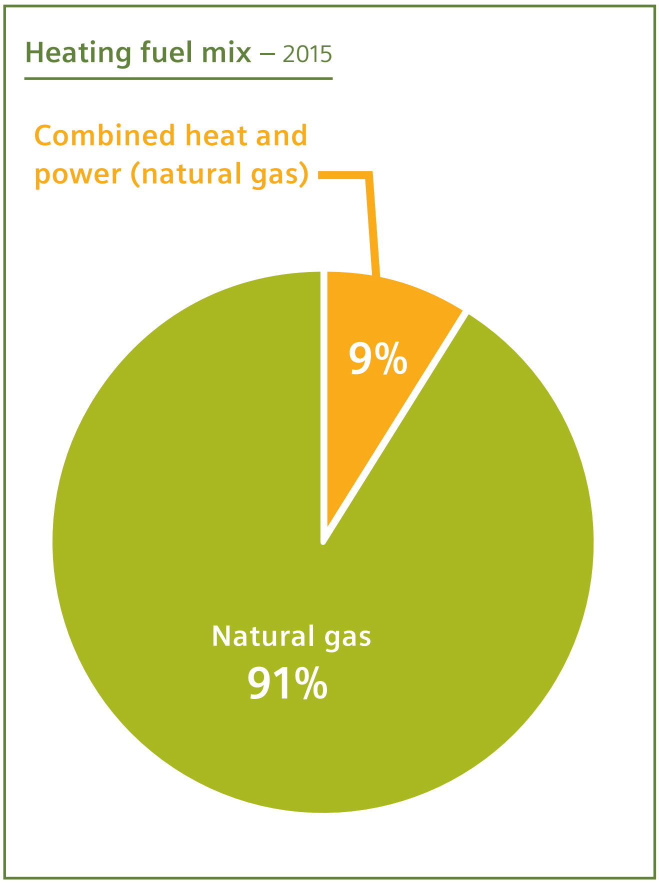


Chart 5: Heating Fuel Mix 2015

Passenger Modal Share

The Dutch are famous for their cycling culture and separated cycling lanes, and this reputation is consistent with the city's actual modal share. Cycling represents about 8% of passenger km travelled, one of the highest levels of cycling in the cities we have analyzed. However, car transport still represents 63% of passenger km travelled, as it is more likely to be used for longer distances. Chart 6 illustrates the actual modal share of The Hague, with car, train and cycling comprising about 88% of all passenger kilometers travelled.

The modal share chart, Chart 6, represents passenger km travelled, as opposed to the proportion of total journeys taken. In terms of total journeys taken, cars were only used 47% of the time, whereas bicycles comprised 28%, far more than suggested in Chart 6. It is important that we analyze the data in terms of distance travelled, because emissions are linked to the actual amount of kilometers travelled irrespective of the number of journeys.

Passenger modal share by passenger km – The Hague, 2015

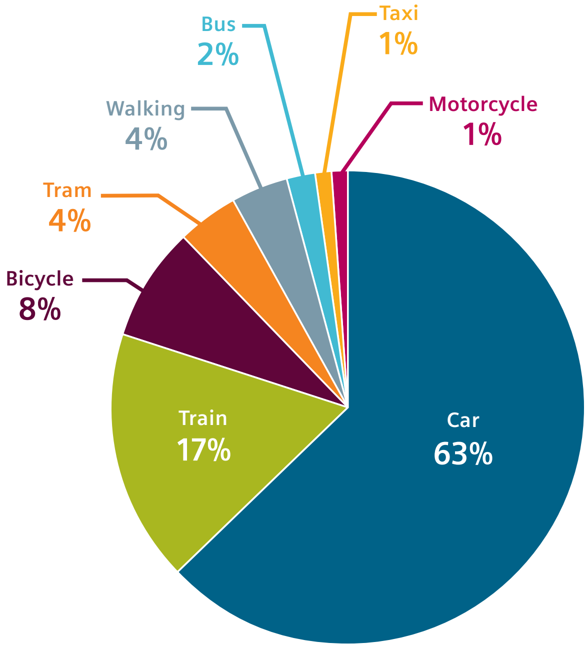


Chart 6: Passenger Modal Share by Passenger Kilometers

Sources of Carbon Emissions in The Hague Today

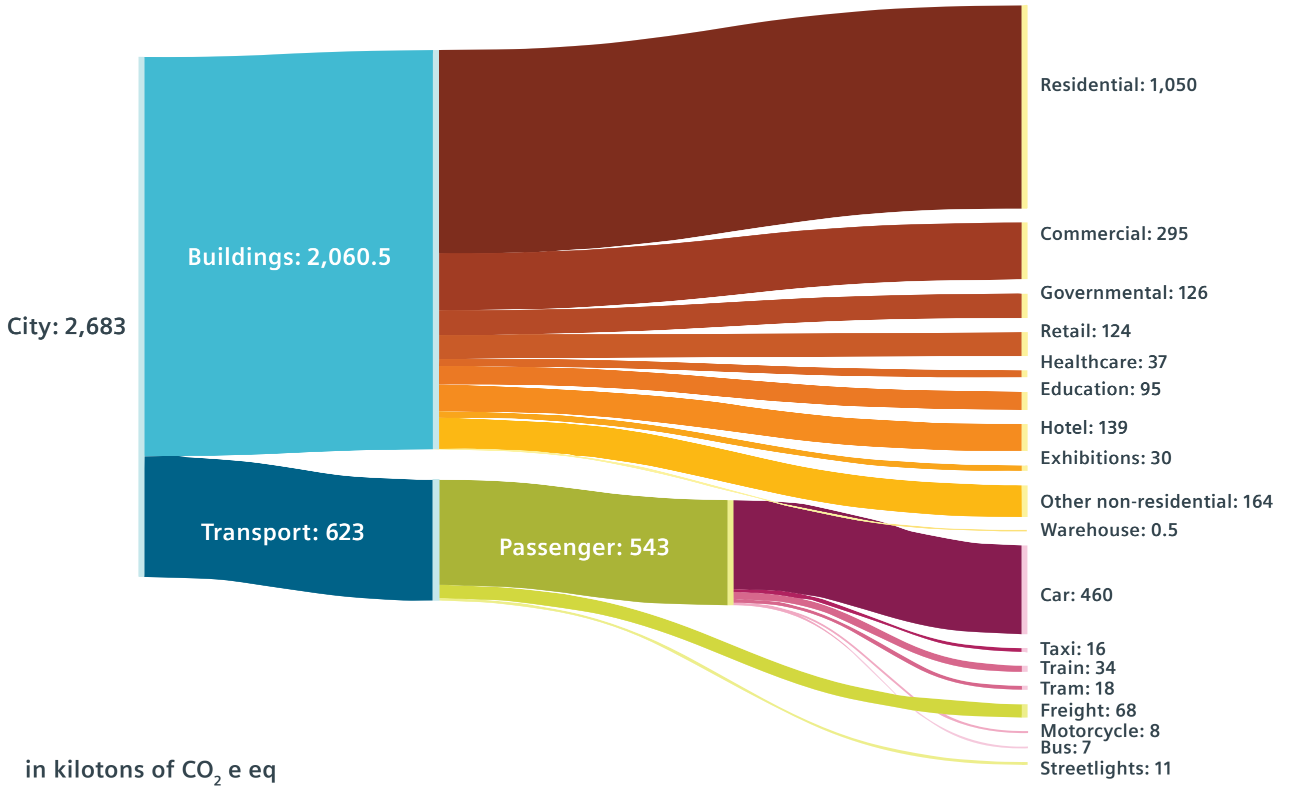


Diagram 1: Sources of Carbon Emissions in The Hague Today (2015)

The Sankey diagram for carbon emissions, Diagram 1, identifies the specific sources of The Hague's annual carbon emissions. This Sankey diagram emphasizes the specific areas where city action can reduce emissions the most. Residential buildings are by far the largest carbon emitter, followed by private, car-based transport.

Of transport-generated carbon emissions, the passenger car is by far the worst offender, accounting for 75% of total transport emissions. Freight vehicles rank second, but generate far less emissions than passenger vehicles. Public transport, train and tram produce far less total emissions, and because they are electric, they produce no local air pollution.

Air quality

The CyPT analysis considers air quality emissions in addition to carbon emissions for all three emissions scopes. Across all scopes, the majority of air pollution is linked to buildings and transport. Passenger cars are by far the largest emitters of air pollutants.

There are a number of air quality measures. For this analysis, Siemens is considering only PM_{10} and NOx on a global scale.

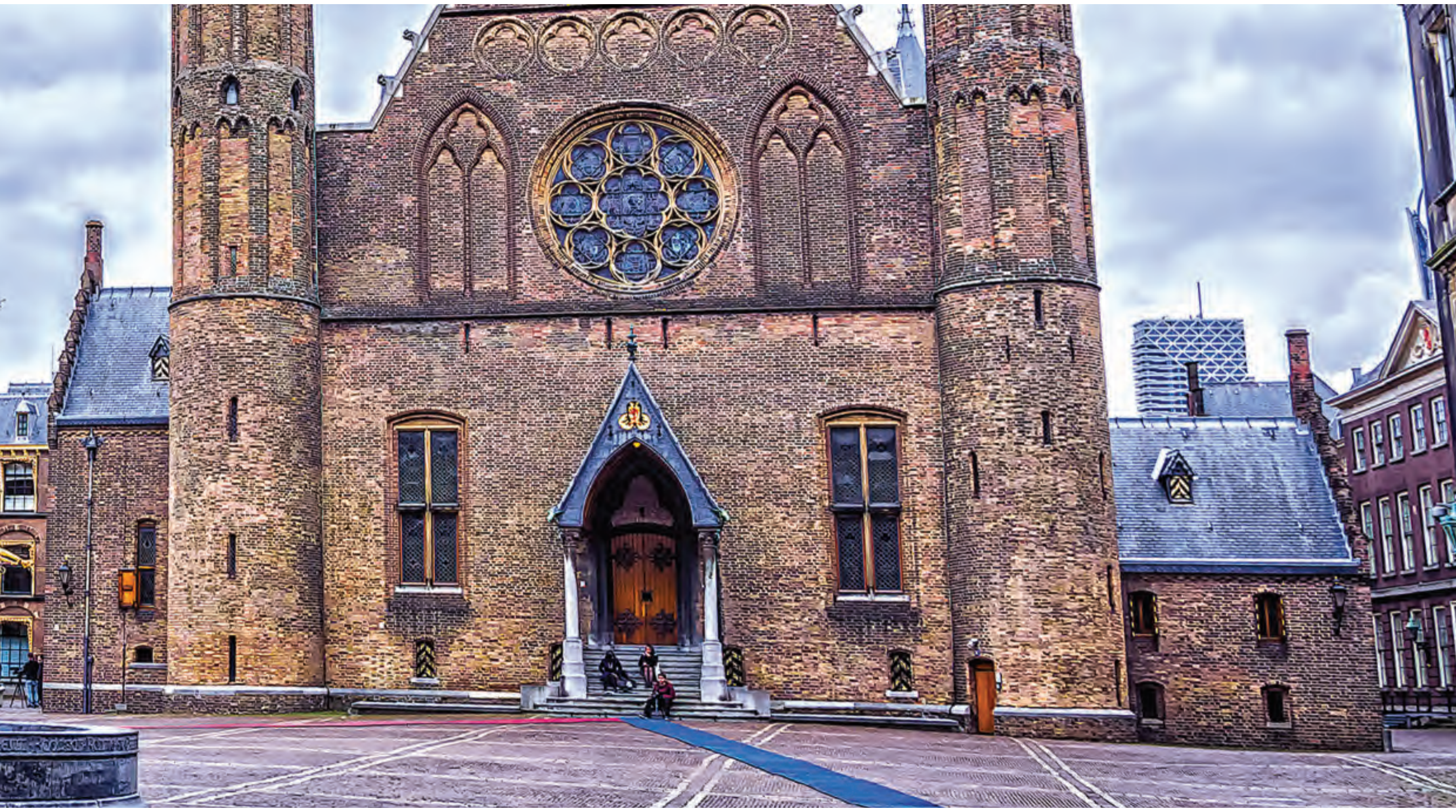
PM_{10} – represents the airborne particulate matter PM_{10} (solid and liquid particles of a very small size (<10 µm)). These small particulates are easily inhaled deeply into the lungs. The main sources of PM_{10} emissions for all scopes are road traffic (particularly diesel vehicles), residential gas-fired boilers, and centrally produced electricity.

NOx – this can describe both nitric oxide (NO) and nitrogen dioxide (NO_2). These gases are formed by a combination of oxygen and nitrogen from the air, and can damage our bronchial systems. Global NOx emissions are created from combustion of fuel in transport, industrial processes and power generation. [1]

Sources of PM_{10} Emissions in The Hague Today – 2015

The following Sankey diagram highlights the main sources of PM_{10} emissions generated by buildings and transport in The Hague. Compared the carbon emissions analysis, the sources are more evenly split. While buildings are still the largest emitters, emissions are shared more evenly across building types. Similarly, in the transport sector, freight vehicles increase in emissions relative to passenger vehicles.

[1] *www.airqualitynow.eu Pollutants of Main Concern. Sourced in November 2016.*



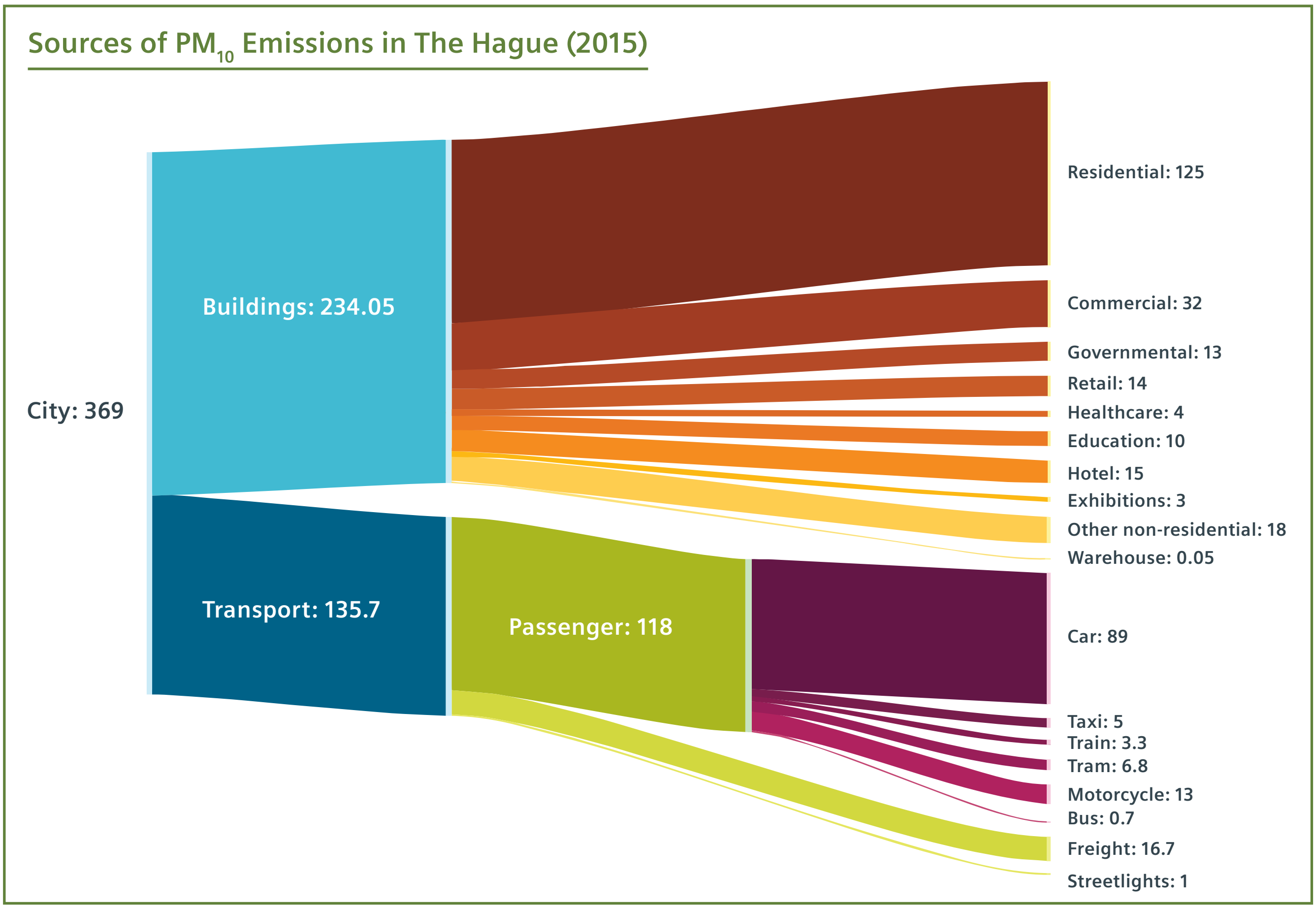


Diagram 2: Sources of PM_{10} emissions in The Hague (2015)

Developing Scenarios

CyPT Business as Usual (BAU) – Projected 2040

The Siemens CyPT team has reviewed current policies and programs with the City of The Hague to estimate a Business-As-Usual (BAU) baseline for 2040. Because The Hague's 2040 carbon-neutrality target is ten years earlier than the national and EU targets, the analysis assumes continuing significant levels of fossil fuel use. The 2040 BAU electricity mix includes more renewable sources, but still contains 40% fossil fuels. The 2040 heat mix will be the same as today, using exclusively natural gas.

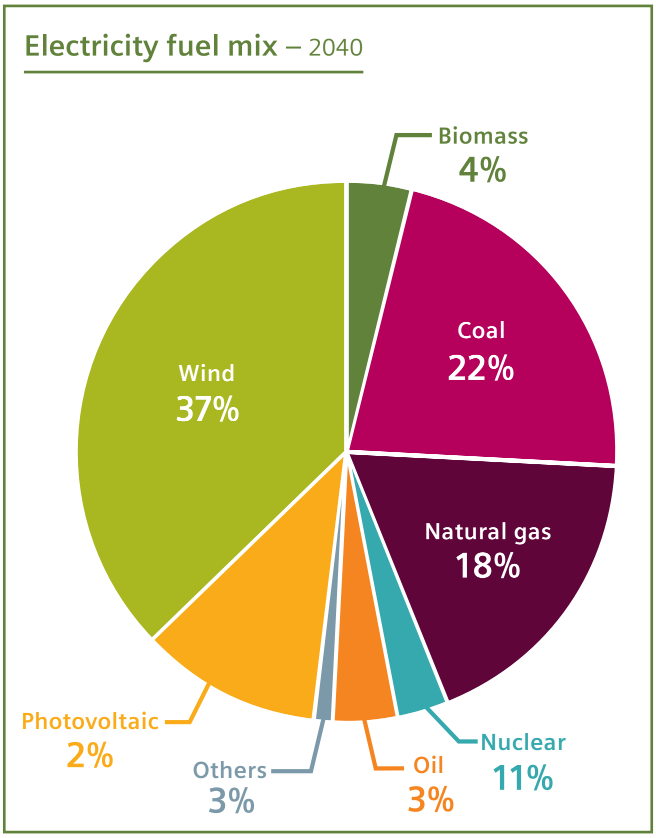


Chart 7: Electricity Fuel Mix 2040

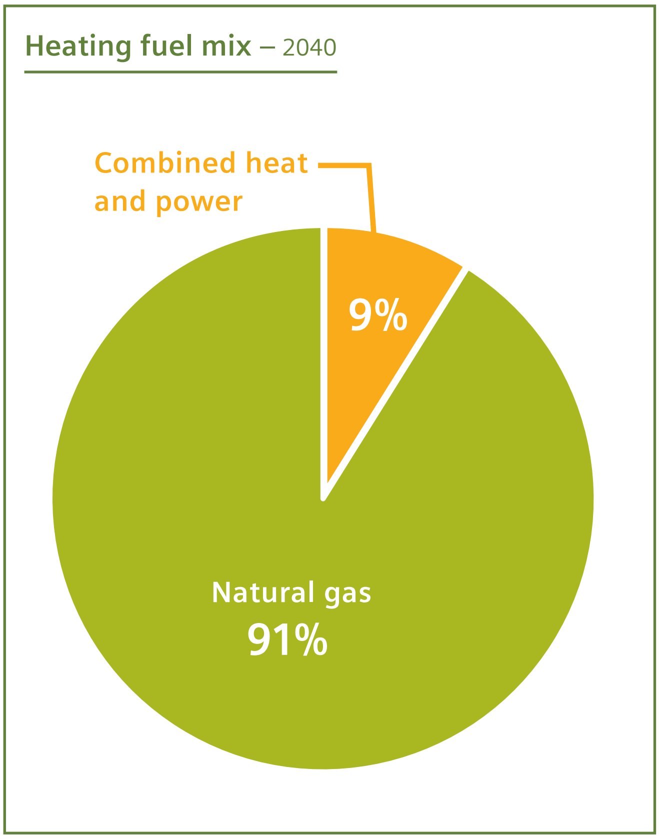


Chart 8: Heating Fuel Mix 2040

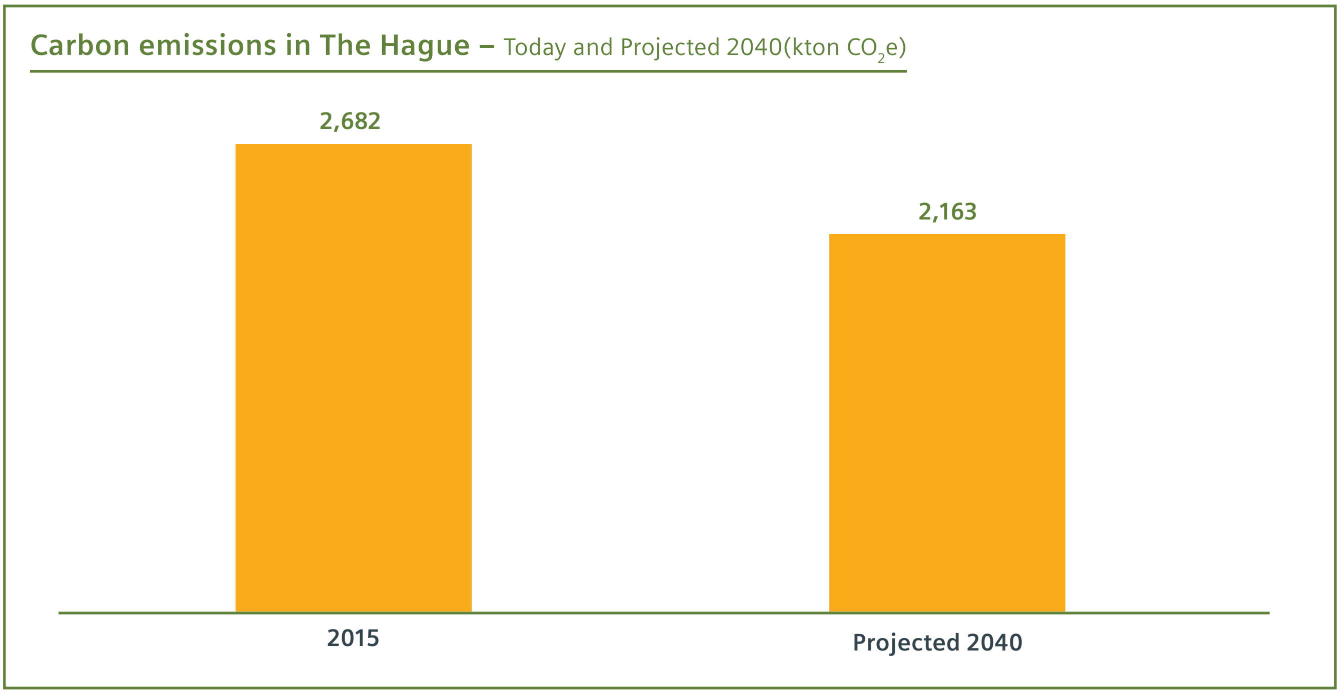


Chart 9: Carbon Emissions in The Hague Today and 2040

The diagram above highlights the difference between The Hague's current carbon emissions and the 2040 Business as Usual scenario. The estimate incorporates the most probable heat and electricity mixes, as well as already funded transport and infrastructure projects. The CyPT calculations also account for projected population growth and the resulting increase in energy demand. Without significantly changing the energy mix, the 2040 emissions levels will decrease by only 0.518 MT. This projected 2040 scenario is the baseline for the CyPT analysis. All carbon savings from technologies will be subtracted from this baseline, based on the year implemented, to determine how The Hague can achieve its carbon neutrality target.

The City of The Hague also wishes to test a more positive scenario, with more deliberate action to clean both the electricity and heat mixes. This mix would require far bolder actions than appear in plans today. These more positive mixes are referred to as the Ideal mix, and their composition is illustrated overleaf in Charts 10 and 11.

The Ideal heat and electricity mixes that The Hague believes are possible are less carbon intensive, but still retain some fossil fuels. The Ideal electricity mix still utilizes natural gas, but there is no coal and substantially more wind and photovoltaic power. The Ideal heat mix illustrates a significant shift away from natural gas to biomass and geothermal heat generation through a heat network as well as the use of electric, air source heat pumps.

Chart 12 illustrates the significance of the energy mixes. If The Hague only delivered the ideal heat and electricity mixes, and buildings were retrofitted to utilize this heat, the city would reduce its emissions by 56%.

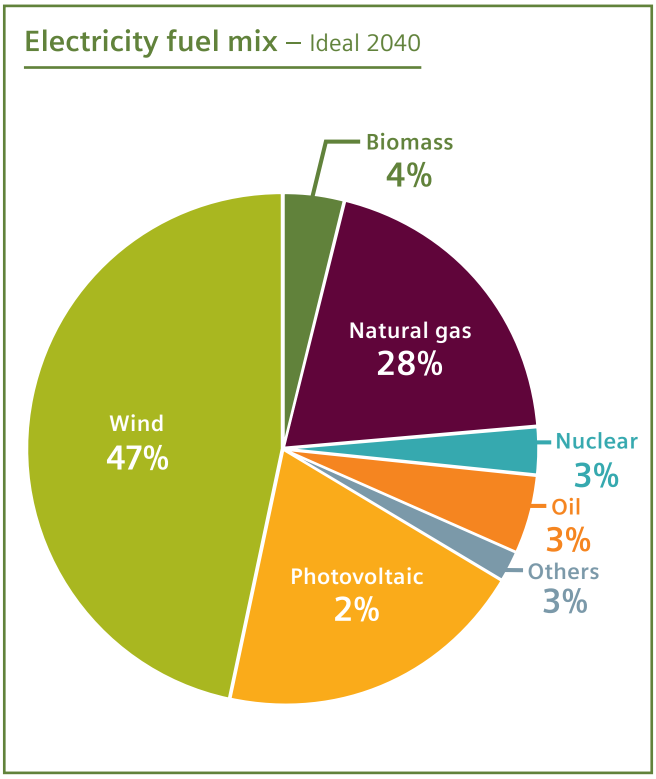


Chart 10: Electricity Fuel Mix Ideal – 2040

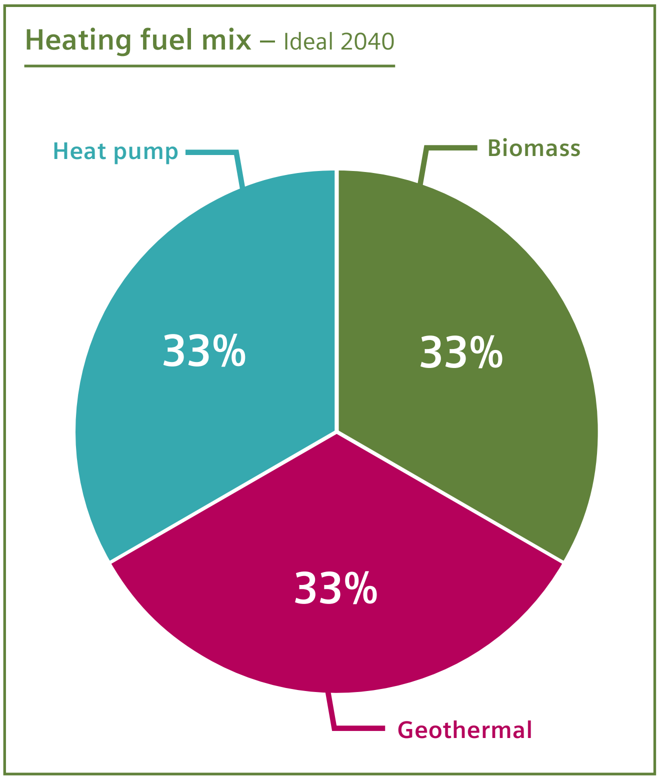


Chart 11: Heating Fuel Mix Ideal – 2040

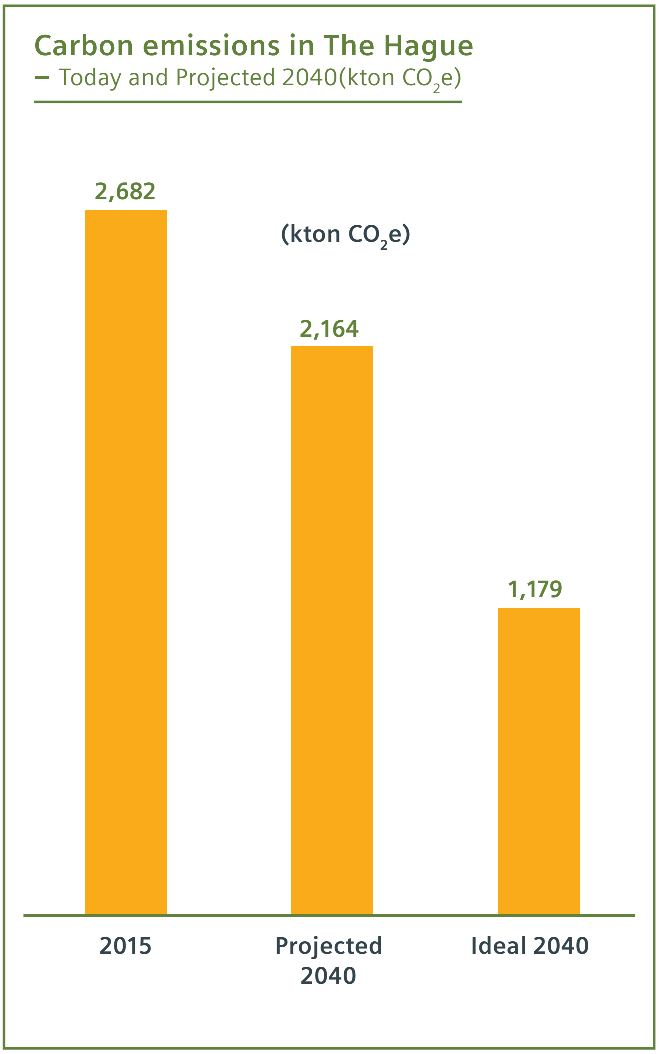


Chart 12: Carbon Emissions in The Hague Today and 2040

The CyPT model calculates impact based on emissions factors, and the relative cleanliness of emissions factors is a key determinant of when it is environmentally sensible to switch, for example, from a fossil fuel based source to an electric source. The diagram below illustrates the emissions factors for both electricity and heat for today, Projected 2040 and the Ideal 2040.

The Projected electricity mix for 2040 significantly decreases the use of coal, and the Ideal mix eliminates it entirely. This is the main driver of emissions reductions in both scenarios. Both also scale back the use of natural gas, replacing it with wind power. Wind power generation is expected to increase by 30% from today, to represent an additional 10% of total generation supply.

The heat mix is not expected to radically shift in the projected 2040 BAU baseline. Heating infrastructure is more difficult to change, particularly when private homes require retrofit. However, the Ideal mix does assume a significant change in heat generation and delivery. If a potential upcoming change in gas supply would already require retrofitting individual boilers and homes, this provides an opportunity for simultaneous broader fuel change. The Ideal mix also incorporates district heating networks, which would utilize geothermal power.

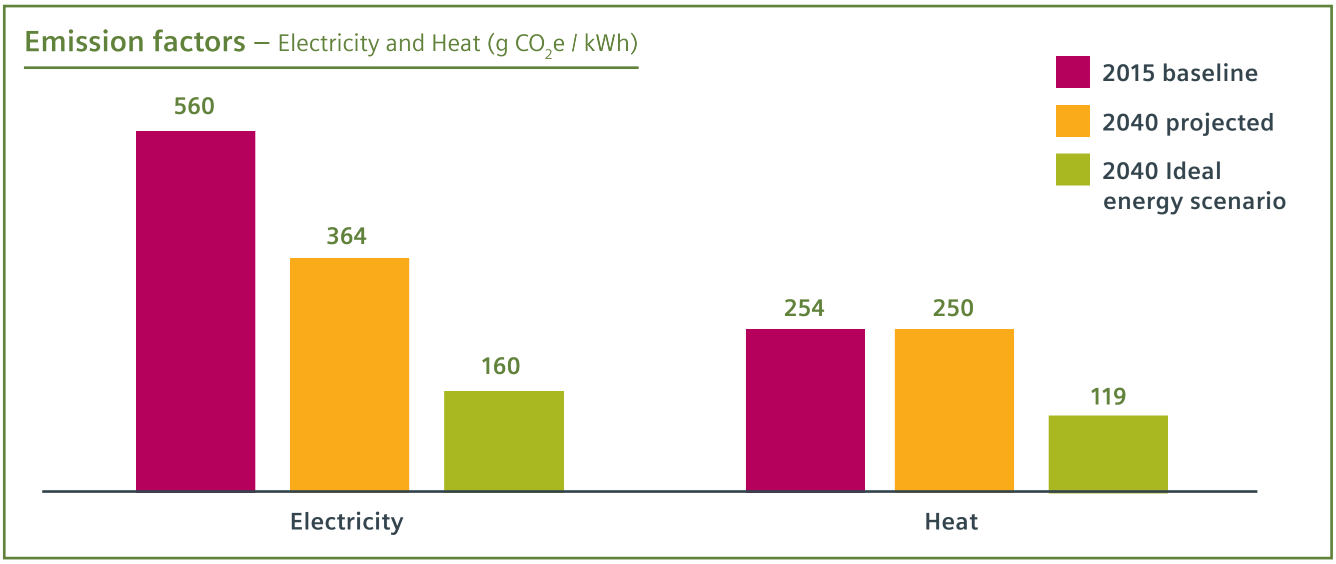


Chart 13: Emission Factors: Electricity and Heat

The relative emissions chart shows that today's heating systems produce relatively less emissions than today's electricity systems. If we only consider today's emissions and BAU 2040, Siemens would advise The Hague to focus on technologies that reduced electricity demand.

However, the two systems are linked. Decarbonizing the electricity mix would enable more sustainable electric generation of heat. Also, since appliances using electricity tend to be more efficient than those using combustion, electric appliances will generate less emissions than combustion appliances even before the electricity grid is emission-neutral.

The Ideal heat mix assumes that roughly 2/3 of the heat would be generated by electric heat pumps (air source) and geothermal sources. The remaining 1/3 of heat would be sourced from burning biomass. Based on this combination of improved electricity mix, biomass, geothermal, and potentially even residual heat, future heat generation could produce significantly less carbon emissions.

However, the electricity or heat mixes would be climate neutral. Therefore, for best results, The Hague could combine these mixes with energy demand reduction strategies, as highlighted in the following sections.

Buildings

Despite buildings being the largest carbon emitters, an increasing population, and growing demand for floorspace, The Hague still expects overall building emissions reductions. These reductions are expected to result from building improvements and cleaner energy mixes. The City of The Hague has targets to reduce building electricity consumption by 20% and heat by 14% in 2020.

The Government of The Netherlands has passed very progressive legislation. It has required the implementation of specific efficiency-enhancing retrofits that have short repayment periods of 3-6.5 years. In addition, there is pending legislation that could mandate that all commercial buildings achieve a Label C in energy efficiency by 2023, with some exceptions for historic or very small offices. If enforced, such legislation would theoretically spur many projects and significantly speed building retrofit. However, actual delivery of these projects is assumed to be far lower.

Absent any legislation, the model assumes that a baseline 1% of buildings per year would be renovated with technologies to improve their efficiency. Thus, by 2040, 25% of buildings in The Hague would have such improvements. Any new legislation would increase this normally-occurring building renewal rate.

Transport

Considerable efforts are being made by both The City of The Hague and The Government of The Netherlands to support cleaner transport. The City of The Hague is delivering a new fleet of electric, low-emission tram vehicles. Furthermore, significant efforts have been made to incentivize a market shift towards electric vehicles, through agreements to supply charging points and additional electricity infrastructure.

Scenarios

Siemens and The Hague have identified four key technology bundles, which will be combined into scenarios to illustrate their possible impacts. The four technology packages are outlined overleaf in Table 1.

Solution	Description	Examples
1. Buildings Mandated	Implementing the already-mandated building retrofit projects that have a defined, short repayment period.	▪ Heat recovery ▪ Building Automation ▪ Demand-oriented LED lighting
2. Transport Planned	Implementing the already-approved short-term transport upgrades and technologies.	▪ New metro vehicles ▪ New tram vehicles ▪ Low emission bus and taxi fleet ▪ Car-sharing
3. Buildings Plus and Transport Plus	Implementing additional building and transport technologies that extend beyond the remit of the city.	▪ Cleaner private vehicles ▪ City Tolling
4. Ideal Energy	Delivering cleaner electricity and heat mixes, through cooperation with utilities and national policy decision-makers.	▪ Replace coal with wind power and photovoltaics ▪ Replace gas with biomass, heat pumps and geothermal

Table 1: Scenario Descriptions

Specific technology implementation rates are described in pages 36 – 45.

These technology packages are then incorporated into scenarios that our team has combined to show the incremental benefits that can be achieved by taking certain actions. The four scenarios are described below:

Scenario 1	Scenario 2	Scenario 3	Scenario 4
Building mandated	Building mandated	Buildings Plus	Buildings Plus
	Transport planned	Transport Plus	Transport Plus
		Building mandated	Building mandated
		Transport planned	Transport planned
			Ideal Energy

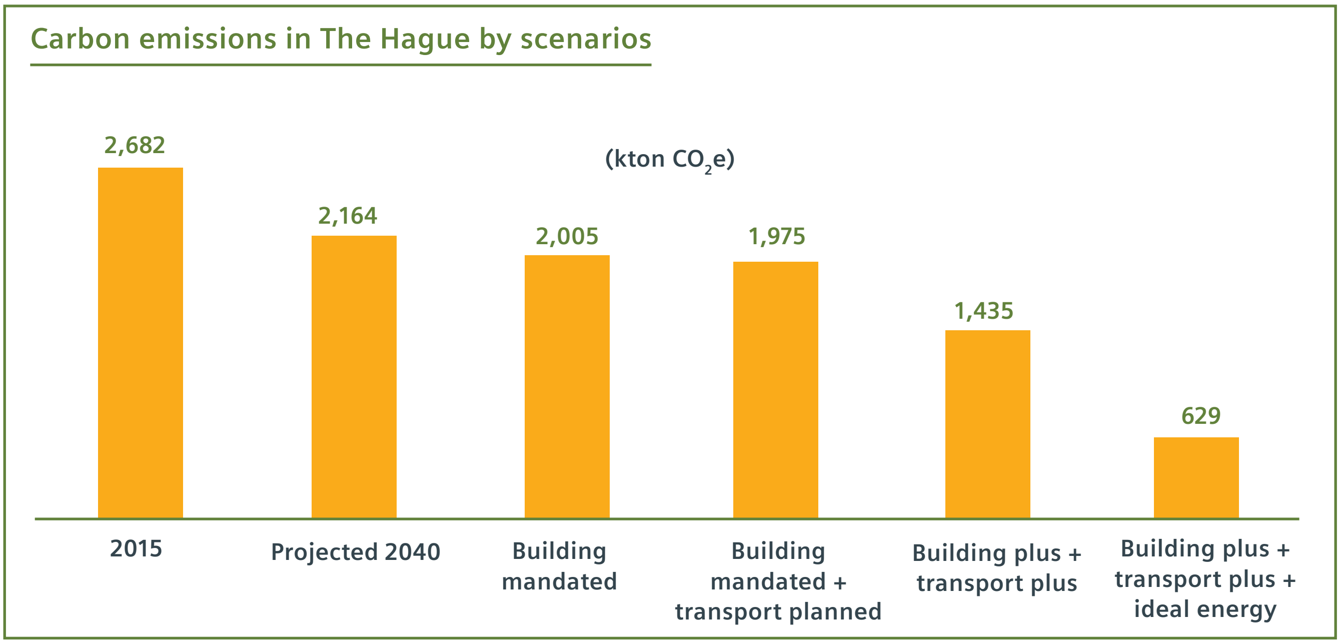


Chart 14: Carbon Emissions in The Hague by Scenario

Scenario 4 has the greatest impact. It incorporates all of the technology bundles and utilizes the Ideal energy mixes. However, even in this scenario, there remain approximately 600,000 kt of emissions. These result primarily from continuing fossil fuels usage, an effect of the time gap between The Hague's 2040 carbon-neutrality target and The Netherlands' 2050 carbon-neutrality target. Residual emissions also result from the analysis' assumption that sustainable technology take-up will not reach 100%. This leave scope for further technology implementation.

The CyPT analysis also estimates the local job creation potential of each scenario. These estimates reflect the local direct and indirect employment potential, but exclude jobs linked to manufacturing of any materials. The large, longer-term infrastructure works such as a new metro line deliver the most potential jobs. eCar charging point installation and wall insulation also performed very well. These three types of projects create jobs with very different skill levels and requirements. In terms of jobs per Euro spent, the top-performing technologies have a strong local service element, such as eCar-sharing or bike sharing.

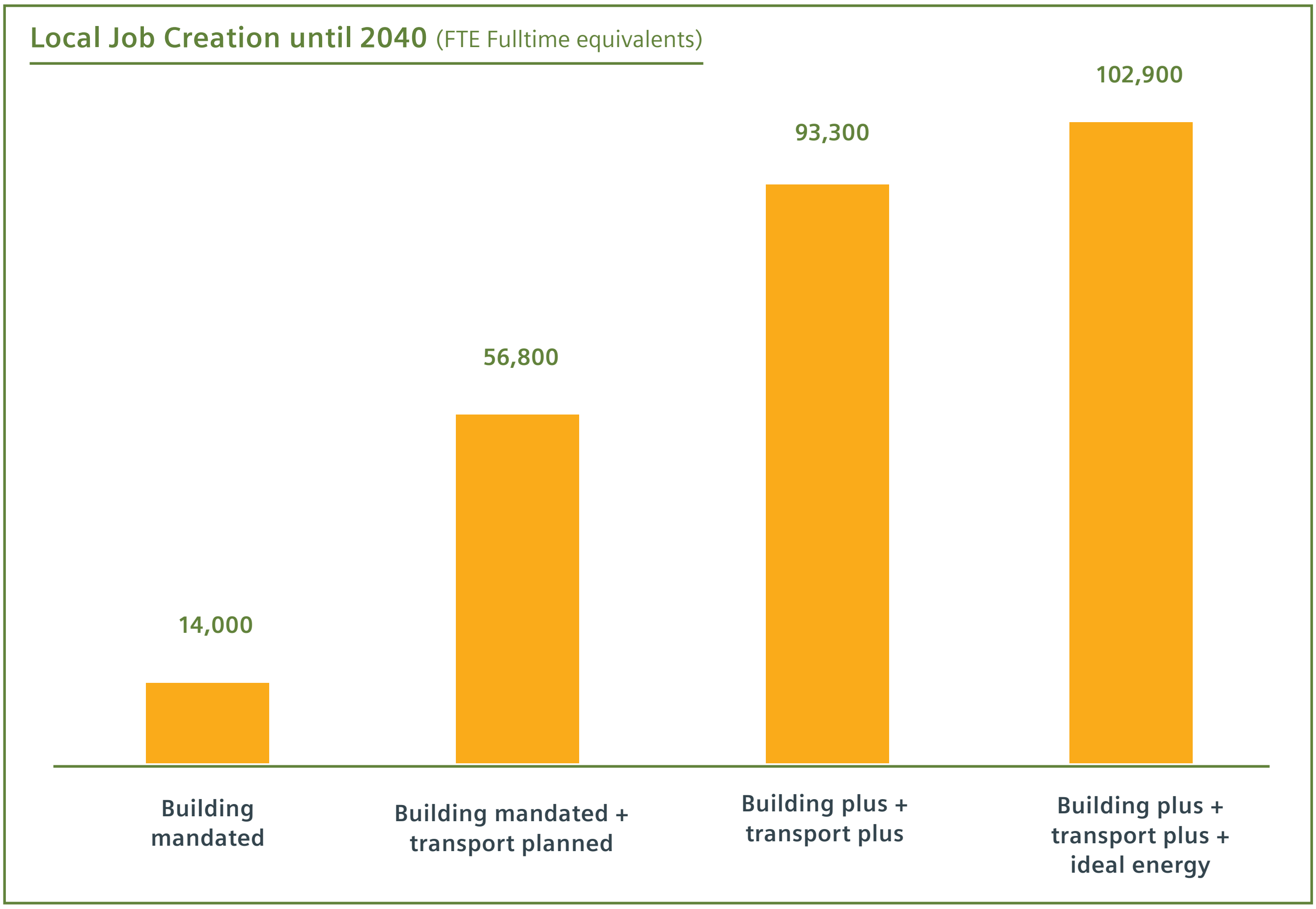


Chart 15: Local Job Creation

The quality and skills levels of the employment are also of critical importance. The CyPT model includes assumptions about the relative skills levels of jobs associated with particular technologies. The categories include a local, low-skilled job, a technical, skilled job, and a highly-skilled job. In the case of the technologies selected by The Hague, the relative proportion of skills levels does change by scenario, as described following.

Buildings Mandated

- Low-skilled, local jobs: 15%
- Technical-skilled jobs: 78%
- High-skilled jobs: 6%

In the Buildings Mandated scenario, improvements to the building envelope, windows and insulation generate the most jobs. The majority of this employment would be a mix of low- and technical-skilled jobs. Building automation delivers more highly-skilled jobs.

Building Mandated and Transport Planned

- Low-skilled, local jobs: 34%
- Technical-skilled jobs: 40%
- High-skilled jobs: 26%

The jobs in the Buildings Mandated and Transport Planned scenario require a more even balance of skill levels. The additional technologies in this scenario include a new tram line, new metro, low emission buses and taxis, and car sharing. More of these technologies would have a digital component than in the buildings only scenario.

Building Plus and Transport Plus

- Low-skilled, local job: 44%
- Technical-skilled job: 37%
- High-skilled job: 20%

The Buildings Plus and Transport Plus scenario builds on the previous scenarios and includes cleaner private vehicles and city tolling. Specific technologies impacting the skills balance include alternative fuel cars.

Overall, the technologies that create the most jobs include:

Non-Residential Buildings

- Wall insulation
- Heat recovery
- Building Automation

Residential Buildings

- Wall insulation

Transport

- New tram and metro lines
- Electric and hydrogen cars
- E-car sharing

Scenario 1: Buildings Mandated – focusing on Non Residential Buildings

This initial, non-residential only buildings scenario is the easiest to deliver because it requires only the implementation of already-mandated technologies and retrofits. Currently, the national building legislation We Milieubeheer/Laws of Environmental Conservation requires commercial building owners to implement specific efficiency-enhancing retrofits that have short repayment periods of 3-6.5 years. These specific measures are detailed in the appendices of this report (Appendix III), and include room heating and ventilation improvements and upgrades to indoor and outdoor lighting. Several of these technologies are included within the CyPT, including insulation, efficient and demand oriented lighting and heating and ventilation improvements through the use of Building Automation and Controls Systems – Grade C (BACS). Table 2 specifies implementation rates used in the analysis. It is assumed that these technologies use the BAU 2040 energy mixes. There could be further high-level support for increasing the number of commercial building upgrades, as proposed legislation would require all non-residential buildings to achieve a minimum energy performance certification of 'C.' Additionally, building owners could choose to implement a higher performing building management system (Grades A and B) and further improve building performance.

Building lever	Unit	Annual Implementation	Implementation by 2040
Demand-oriented lighting	Non-residential building stock	3%	75%
Heat recovery	Non-residential building stock	3%	75%
Efficient lighting	Non-residential building stock	3%	75%
Wall Insulation	Non-residential building stock	3%	75%
BACS C	Non-residential building stock	3%	75%
Efficient Motors	Non-residential building stock	3%	75%

Table 2: Technologies and Implementation Rates for Scenario: Buildings Mandated

The CyPT considers additional wall insulation both in terms of the impact of the stand-alone technology, and as a benchmark for analyzing the impact of other technologies. The CyPT does not specifically test roof or other forms of insulation because the overall impact is the same – a savings of heat energy. Thus, in this context, they are interchangeable technologies.

The impact of the mandated buildings scenario is about 150,000 kt of CO_2e, all derived through measures that make economic sense to implement. This savings is not huge when compared to the overall challenge, but is a good result given its relative ease of implementation and the ongoing level of fossil fuels in the energy mix today and in 2040.

Scenario 2: Transport Planned

This scenario incorporates many of the transport technologies that the city is already considering or committed to delivering, including new and cleaner trams, eBuses and a new tram line. The specific technologies are detailed in Table 3.

Lever	Unit	Business as Usual 2040	Implementation by 2040
Electric buses	fleet	0%	100%
Metro – new line	new line(s)	0	1
Electric taxis	car fleet	0%	100%
Electric car sharing	cars/1000 inhabitants	0	3
Tram – New vehicles	fleet	0%	70%
Tram – Automated Train Operation (ATO)	lines	0%	10%
Cycle highway (Sternet)	km/100.000 inhabitants	0.6	10
Public Transport – eTicketing	users	90%	100%

Table 3: Technologies and Implementation Rates for Scenario: Transport Planned

This is a small incremental change for two reasons because The Hague either has or will be delivering the emissions reductions within its authority to deliver, and private cars, the largest single source of transport related emissions, are not targeted within this scenario.

Compared to Scenario 1, Scenario 2 offers more incremental changes, for two reasons. First, Scenario 1 already incorporated The Hague's large amount of planned or delivered emissions reduction. This small

improvement between Scenarios 1 and 2 is a positive sign, indicating that The Hague has already successfully selected and implemented the most impactful single technologies. For example, The Hague has already decided to provide efficient, electrically driver trams and eTicketing. Furthermore, cycle lanes are already a part of the local transport system and increasing these is already a local standard. The second reason for the small gap is that Scenario 2 does not target private cars, which are the largest single source of transport related emissions.

One area with high potential for improvement is the electrification of the local taxi fleet. Today, the taxi fleet is comprised of typical petrol vehicles. Because these vehicles travel more than private cars, reductions in emissions per km travelled make a relatively larger impact. Beyond these emissions reductions, electrifying the taxi fleet signals to private car owners that the city is taking visible steps to improve air quality.

Delivering eBuses is a similarly visible signal to residents that the city is serious about improving air quality and reducing carbon emissions. In The Hague, their current CNG buses are already cleaner than typical diesel buses. However, since they still use fossil fuels, their continued operation would remain a barrier to carbon neutrality.

The city could further boost the impact of these technologies by increasing utilization rates of buses and trams. Today, the utilization rates over a 24 hour period are relatively low, though peak periods seem very busy. The overall utilization rate is used to determine future impact of a new tram or metro line. Accordingly, the city should consider how to boost off-peak tram and bus use, such as by improving service or penalizing driving with a congestion charge, road tax, or increased parking charge. A congestion toll is analyzed in the next scenario (Scenario 3), which considers technology options linked to reducing the emissions of private, car-based transport.

Scenario 3: Building Plus and Transport Plus

This scenario assumes that by 2040, 75% of residential units not only utilize home automation and efficient lighting systems, but also are well insulated. These residential technologies are the most cost effective for carbon savings. The individual results of these technologies are highlighted in the buildings results table on page 46.

To achieve a high uptake of both building technologies and traditional upgrades like insulation, some policy support will be needed. For residents outside small group of early adopters of home automation, The Hague could consider incorporating home automation within local building codes for new homes or major renovations. In existing buildings, The Hague may also consider including some automation technologies within existing insulation programs.

The transport levers in Scenario 3 address the largest transport carbon emitter: private Cars. It assumes a 70% take-up of alternative fuel cars. This requires a large increase from the assumed 0.1% take-up in the BAU 2040, but it is necessary for the city to reach its 2040 climate neutrality target.

The technologies in these key scenarios are included in the following tables 4 and 5. Each proposed technology or technology bundle, such as Home Automation, is described in more detail within Appendix 2.

Building Plus

Building lever	Unit	Annual Implementation	Implementation by 2040
Wall Insulation	Residential building stock	3%	75%
Home Automation	Residential building stock	3%	75%
Efficient lighting	Residential building stock	3%	75%

Table 4: Technologies and Implementation Rates for Scenario: Buildings Plus

Transport Plus

Lever	Unit	2015 Fleet Share or Standard	Implementation by 2040
Electric cars	car fleet	0.1%	50%
Hydrogen cars	car fleet	0%	50%
Intermodal traffic management	users	0%	30%
Lorries/Trucks - Low emission zone	minimum EURO class	EURO 2	EURO 6
Car & Motorcycle - City tolling	road traffic reduction	0%	30%

Table 5: Technologies and Implementation Rates for Scenario: Transport Plus

This scenario targets private sector transport, since the second 'Planned Transport' scenario already addressed transport technologies that the city can deliver. This scenario provides an additional 540,000 kt of carbon savings. This is the largest single scenario savings. However, impact is limited by the remaining fossil fuels in the electricity mix. In this scenario, it is cleaner to run both fossil-fuel and alternative fuel vehicles in 2040 when compared to today, but an even cleaner electricity mix would increase the positive impact. In 2040, if the Ideal energy scenario were achieved, driving an electric vehicle would be roughly 260% better than today. Some indirect emissions would remain, but eCars would not produce any exhaust emissions, significantly improving local air quality. The following section includes details of relative vehicle performance.

City tolling is the single most impactful way that The Hague can reduce car journeys and shift travelers to public transport. In this analysis, we have assumed that city tolling has been implemented, reduced car pkm (passenger kilometers) travelled, and shifted car users to public transport and bicycles. This 30% shift of private vehicles would translate into a 50% demand increase of pkm for public transport. The relatively low utilization of public transport from the Planned Transport scenario would essentially double (tram 25%, regional train 46% and bus 28%). The existing system could support this increased use at most times, but accommodating peak hours would likely require investment in new trams, bus lines, or automated shuttles and vehicles.

Low Emission Zones are described here as requiring a EURO 6 standard, but could run at any standard using the on number plate recognition software. Currently, battery powered eTrucks are not commercially available. However, it is possible that by 2040 these technologies will exist. The Hague would need to be part of a wider regional or national program to ensure that high capacity chargers will be available within the city for freight trucks, cars and buses. Today, there is a technology for hybrid electric/diesel freight trucks, the eHighway, which is powered through catenary lines. This system is currently operating on the E16 highway in Sweden, and is under development at the Port of Los Angeles, USA.

This scenario is particularly important because it demonstrates the benefits of engaging the wider public. They could be persuaded to choose low-carbon travel by incentive to drive eCars or by disincentives to drive within the city center. A disincentive, such as city tolling, should be complemented with benefits such as new buses or cycle lanes that speed people's journeys, or free Wi-Fi on public transport.

Scenario 4: Ideal Energy – Buildings and Transport Plus

This scenario includes the same technologies as scenario 3, at the same implementation rate, but uses the Ideal, electricity mix. This scenario has by far the most positive impact. The CyPT estimated a total carbon reduction of 77% compared to 2015 and a 71% reduction compared to the 2040 BAU scenario. In this scenario, In this scenario, the buildings have been retrofitted to use less electricity and heat, drivers are using electric or alternative fuel vehicles, and both the electricity and heat mixes are the significantly cleaner Ideal mixes.

Relative Emissions Factors of Passenger Vehicles

A critical question for The Hague is when to incentivize electric cars or other alternative fuel vehicles. The first decision is selecting an emphasis on reducing overall carbon emissions, improving local air quality, or both. The second question is when the electricity mix will be clean enough for eCars to reduce emissions more than other strategies.

In response to the first question, if local air quality is a critical issue then eCars or other local zero emissions technologies such as hydrogen cars should be immediately delivered to improve the well-being of residents. However, if the priority is overall carbon reductions, the answer is more complex. The two critical points are the relative emissions factors of each technology and their relative cost per unit of carbon saved. Chart 16 highlights the relative emissions factors and the cost per unit of carbon saved in the following pages.

It shows that today, a single car owner would reduce their emissions by 40% by switching from a petrol vehicle to an electric vehicle. Our calculations assume that all electricity is sourced from the national grid. Our modeling indirectly penalizes hydrogen-fueled vehicles because creating hydrogen for fuel requires an additional energy transformation, increasing the vehicle's overall energy consumed per mile. However, generating hydrogen as a waste by-product or from a fully renewable source, would significantly decrease its carbon intensity.

In 2040, because of the cleaner electricity mix, the eCar offers a carbon performance that is 66% better than its petrol equivalent. In this 2040 Projected scenario, the improved electricity mix also means that hydrogen vehicles out-perform petrol and diesel vehicles. However, the most significant gains for both eCars and hydrogen cars occur with the Ideal electricity mix. In this 2040 Ideal Energy scenario, the eCar reduces carbon emissions by 83% compared to a petrol vehicle, and hydrogen vehicles produce a 63% reduction.

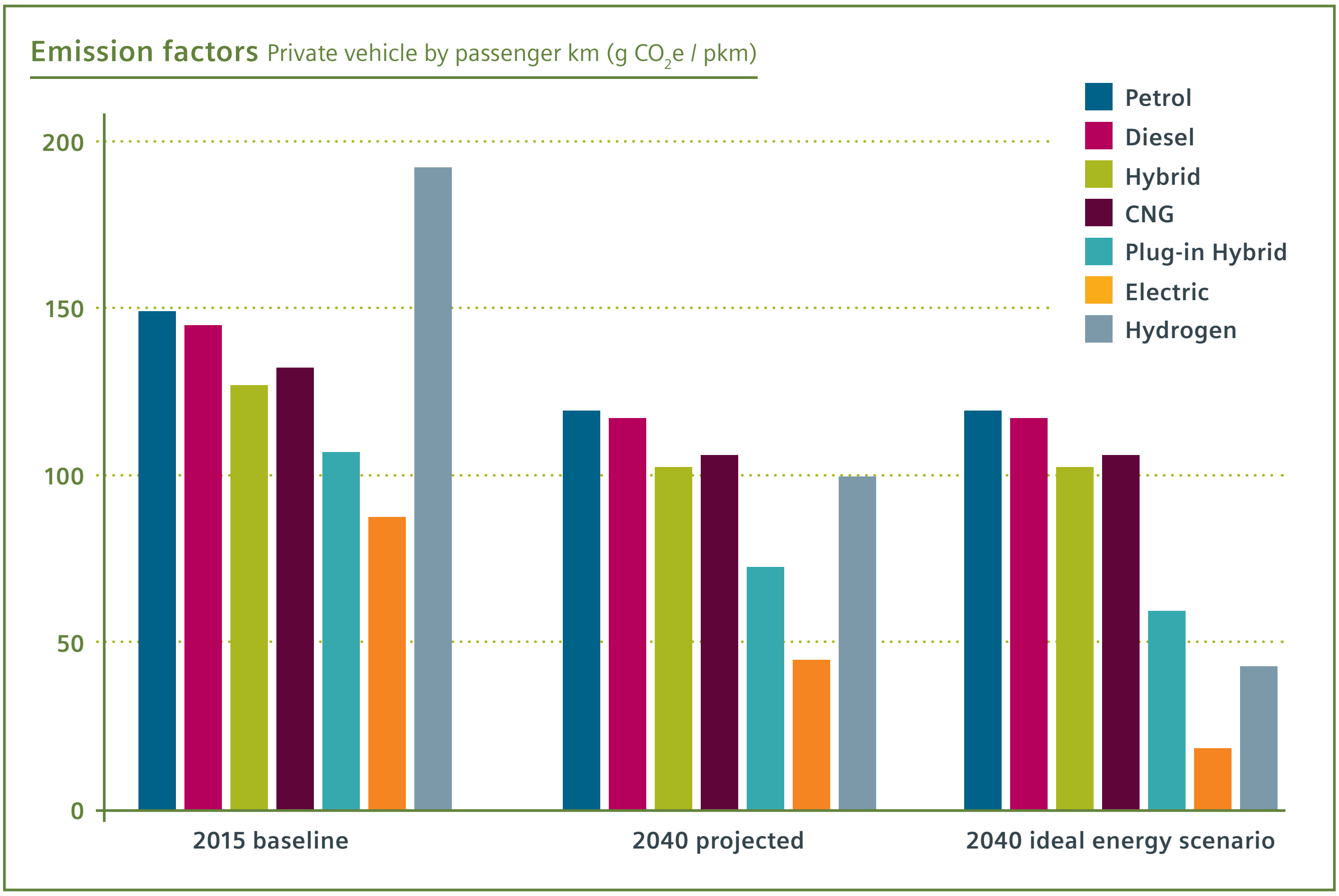


Chart 16: Emission Factors for Private Vehicles Today and 2040

Individual Technology Results

It is important that all technologies are evaluated on both their ability to reduce carbon emissions and their relative cost. The following tables illustrate both the carbon or air emissions reductions relative to cost.

Building technologies

Building Carbon Reduction and Cost Efficiency

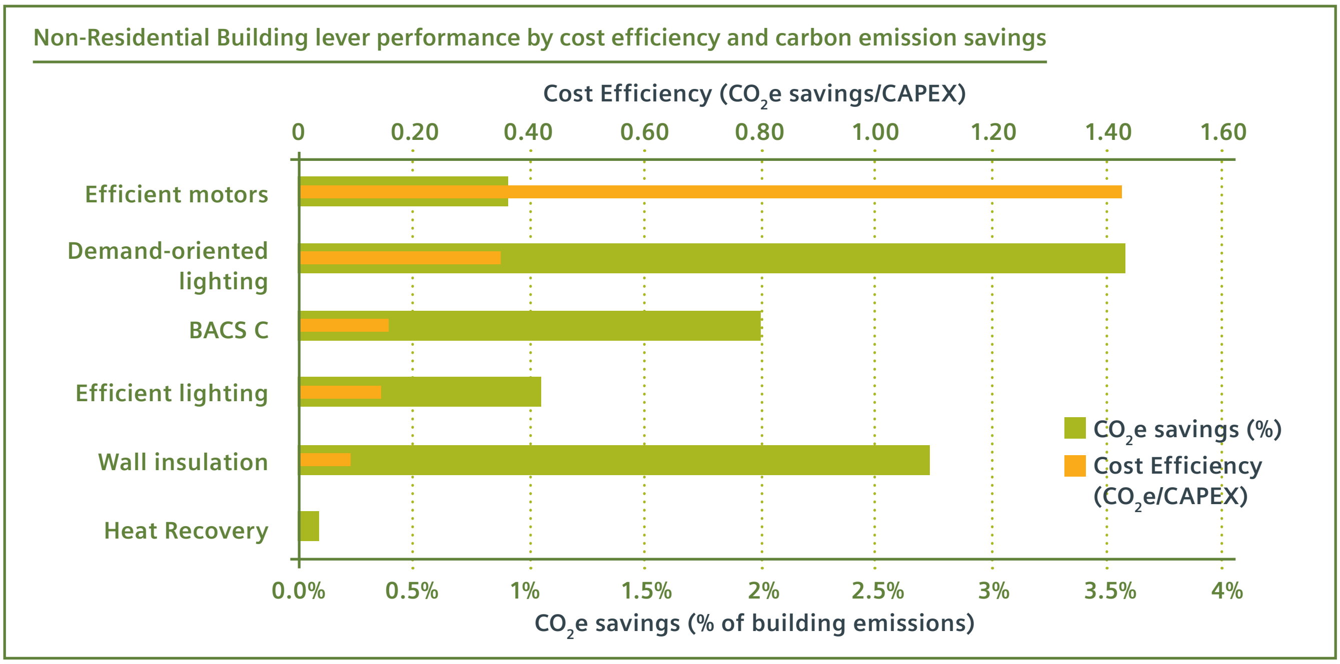


Chart 17: Building Lever Performance: Non-Residential Buildings

The most cost-effective carbon-saving building technologies are improved motors in commercial building heating, cooling and ventilation systems. The next most impactful technologies are more efficient lighting technologies, including the use of LED lights, and demand oriented lighting with occupancy sensors in commercial buildings. The efficient motors and drives are cost effective because they are relatively inexpensive and target the current electricity mix, which has a large proportion of coal and fossil fuels.

Residential Building lever performance by cost efficiency and carbon emission savings

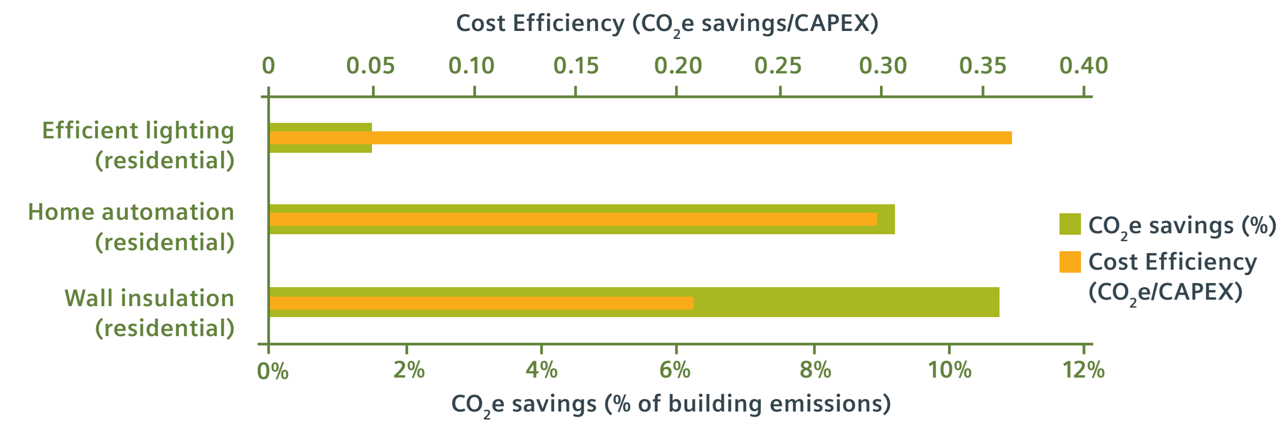


Chart 18: Building Lever Performance: Residential Buildings

In residential buildings, the three highest-performing technologies were efficient lighting, home automation and wall insulation. Home automation yielded the most balanced results in terms of CO_2eq savings and relative cost.

On a city level, residential technologies offer greater emissions savings potential, because they occupy roughly double the total area of non-residential buildings.

Building Technology Air Quality Impact

The CyPT analysis also considers air quality emissions – PM_{10} and NOx, in both non-residential and residential buildings.

The following chart for PM_{10} emissions in Non-Residential buildings is very similar to the previous findings for carbon emissions. Thus, electricity-saving lighting and ventilation improvements performed as well as heat-saving wall insulation.

It is important to consider the local air quality element, as heating is likely to generate the only direct emissions in the city. However, because the heat mix is cleaner than the electricity mix, electricity use reduction has a larger impact.

Non-Residential Building lever performance by cost efficiency and PM_{10} emission savings

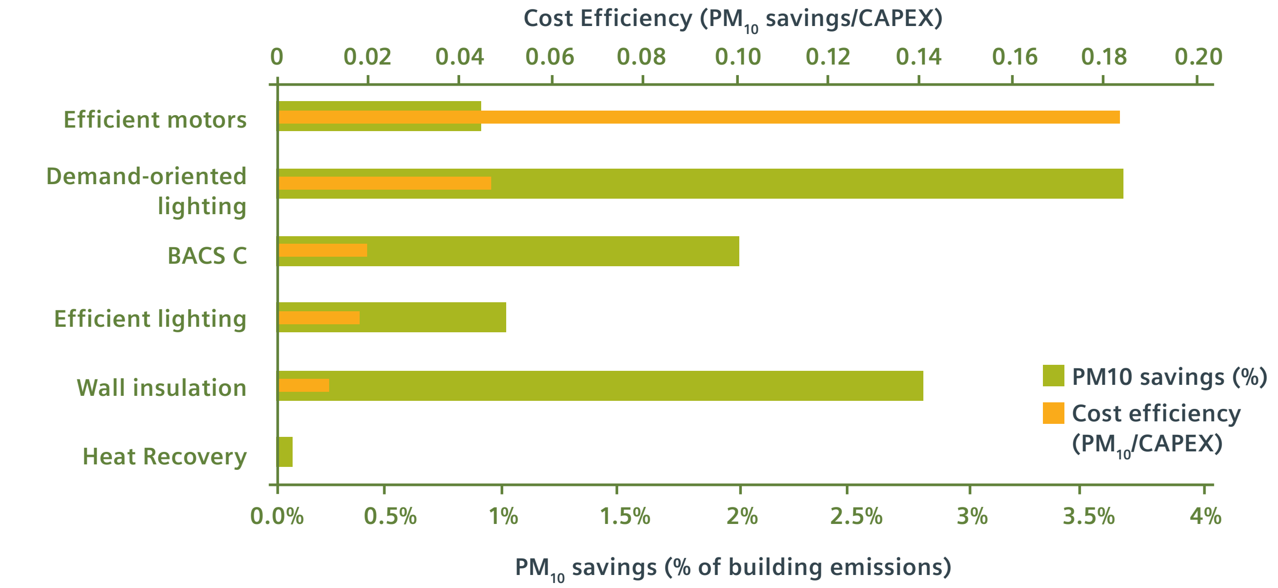


Chart 19: Air Quality PM_{10} Building Lever Performance: Non-Residential Buildings

PM_{10} savings in residential buildings follows a similar pattern to carbon emissions. In this analysis, lighting upgrades are the most cost efficient, and home automation provides the most balanced result. Wall insulation would deliver the most actual PM_{10} savings.

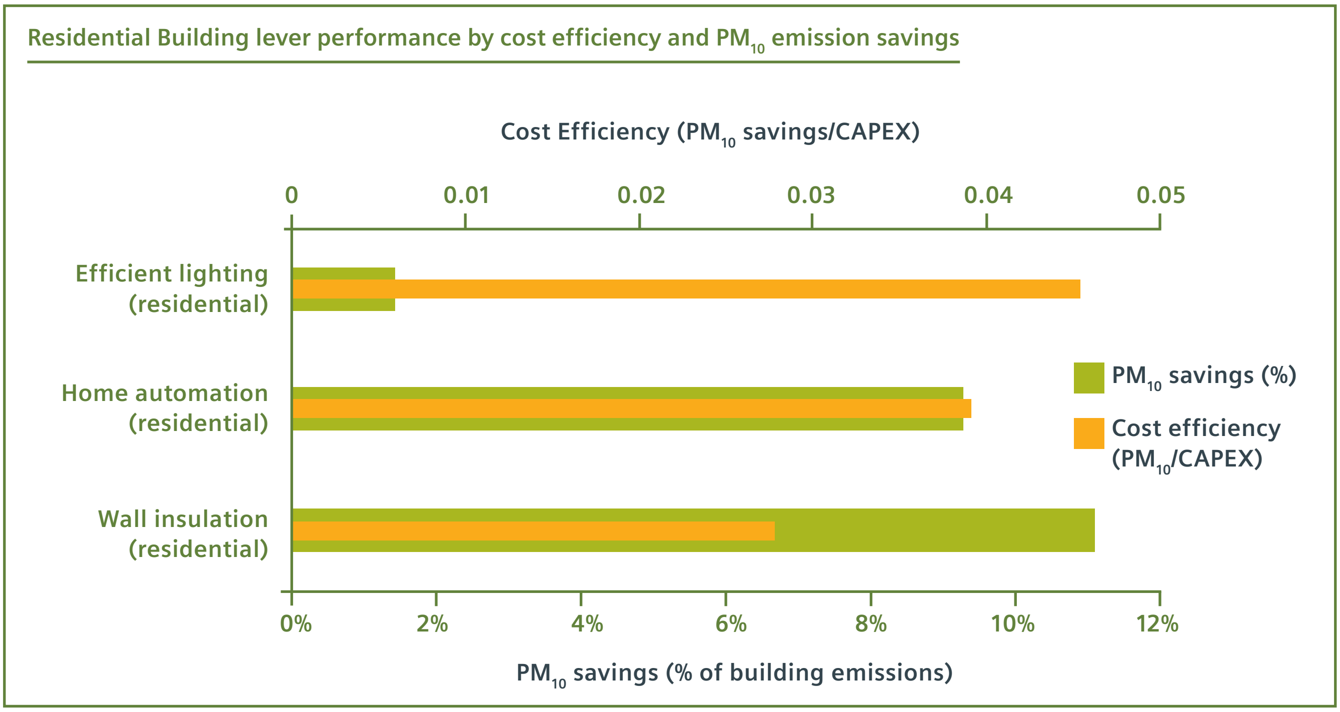


Chart 20: Air Quality PM_{10} Building Lever Performance: Residential Buildings

The results for NOx savings are different, as building automation in commercial buildings or home automation in residential buildings reduces this emission far more significantly than wall insulation. Efficient motors and drives and lighting technologies are still most cost-effective, mirroring the results for carbon and PM_{10}.

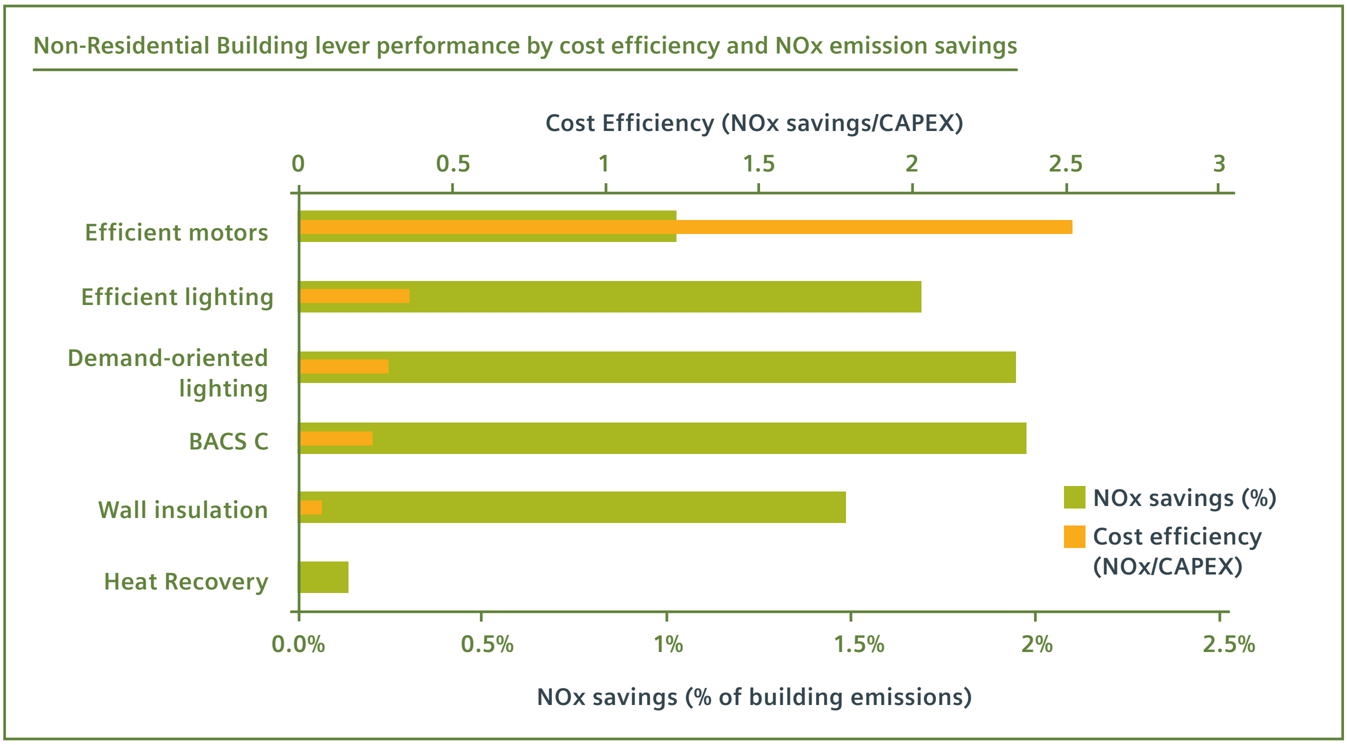


Chart 21: Air Quality NOx Building Lever Performance: Non-Residential Buildings

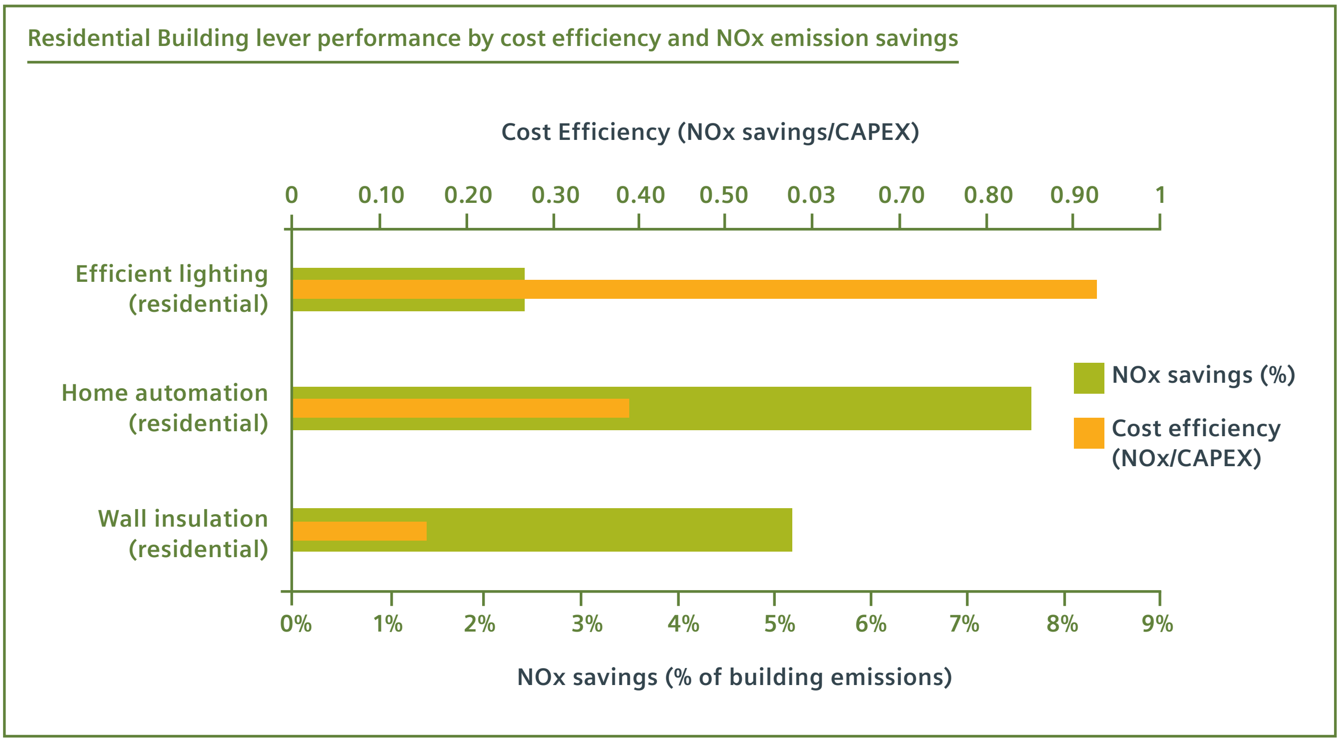


Chart 22: Air Quality NOx Building Lever Performance: Residential Buildings

Transport technologies

The CyPT analysis considered the potential for additional, new public- and private-sector transport technologies to reduce CO_2eq, PM_{10}, and NOx emissions. The CyPT analysis also considers the relative impact of alternative fuel buses and private cars powered by the national electricity grid mix.

Public transport

The CyPT analysis measured the impact of several transport technologies that fall within The Hague's remit, including city tolling, e-ticketing, low emission bus and taxi fleets, a new metro line, a low emission zone, e-car sharing, and cycle lines.

Carbon reduction

The technologies that deliver the largest overall emissions reduction are city tolling, eCar sharing, cycle highways, eTaxi and eBus. The city tolling lever is also the most cost effective, so it performs best on both measure by a large margin. eTaxi, cycle highways and eCar sharing deliver the next best performance for cost efficiency.

Implementing city tolling alone could reduce The Hague's car use enough to decrease transport-based carbon emissions by 23%. eCar sharing, the next best carbon reduction technology, has a potential impact just above 5%. Some cities with city tolling schemes implemented them in conjunction public transport improvements, to ensure a viable alternative to driving.

Maximizing the carbon reduction potential of larger initiatives, such as a new metro or tram line, requires the city to incentivize public transport and increase ridership during off-peak hours. Technologies that promote public transport use include e-ticketing, city tolling, and intermodal trip-planning apps.

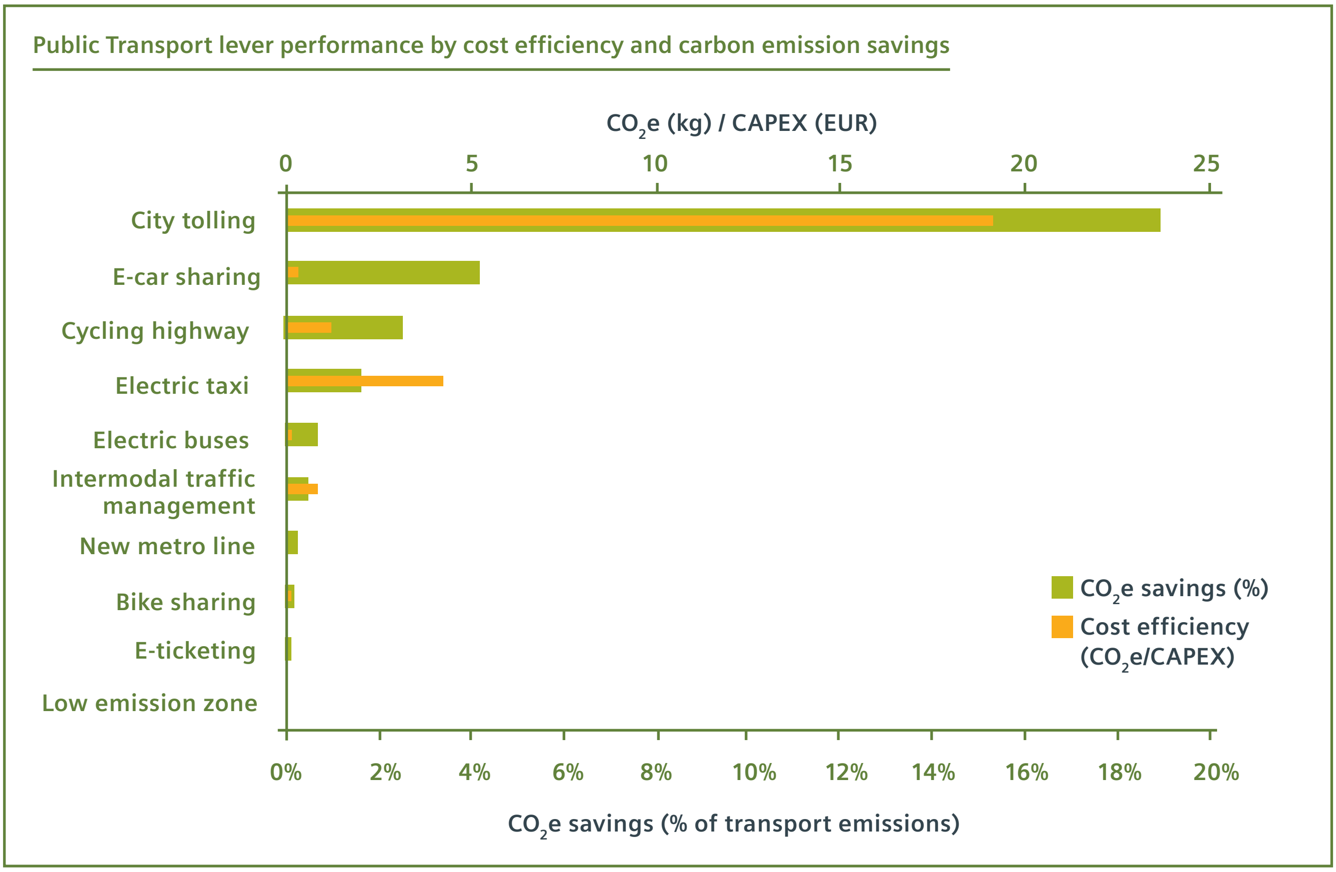


Chart 23: Public Transport CO_2 Lever Performance

PM_{10} Reduction

The most effective technologies for reducing PM_{10} were also city tolling, eTaxis, and cycle highways, with the addition of the Intermodal Transport App. City tolling again had the largest carbon emissions reductions, because it reduces overall use of both diesel- and petrol-fueled cars. The Intermodal transport app shifts residents towards public transport, also reducing emissions from car use. eTaxis again perform well because the electricity mix is still cleaner than diesel fuel. A low-emission zone for trucks would no longer have a significant effect by 2040, as the emissions of truck fleets would decrease by then.

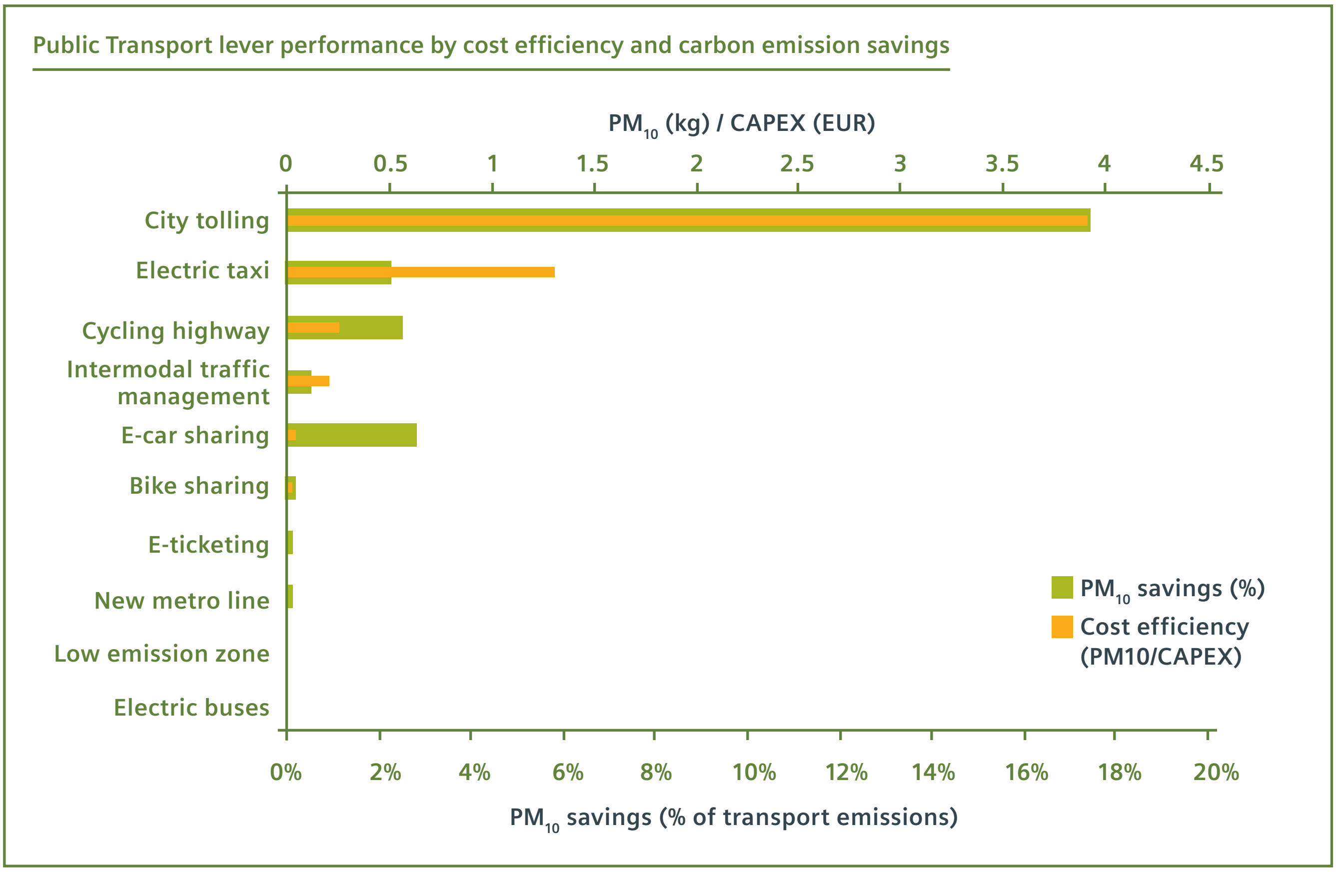


Chart 24: Public Transport PM_{10} Lever Performance

NOx Reductions

The technologies that most reduce NOx are again similar to those for carbon and PM_{10}. Again, reducing car use with city tolling is most effective and most cost-efficient. The eTaxi and eCar sharing are also impactful, jointly reducing transport-related NOx by more than 6%.

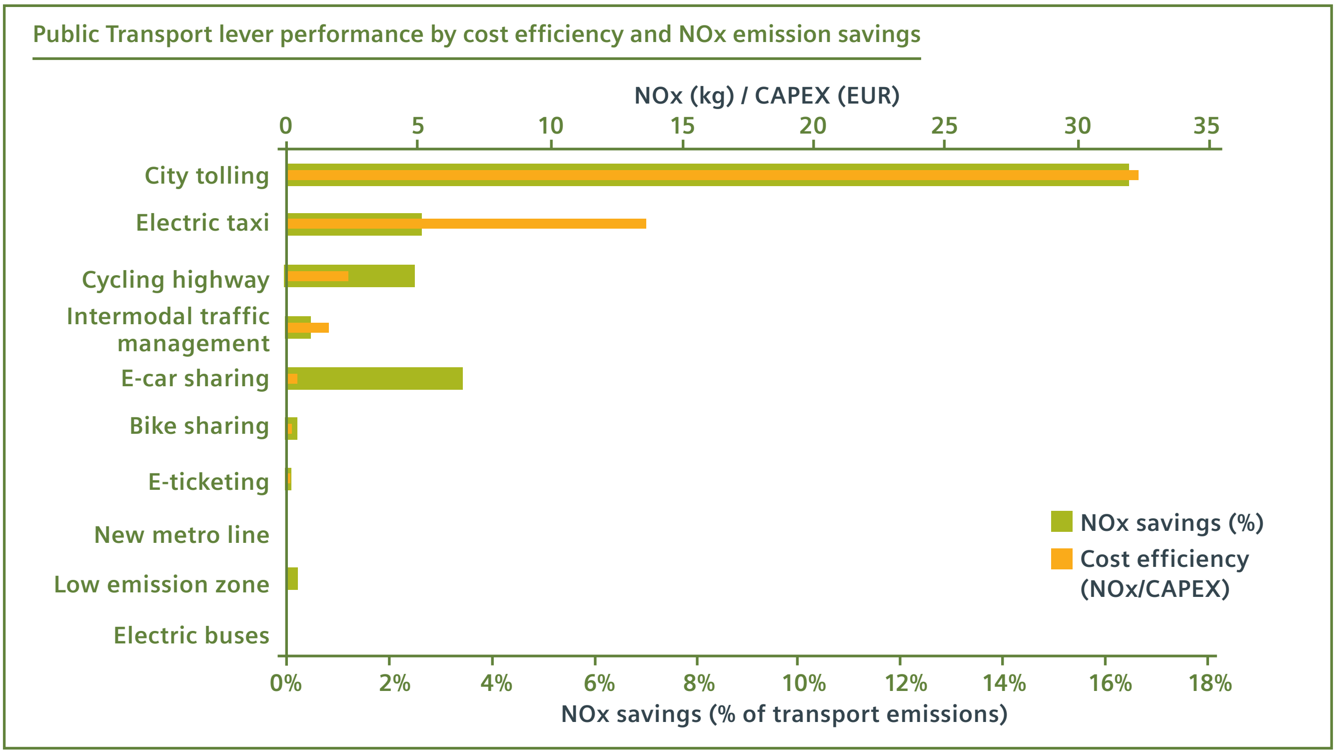


Chart 25: Public Transport NOx Lever Performance

Alternative Fuel Buses in The Hague

Chart 26 illustrates the relative carbon emissions levels of the main types of alternative fuel buses. in 2015, the eBus had the fewest carbon emissions and zero local emissions. In 2040, the eBus is still expected to have the lowest carbon emissions, for both the projected and ideal electricity grid mixes.

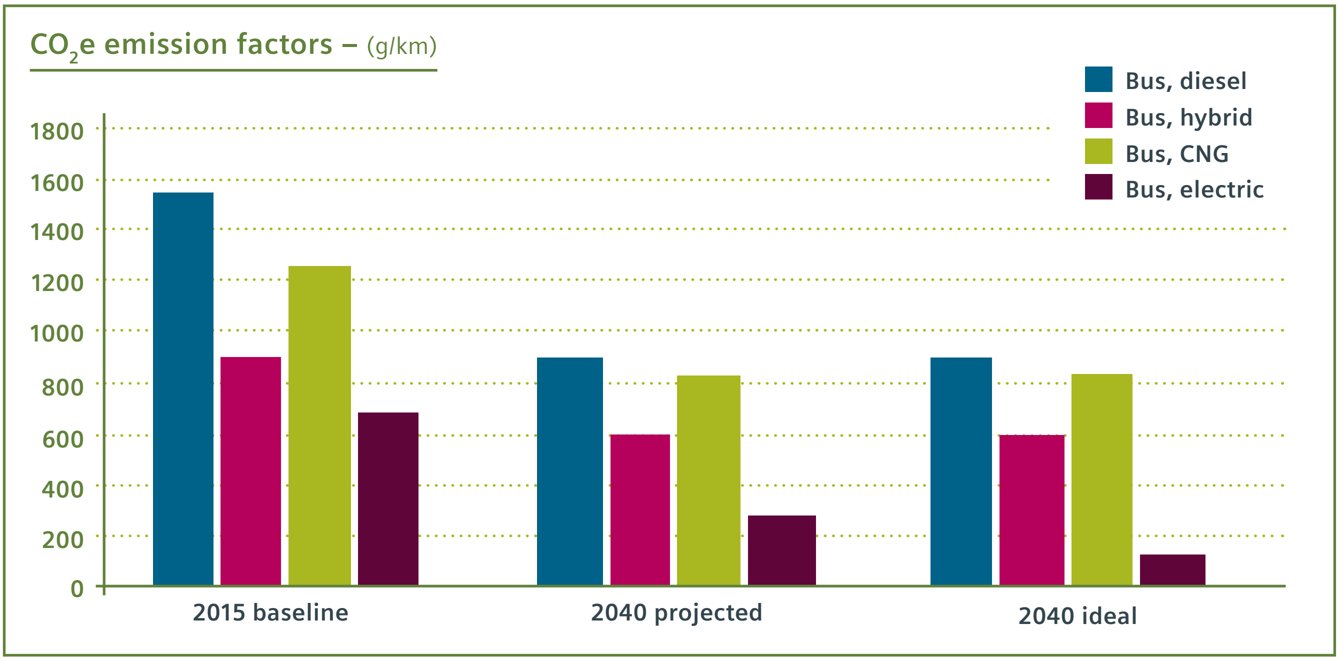


Chart 26: Bus Technologies: CO_2 Emission Factors

Carbon emissions

Emissions factors based on the 2015 electricity mix and bus performance show that diesel buses would produce 20% more carbon emissions than today's CNG buses, and over 100% more carbon emissions than electric buses.

PM_{10} emissions

Today's CNG bus is the best performing technology when considering global PM_{10} emissions. Switching to electric buses today would double global PM_{10} emissions in The Hague. However, there would be zero local exhaust emissions from eBuses. In The Hague, this would improve air quality but increase electricity demand, while lowering air quality at the place of production. Both CNG and electric buses would produce fewer PM_{10} emissions than diesel or hydrogen buses, and are expected to remain the better performers in 2040.

A theoretical move back to diesel buses would increase global PM_{10} emissions by 600%, most of them emitted locally due to the combustion process.

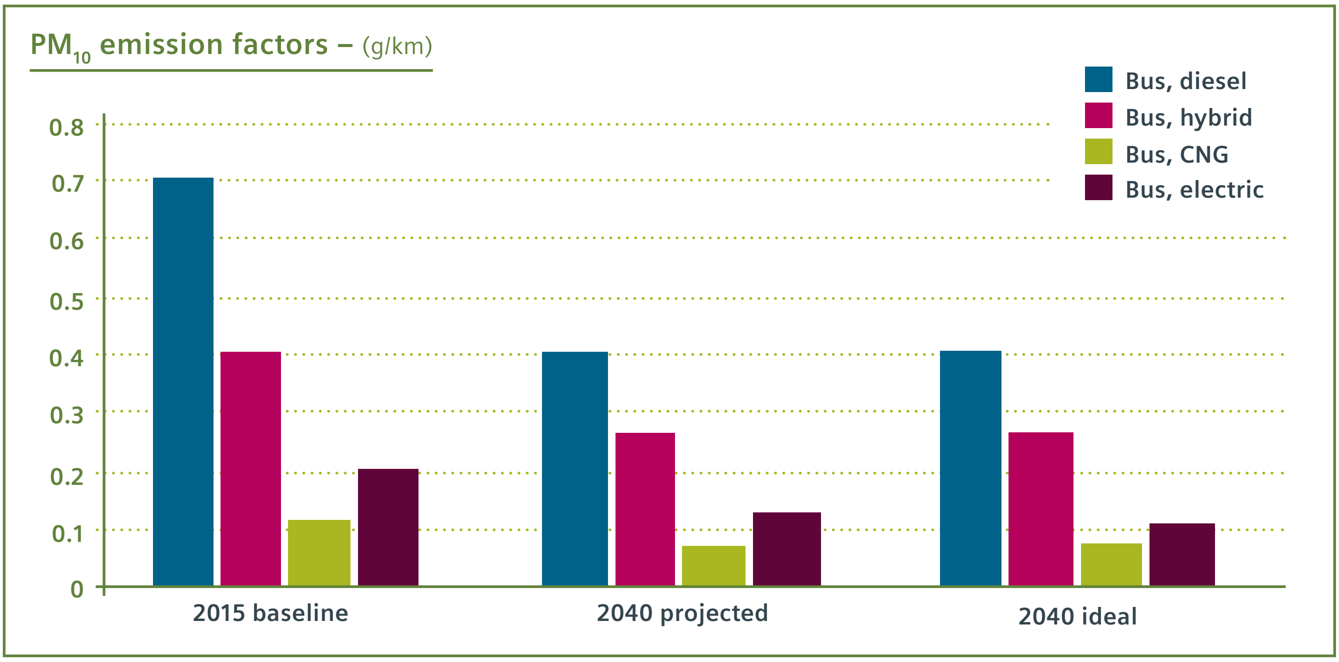


Chart 27: Bus Technologies: PM_{10} Emission Factors

NOx emissions

Today's CNG and electric buses produce by far the fewest NOx emissions out of all of the bus types today. CNG and electric buses are expected to remain the best performers in 2040. Again, a switch to electric buses would increase these emissions, while returning diesel buses would most dramatically increase NOx emissions, a relative gain far more than in carbon or PM_{10}.

Comparison of Bus Fuel Types: Findings

Using today's emissions factors, The Hague would most reduce both its carbon emissions and local emissions by switching to an electric fleet. Today's current CNG buses produce the fewest air quality emissions, but these emissions are occurring within the city, thereby worsening local air quality. When evaluating total emissions, electric and CNG buses by far outperform diesel and hydrogen buses.

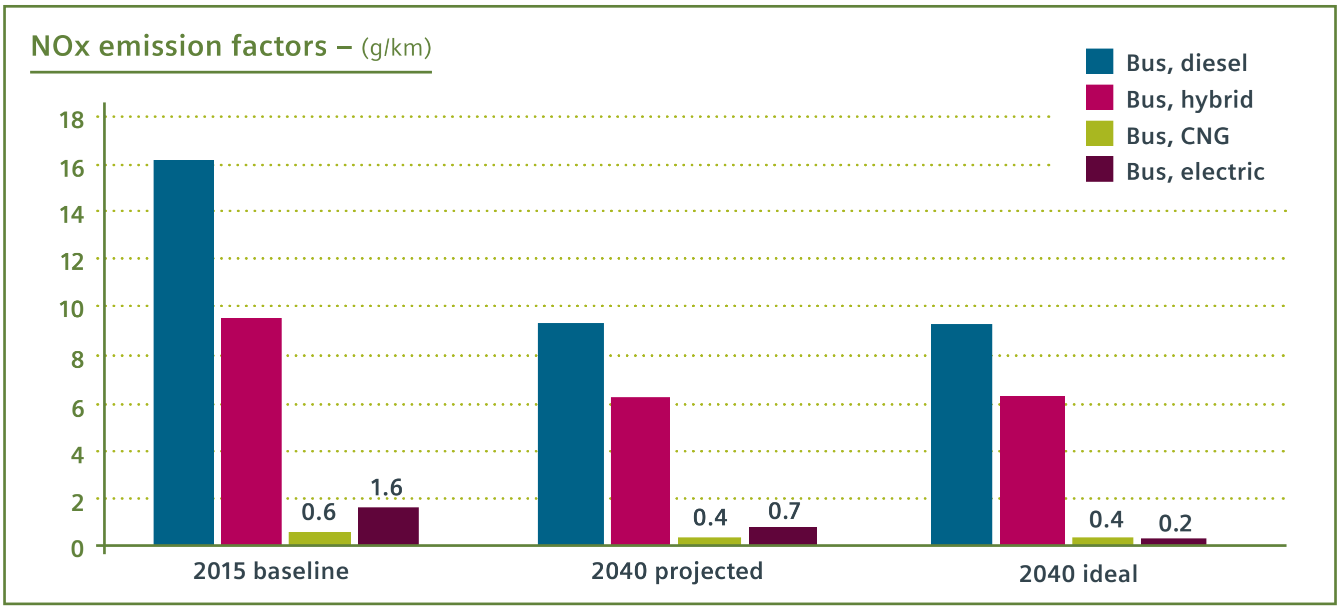


Chart 28: Bus Technologies: NOx Emission Factors

Private transport

The CyPT analysis found that private, alternative-fuel cars are by far the largest producer of transport carbon emissions in the city. The public-sector technologies focused on incentivizing public transport or directly reducing the number of cars on the roads. This section analyses which car fuel types would best reduce carbon emissions and air quality emissions.

Carbon reduction

The most environmentally efficient car for The Hague is an electric car. Using an electric car today would reduce CO_2eq, PM_{10} and NOx emissions. Because private cars travel the most passenger kilometers in The Hague, large-scale uptake of electric cars would deliver the largest benefit. The following chart shows that replacing 50% of today's car fleet with electric vehicles could reduce current transport emissions by 24%.

Private Transport lever performance by cost efficiency and carbon emission savings

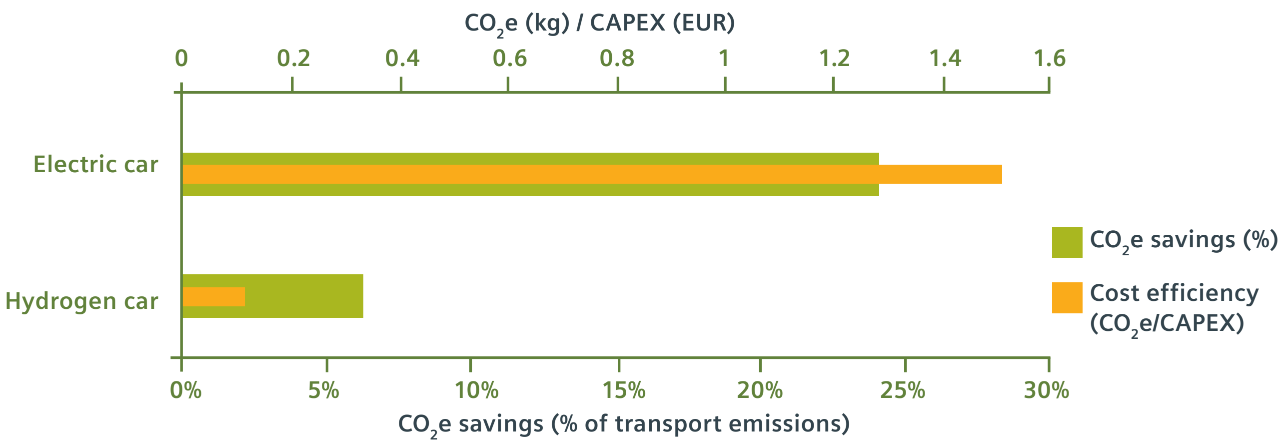


Chart 29: Private Transport CO_2 Lever Performance

PM_{10} and NOx Reductions

Replacing 50% of The Hague's car private car fleet with electric vehicles today would reduce transport PM_{10} emissions by 15%. The PM_{10} reduction is less than the carbon reduction because car braking systems contribute to PM_{10} emissions, which would not be impacted by a change in fuel source.

Private Transport lever performance by cost efficiency and PM_{10} emission savings

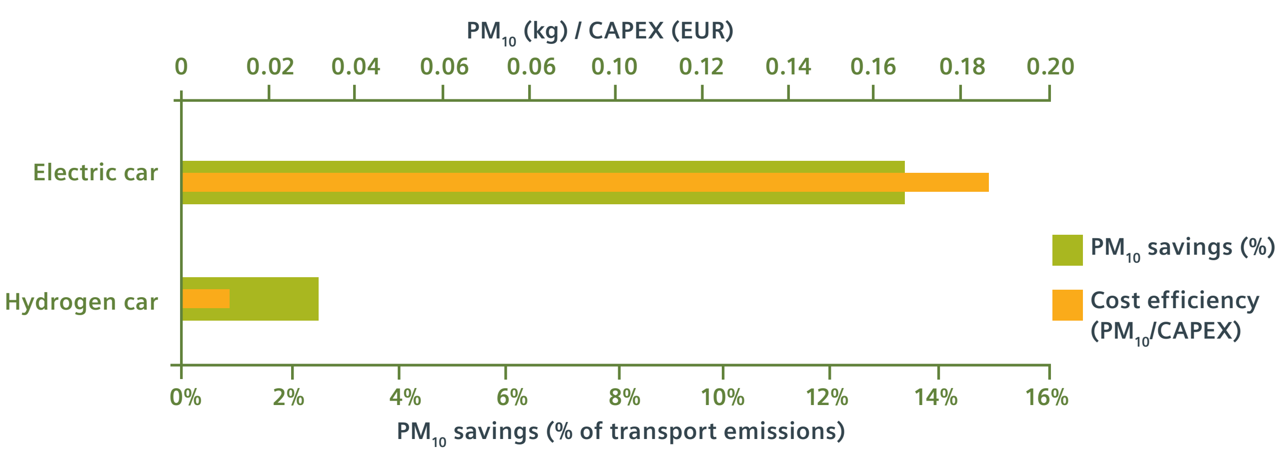


Chart 30: Private Transport PM_{10} Lever Performance

NOx Reductions

Replacing 50% of The Hague's private car fleet with electric cars today would reduce NOx emissions by more than 15%. Switching to hydrogen cars could actually increase NOx by just over 5%. This results from the energy required to produce the hydrogen to fuel those cars. An overall air quality improvement would need to utilize hydrogen made from a fully renewable source.

Private Transport lever performance by cost efficiency and PM_{10} emission savings

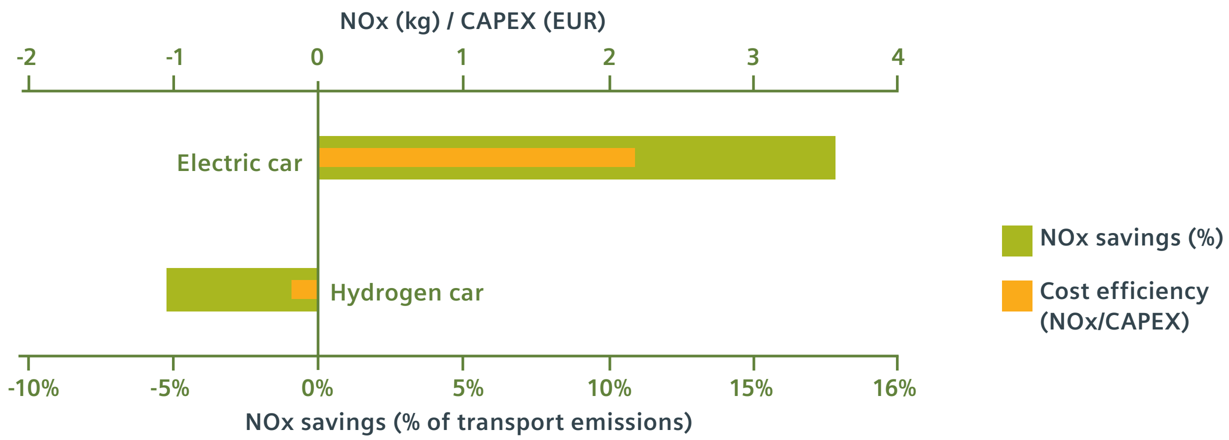


Chart 31: Private Transport NOx Lever Performance

Energy

The Hague's systems for producing and transmitting electricity is critical in the performance of all CyPT technologies. Any increase in the city's proportion of renewable energy has significant knock-on benefits in the buildings and transport sectors. This is seen in the high carbon reduction potential of wind and photovoltaic energy production as well as heat pumps (Chart 32). However, these technologies are not the most cost effective because they are expensive. Assuming there is already sufficient electricity capacity in the grid, the most cost effective measure to reduce carbon emissions is improving the efficiency of electricity transmission. The CyPT found that Smart Grid, network optimization and power system automation deliver the most cost effective carbon reduction.

The results illustrated in the following chart highlight the potential of full deployment of grid technologies and increases in renewable power. Delivering cleaner or Ideal electricity and heat mixes are critical for meeting The Hague's carbon neutrality target. While grid technologies will help to further reduce emissions, their most important role is upgrading the transmission grid, allowing for more intermittent renewable generation and battery storage.

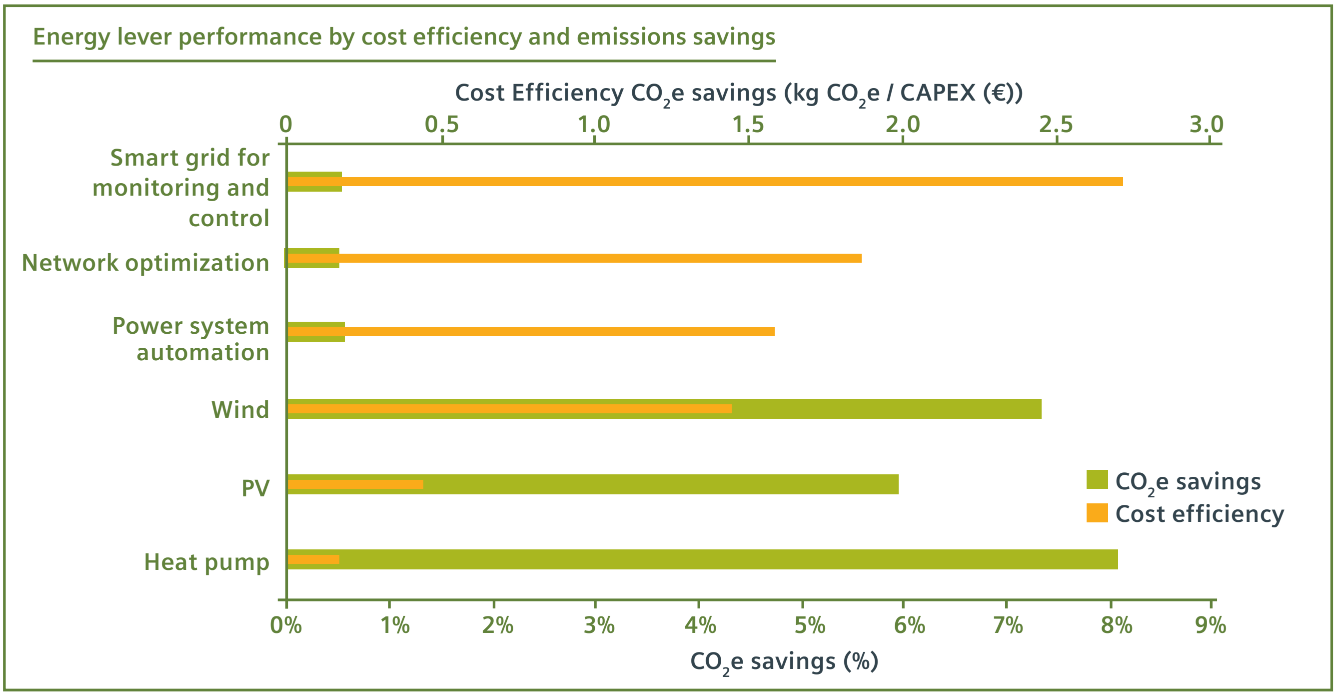


Chart 32: Energy Lever CO_2 Performance

Contextualizing the Results

The CyPT analysis provides evidence that can be used by The Hague's decision-makers. These results consider the relative impact of many relevant technologies, and the report explains important trade-offs between technologies. The following section adds more local context to these results.

Keeping homes warm: Transitioning away from North Sea natural gas

Today, more than 90% of homes in The Hague are heated using natural gas. Generally speaking, there are four realistic options for transitioning away from natural gas with different trade-offs between them, below is a rough sketch of these options:

- Switch supply of gas away from Groningen and import from abroad. There would be two main costs involved in this option, the first being that individual boilers and systems would need to be modified due to the different qualities of gas and second, the city of The Hague would likely not be able to deliver its carbon reduction target.
- Construct heat distribution networks that use more sustainable heat sources such as geothermal heat, these networks are cost efficient only in densely populated areas.
- Utilize ground and air source heat and cooling through the installation of heat pumps within existing home boiler/radiator systems. There are many variations of these systems, with the larger-scale ground source heat

systems only being feasible for new build homes. Air source heat pumps are less disruptive to install, but are not as efficient. These pumping systems utilize electricity.

- Produce all electric homes that utilize only electricity for heating and all appliances.

These options, with the exception of the first, all require a shift towards electricity, even the geothermal systems will utilize some electric pumps and motors. Today, the emissions factor for heat is far cleaner for gas than electricity. Should The Netherlands retrofit existing heating systems to use a different type of natural gas with a higher caloric value, then carbon emissions will not be reduced. There is an opportunity here through the transition to be more ambitious and change heat delivery and include more geothermal energy and electric heat. However, should The Hague move towards a significant increase in electric heat demand then it must simultaneously address the electricity mix as using today's mix would create even more emissions. These results also demonstrate a real need to implement measures to reduce both heat and electricity demand.

Delivering emissions reductions in private residential

Any carbon emissions reduction strategy in The Hague must include houses, because they generate a large proportions of today's emissions. The Hague must plan for alternative gas sources for public buildings, and work with residents to shift private homes. The city's major consideration will be how to incentivize the transition to fully electric homes. The shift away from North Sea gas may create a unique opportunity for change, if all homes will be retrofitted anyway in a short time frame.

City-wide electrification of residential heat is the only way to eliminate local and indirect emissions from homes, as long as electricity is generated from renewable, carbon-neutral sources. However, in 2040, the heat mix is still estimated to be less carbon intensive than the electricity mix in terms of CO_2e per kWh. Significant efforts would be need to be green the electricity mix ahead of any large-scale conversion of homes to electric heat.

In addition to moving homes to a fully electric or even an Ideal heat mix, the city should work to reduce overall consumption. Even green energy has financial costs, which increase in tandem with growing energy demands. Several technologies are well poised to achieve energy savings at the individual home level.

Technologies can reduce demand for electricity, heat, or both, with different implications for the technology's impacts. Given The Hague's relatively clean heat mix with natural gas, reducing electricity consumption has a relatively larger impact. In this analysis, the two best performing residential technologies were home automation and wall insulation. Home automation reduces consumption of both heat and electricity, while wall insulation reduces only heat consumption.. Those two technologies performed similarly in reducing CO_2 and PM_{10}. However, in terms of NOx savings, home automation had a greater impact than wall insulation. Additionally, home automation was more cost-effective.

In The Hague, increasing or upgrading insulation of walls and roofs is the traditional method to reduce residential heating bills. Cities worldwide have public programs that support energy efficiency renovations in private homes. However, despite being active for decades and some positive results, take-up remains challenging and limited. In new homes, building codes ensure adequate insulation, but no equivalent policy impacts existing homes.

The CyPT shows that wall insulation and home automation deliver similar levels of performance. Home automation is

less disruptive to install, but wall insulation is simpler to maintain after installation. The need to periodically optimize home automation is a downside but, all home systems require some maintenance. As automation becomes more a part of all of our lives, it should blend more into the lives of residents.

These results demonstrate that wall insulation and home automation can achieve similar levels of carbon savings. The City of The Hague could support delivery of both technologies, to achieve wins where they can. The city could lobby for building codes updates that would require some home automation in new homes, just as current building codes require insulation. For existing homes, the city could bundle home automation into its current insulation support programs, to encourage more installation.

eTechnologies and impact on local health

In terms of local health implications, diesel, CNG and eBuses are differentiated by the location of their emissions. Petrol, diesel and CNG vehicles generate emissions at the point of combustion, polluting city streets with exhaust. Today, the relatively dirty electricity mix results in similar overall carbon emissions for diesel vehicles and eTechnologies, such as eBuses and eCars. However, because no combustion occurs, eTechnologies produce significantly less local air quality emissions.

When considering diesel and eBuses today, it is critical to point out that the difference overall carbon emissions is not huge because the grid is relatively dirty, that the air quality emission reductions are significant.

Private car transport, emissions zones and eCars

Given the dominance of private cars in generating The Hague's transport emissions, effective efforts must address private car use. Strategies could include reducing car use through a road pricing or city tolling, or incorporating electric vehicles into the private car fleet, provided a low-emissions grid mix. The city tolling technology is most effective, because it reduces overall car use and traffic congestion. Moving towards eCars would tackle carbon and air quality concerns, but would not improve congestion. eCars' increased electricity demand could strain the grid, necessitating grid infrastructure upgrades.

Rotterdam/The Hague Heat Network

Rotterdam and The Hague have ongoing conversations on the future of residential heating. Both are considering capturing waste heat from the Port of Rotterdam, which represents a sizable potential of 150 petajoules of heat from waste incineration, the port industrial complex, and connecting coal plants. The city can continue to waste this heat, or choose to use it more productively, but an intense debate continues. Discussions include a €4 billion heat network to utilize this heat.

There are additional questions concerning the longevity of the chemical producers. If technologies improve those plants' efficiency, waste heat would be reduced. If coal plant operations are discontinued in the future, that heat source would disappear as well, although with benefits for the sustainability of the grid mix. There is the need for a clear roadmap of how the grid will incorporate more renewables and where opportunities like this may fit. Converting all residential homes to electricity today would require increasing the outputs of existing producers, or increasing electricity imports, likely from Germany where the mix still relies heavily on coal. Waste heat could offer The Hague a transitional, low-emissions heat source while the supply and sustainability of electricity are increased. However, this project's high capital costs may outstrip a reasonable budget for a transitional project. Therefore, the city should attempt to determine:

- The likelihood of consistent production of waste heat in the port over the coming 30 years.
- The potential to augment the system with green heat such as experimental geothermal sources, to gradually replace dirtier sources.
- The possibility of mandating that power producers link with local research institutions to test carbon capture technologies.
- Which housing areas are the most economically viable for the €4 billion network, including the opportunity to include ground source heating systems around these buildings and open sites, and the potential to support the network with solar thermal generation.

Hydrogen

The report has already highlighted the poor performance of hydrogen, due to the electricity consumption required to produce hydrogen fuel then convert it to energy in the vehicle. However, availability of cheap, renewably sourced electricity would strengthen the economic case for hydrogen.

The Hague in 2040: Conclusions

The Hague's 2040 vision is to retain its position as a global leader for peace and justice while delivering the highest possible quality of life for its residents. It also aims to be a carbon neutral city, and making this leap ahead of national policy will require efforts beyond current plans. Technology will be fundamental to this achievement. As with all cities, challenges will include limited funds and high resident expectations. To reach its targets, The Hague will have to be both visionary and pragmatic.

The Hague must be visionary in cleaning both its electricity and heat mixes without the benefit of mandated national delivery targets, which take effect only after the 2040 target year. To reduce private transport carbon emissions and air pollutants, it will need to incorporate additional sources of renewable electricity. The city could choose to tap into waste heat from local, dirty sources, incorporating a clear research agenda to it, while pushing for more clean electricity and heat generation through city-level photovoltaic and wind power. The Hague has substantial geothermal heat potential that could be utilized within local heat networks.

The Hague has the opportunity to be a leader within The Netherlands. It will be the first city to plan and deliver a credible transition path away from natural gas, complemented by reducing electricity and heat demand in its public buildings. It will also be the first Dutch city to electrify the entire city car fleet, and incentivize small scale electricity storage by prioritizing it in research and funding.

The Hague will advocate for the national government to reduce the carbon intensity of the national grid and to avoid passively resorting to imported energy.

The Hague will incentivize change in all areas where it has jurisdiction, and will encourage change in areas where it cannot direct policy. It will harness the opportunity of its own energy transition to create jobs, building the infrastructure needed to generate greener wind, solar, tidal and geothermal energy to power buildings throughout the city

Conclusions

Identifying the optimal mix of technologies

Short-term

eBus – The Hague will replace the current CNG bus fleet over the coming years, before the implementation of policy that mandates emissions-free buses.

City tolling – Private car transport is the main source of transport emissions. City tolling is politically difficult but most effective, and can be quickly implemented once approved.

eCars (public sector) – The Hague can lead the market by transitioning the public sector car fleet to eCar. It can support this transition by installing charging points in city parking lots, powered by adjacent photovoltaic cells.

Electricity technologies – The Hague can initiate research that focuses on geothermal power, electricity storage and carbon capture

Building Efficiency – The Hague can work in partnership with national government's building codes to ensure new homes to reflect current energy savings technology. It can offer developers density bonuses if they construct energy-efficient buildings. It can also ink home automation and residential building technologies to wall insulation in public-sector home retrofit programs, to provide more options and attract more residents to the scheme.

Medium-term

Smart meters and thermostats – Smart metering combined with smart thermostats can cost-effectively reduce residential electricity and heat demand. Planning permissions for new homes and retrofits could be contingent on incorporating smart meters and thermostats.

eCars (private sector) – The Hague can offer incentives for private individuals to purchase an eCar, such as by reducing parking charges.

Cycle Highway – Even though The Hague already has a high proportion of cycling, it still constitutes less than 10% of all km travelled. To meet the other European cities that have reached the 10% threshold, The Hague could further improve their cycling infrastructure, for positive impacts on carbon emissions and air quality.

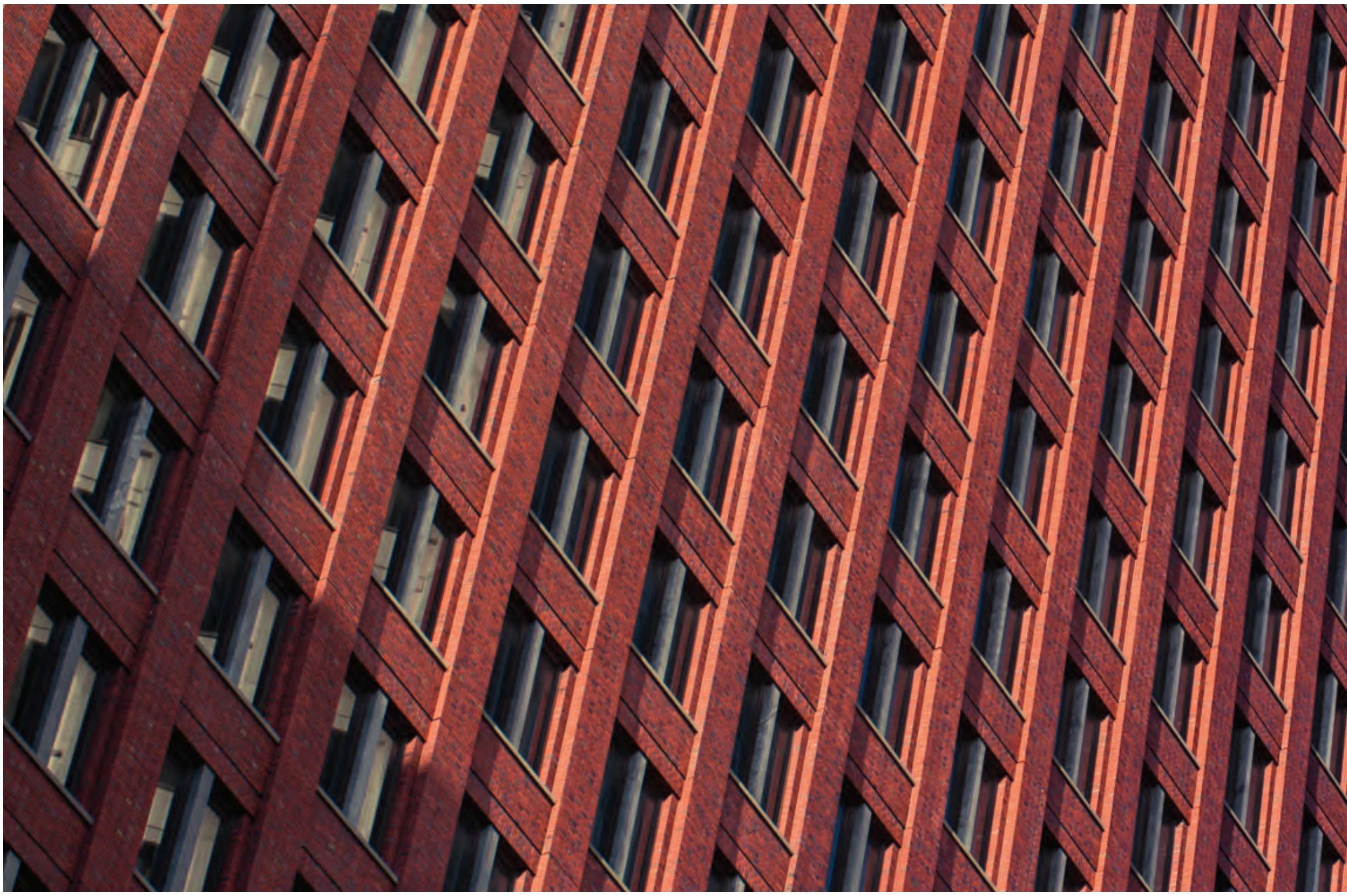
Long-term

Smart Grid – Grid improvement technologies target electricity losses in the current system deliver very cost effective results. The Hague could incentivize grid upgrades with local utilities, and initiate Smart Grid projects where feasible.

Urban electricity and heat generation – The Hague could utilize existing city assets to host local, small-scale, renewable energy generation.

Home Electrification – Develop options for homeowners to transition their homes to electric heat, and offer training programs for local residents to work on the retrofits.

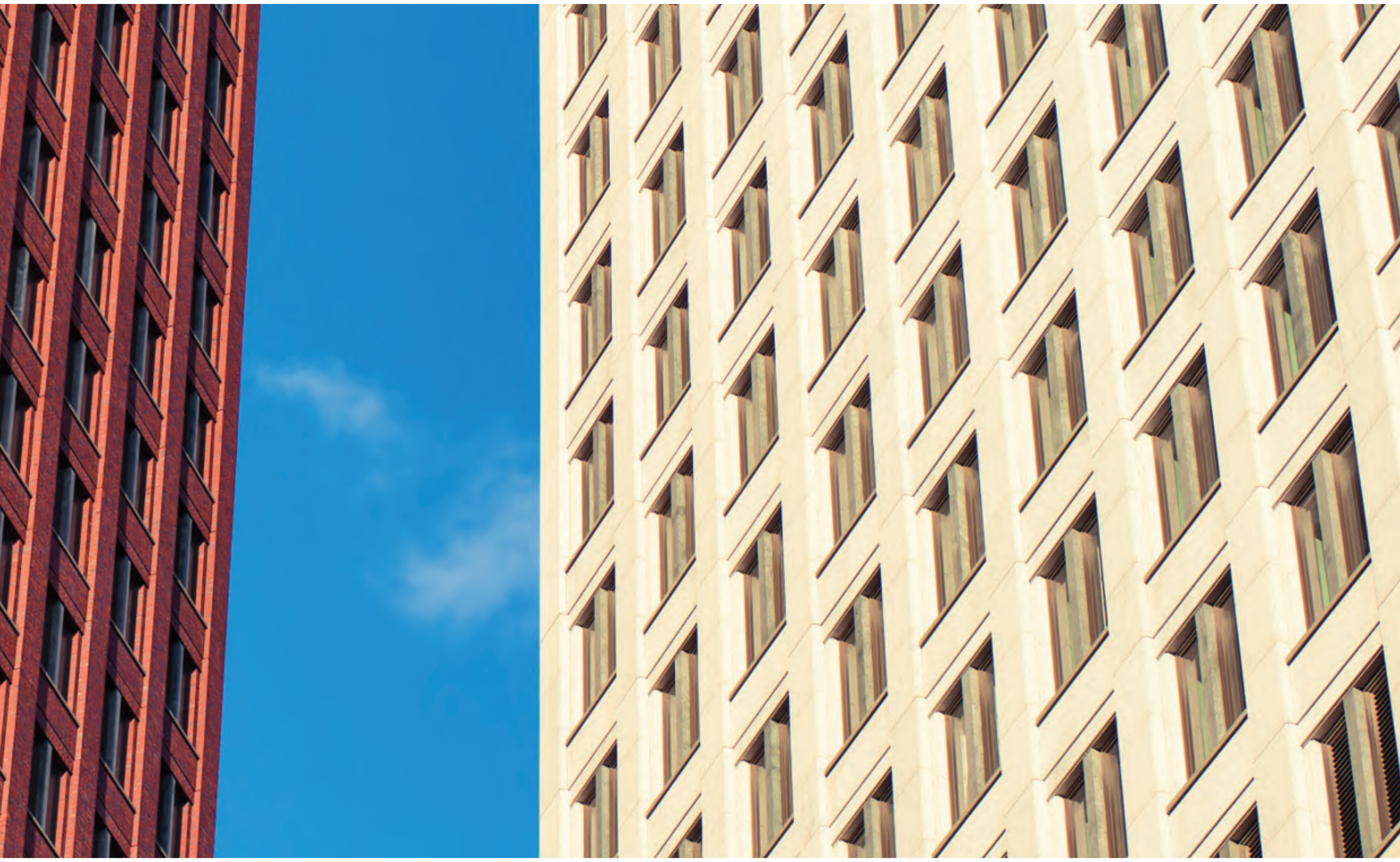
Government Partnership – Continue to partner with all levels of government, to support and fund increased renewable generation and ensure that the city purchases green energy.



Electric Buses in Oslo, Norway

Oslo is committed to providing a fossil-fuel free public transport system across the city and into its suburbs by 2020. Buses in Oslo carry 140 million passengers per year and are a cornerstone of local public transport. Ruter, the Oslo transport authority, conducted a feasibility study of all proven technologies that could contribute to their 2020 objective. Technologies were evaluated on three key criteria: cost, emissions, air quality and ease of implementation. The study found that rechargeable, battery-operated hybrid buses provided the best solution. They created zero local emissions, improving local air quality. They were more efficient than buses run on alternative fuels, which let them operate three to four times longer than a diesel bus with the equivalent amount of power. With fast recharging at bus stops, eBuses could be rolled out across 80% of the city's 64 bus lines without changing timings or routes.

On the lines requiring some modifications, the changes were minimal. eBuses were more economically efficient than diesel buses, because of Oslo's very low electricity costs and eBuses' high efficiency. Charges for local pollution also helped the economic case for eBuses. Ruter estimated that rechargeable hybrid eBuses would save the company NOK 750 million (80 million EUR) over 10 years.



Appendix I: CyPT Key Indicators

The CyPT tracks technologies' impact of four indicators.

1. CO_2(e) Emissions

CO_2(e) stands for a carbon dioxide equivalency measure that allows for various greenhouse gasses (GHGs) to be expressed in terms of CO_2 as a common unit. Equivalency is determined by multiplying the amount of the GHG by its global warming potential (GWP), where GWP indicates how much warming a given GHG would cause in the atmosphere over a certain period of time (usually 100 years). For example, CO_2 has a GWP of 1, whereas methane (CH_4) has a GWP of 25. Therefore, 1kg CH_4 * 25 = 25kg CO_2e.[1]

2. NOx

Nitrogen Oxides (NOx) most commonly refer to nitric oxide (NO) and nitrogen dioxide (NO_2). Some level of NOx occurs naturally in the air, but NOx is predominantly caused by human activity that is harmful to the atmosphere, particularly the burning of fossil fuels. In urban settings especially, NOx emitted from vehicle emissions can cause significant air pollution.[2]

3. PM_{10}

Particulate matter 10 (PM_{10}) describes very small liquid and solid particles floating in the air that measure only 10 microns in diameter (about 1/7th the thickness of human hair). These particles are small enough to breathe into human lungs and among the most harmful of air pollutants. PM_{10} has many negative health impacts once lodged in the lungs, and can increase the severity of asthma attacks, cause or worsen bronchitis, and weaken the body's immune system. The most common sources of PM_{10} include vehicle emissions, wood burning stoves and fireplaces, and dust from construction, landfills and agriculture.[3]

4. Jobs (Full-time equivalents)

The CyPT measures the gross number of direct, indirect, and induced jobs created in the local economy by investing in CyPT technologies. These include installation, operation and maintenance jobs, which are calculated as full time equivalent jobs of 1,760 hours per year. Manufacturing jobs are not accounted for, because some of these technologies may be produced outside the city's functional area, with no local benefits to the economy.

[1] *http://ecometrica.com/white-papers/greenhouse-gases-co2-co2e-and-carbon-what-do-all-these-terms-mean*
[2] *http://www.eea.europa.eu/data-and-maps/indicators/eea-32-nitrogen-oxides-nox-emissions-1*
[3] *http://www.arb.ca.gov/html/brochure/pm10.htm*

Appendix II – Description of CyPT Technologies

Building Levers

Residential/ Non-residential	Wall Insulation	Solid wall insulation e.g. made of expanded polystyrene (EPS) can be applied to already existing buildings. Applying the rigid foams to exterior side of walls raises thermal resistance. The insulation reduces the heat gain/loss through the walls and thus minimizes the heating/cooling energy needed. Reduction of CO_2e, PM_{10}, and NOx related due to energy savings.
Residential	Efficient lighting technology	Significant electrical energy can be saved by replacing conventional luminaires by more efficient lighting fixtures and/or changing magnetic ballasts to electronic ballasts. Further reductions in power consumption can be achieved with the use of light-emitting diodes (LEDs), which also have a far higher lifespan than conventional lighting. LED solutions combined with intelligent light management systems can lower lighting costs in a building by as much as 80%. Reduction of CO_2e, PM_{10}, and NOx related due to electricity savings.
Residential	Home Automation	Home Automation allows the automatic adjustment of heating, cooling, ventilation and lighting depending on the environmental conditions and the room occupancy by applying sensors and actuators as well as control units. This reduces the energy demand of heating, cooling, ventilation and lighting.
Non-Residential	Efficient lighting technology	Electricity can be saved by replacing conventional light bulbs for room lighting by more efficient light-emitting diodes (LEDs). LEDs consume up to 90% less energy and have a longer lasting in operation hours and turn off/on cycles. LED lamps are compatible to conventional lamps and can substitute them easily. LEDs provide an equal luminosity at lower specified power. Reduction of CO_2e, PM_{10}, and NOx related due to electricity savings.
Non-Residential	Heat Recovery	Heating and cooling losses can be reduced through heat and cold recovery technologies integrated within a building's maintenance system. The technology utilizes a counter flow heat exchanger between the inbound and outbound air flow. For example, cold inbound air flow can be pre-heated by room temperature outbound air flow. The result is that fresh, incoming air requires less heat or cooling and a steady room temperature is maintained and less electricity or heat is utilized.
Non-Residential	BACS Class C	Building Automation and Control System (BACS) are building technologies that can be installed in existing or new buildings. An Energy Class C building corresponds to a standard BACS, which includes: Networked building automation of primary plants, no electronic room automatic or thermostatic valves for radiators, no energy monitoring. Emission reduction is achieved from the electrical power utilized in the heating & cooling of buildings, water circulation, and emissions generated through the combustion process of fuel (renewable or fossil-based).
Non-Residential	Energy Efficient Motors and Drives	Analyzing the drive technology in your building (fans, pumps, compressors or process plant) can lead to significant cost- and energy-savings and help reduce emissions. As an example: changing a standard 30kW motor (IE1) to an equivalent energy efficient motor (IE3) can save 3,500 kWh per year, and 2,000kg of CO_2 emissions. Adding variable speed drive technology will ensure motors only draw as much energy as is actually required. Reduction of CO_2e, PM_{10}, NOx are related to electrical energy savings.

Transport Levers

Passenger	**Electric buses**	Share of the vehicle fleet operated by battery electric vehicles. Battery electric vehicles are "zero" exhaust gas emission vehicles. Significant reduction of local emissions PM_{10}, NOx. A charging infrastructure is set up. The electricity used for charging is generated according to the general local electricity mix.
Passenger	**New line – Metro**	Number new metro lines at target year of average metro length, shifting passengers from all other mode according to the transportation performance of existing lines in the city. Public transport attractiveness is increased and energy demand per person kilometer is reduced together with related emissions.
Passenger	**Electric cars**	Share of conventional combustion vehicles replaced by battery electric vehicles. Battery electric cars are "zero" exhaust gas emission vehicles. Significant reduction of local emissions PM_{10}, NOx. A charging infrastructure is set up. The electricity used for charging is generated according to the general local electricity mix.
Passenger	**Hydrogen Car**	Share of conventional combustion vehicles replaced by hydrogen vehicles at target year. Hydrogen vehicles with fuel cell technology are "zero" exhaust gas emission vehicles. Significant reduction of local emissions PM_{10}, NOx. The hydrogen is generated with fuel cell technology, using the local electricity mix. A refueling infrastructure is set up.
Passenger	**E-ticketing**	Share of public transport journeys paid via smart card and integrated ticketing across all public transport modes. Improved ease of public transport due to simple procedures, better information and faster boarding, which induces a modal shift to public transport. Impact on emissions reduction: Modal shift to less emitting mode of transport. Impact depends on current modal share and electricity mix.
Passenger	**Intermodal Traffic Management**	Intermodal Traffic Management focuses on interoperable multimodal Real Time Traffic and Travel Information (RTTI) services provided to drivers/ travelers – promoting change in mobility behavior from individual to public transport reducing energy demand per person kilometer.
Freight	**Low Emission Zone**	The City area is restricted to vehicles of emission classes Euro 6 and higher. Impact on emissions reduction: Only vehicles with a certain level of off-gas treatment are allowed to enter the city, reducing local PM_{10} and NOx emissions, as well as marginally reducing fuel consumption due to more fuel efficient operation of combustion engines.
Passenger	City tolling	This lever simulates the establishment of a tolling zone in the city. Charges are obtained at a level, where the target reduction in city-internal car and motorcycle use is reached. Impact on emissions reduction: Modal shift to emitting lower emissions mode of transport. Impact depends on current modal share and electricity mix.
Passenger	Electric taxis	Share of conventional combustion vehicles replaced by battery electric vehicles. Battery electric cars are "zero" exhaust gas emission vehicles. Significant reduction of local emissions A fast charging infrastructure is set up The electricity used for charging is generated according to the general local electricity mix.
Passenger	Cycling highway	Additional cycle highway kilometers per 100,000 inhabitants at the target year. The lever increases the modal share of bicycles, reducing the modal share from motorized vehicles. Impact on emissions reduction: Modal shift to zero emission mode of transport. Impact depends on current modal split, the acceptance of bicycles, as well as the existing cycling infrastructure.
Passenger	Bike sharing	Number of sharing bikes/1000 inhabitants offered at target year resulting in a shift from all transport mode equally and lower energy demand per person kilometer together with related emissions.
Passenger	Electric car sharing	Number of sharing cars/1000 inhabitants at target year: model of car rental where people rent e-cars for short periods of time, on a self-service basis. It is a complement to existing public transport systems by providing the first or last leg of a journey. Resulting in fewer driving emissions due to eCar and shift to non-vehicle travel, such as walking, cycling and public transport.

Appendix III: Dutch Government Mandated Energy Efficiency Measures for Commercial Buildings

Offices

Measures

Table 5.4 Designated measures for saving energy in offices

Type of measure	Electric buses
Building shell	New line – Metro
Room ventilation	Electric cars
Room heating	Hydrogen Car
Indoor and outdoor lighting	E-ticketing

Activity

Type of measure	Building shell
Number measure	1
Description measure	Reduce heat and cold losses through exterior wall.
Possible techniques relative to baseline situation	Insulation cavity walls.
Baseline situation based on a reference technique	Insulation in cavity walls is missing. Building is heated, or heated and cooled.
Technical conditions	NA
Economical conditions	Natural gas consumption is less than 170.000 m^3 per year.
Applicable during a independent or a natural moment?	Independent moment: yes, when gross floor area is less than 600 m^2. Natural moment: yes.
Alternative recognized measures	N.v.t.
Special circumstances	In buildings with minimal energy label C or in new buildings, date of construction from 2003 and after, which satisfy the EPC requirements of 2003, these measures are considered to have been taken.

Type of measure	Room ventilation
Number measure	2
Description measure	Prevent needless activation of the ventilation outside working hours.
Possible techniques relative to baseline situation	Apply a timer or a timer with a weekend switch (with or without a overwork timer).
Baseline situation based on a reference technique	Automatic on- and off-switch is missing.
Technical conditions	NA
Economical conditions	NA
Applicable during a independent or a natural moment?	Independent moment: yes. Natural moment: yes.
Alternative recognized measures	NA
Special circumstances	NA

Type of measure	Room heating
Number measure	3
Description measure	Reduce continuous full flow rate ventilation by switching fans to a lower ventilation flow rate.
Possible techniques relative to baseline situation	Apply cascade control.
Baseline situation based on a reference technique	Cascade control is missing.
Technical conditions	NA
Economical conditions	Gross floor area is more than 600 m².
Applicable during an independent or a natural moment?	Independent moment: no. Natural moment: yes.
Alternative recognized measures	NA
Special circumstances	In buildings with minimal energy label C or in new buildings, date of construction from 2003 and after, which satisfy the EPC requirements of 2003, these measures are considered to have been taken.

Type of measure	Room ventilation
Number measure	4
Description measure	Use heat from outgoing ventilation air to preheat incoming ventilation air with a balanced ventilation system.
Possible techniques relative to baseline situation	Apply twin coil system.
Baseline situation based on a reference technique	Heat recovery system is missing in the air handling unit.
Technical conditions	Air supply and exhaust are placed close to each other and not separated by architectural elements.
Economical conditions	CR or VR boilers are available for room heating. Limited insulation is present (indication: less than 40 mm of insulation or date of construction 1975 or earlier). Gross floor area is more than 600 m². Natural gas consumption is less than 170.000 m³ per year.
Applicable during an independent or a natural moment?	Independent moment: yes. Natural moment: yes.
Alternative recognized measures	Apply energy-efficient heat generation
Special circumstances	In buildings with minimal energy label C or in new buildings, date of construction from 2003 and after, which satisfy the EPC requirements of 2003, these measures are considered to have been taken.

Type of measure	Operating a combustion heating system (air emissions)
Number measure	5
Description measure	Control the flow temperature of the CV-water automatically, based on the outdoor temperature.
Possible techniques relative to baseline situation	Apply weather-dependent control.
Baseline situation based on a reference technique	Weather-dependent control is missing on CV-group with high temperature heating.
Technical conditions	Apply weather-dependent control on cv-group, when this is not possible on the boiler because of the hot water supply.
Economical conditions	NA
Applicable during an independent or a natural moment?	Independent moment: yes. Natural moment: yes.
Alternative recognized measures	NA
Special circumstances	NA

Activity	Operating a combustion heating system (air emissions)
Number measure	6
Description measure	Control the start-up time of the heating system, based on the outside temperature and the internal heat demand.
Possible techniques relative to baseline situation	Apply optimizing control.
Baseline situation based on a reference technique	Optimizing control is missing.
Technical conditions	NA
Economical conditions	Natural gas consumption us less than 170.000 m³ per year.
Applicable during an independent or a natural moment?	Independent moment: yes. Natural moment: yes.
Alternative recognized measures	NA
Special circumstances	NA

Type of measure	Room heating
Number measure	7
Description measure	Reduce heat loss through hot water pipes and fittings in unheated rooms.
Possible techniques relative to baseline situation	Apply insulation around pipes and fittings.
Baseline situation based on a reference technique	Insulation around pipes and fittings is missing.
Technical conditions	When manufacturer requires in his warranty that moist and heat must be able to exit, take this into account when choosing type of insulation.
Economical conditions	Natural gas consumption is less than 170.000 m³ per year. Operating time of the installation, belonging to the pipes and fittings is minimal 1.250 uur per year (indication: a standard heating season).
Applicable during an independent or a natural moment?	Independent moment: yes. Natural moment: yes.
Alternative recognized measures	NA
Special circumstances	NA

Type of measure	Operating a combustion heating system (air emissions)
Number measure	8
Description measure	Apply energy-efficient heat generation.
Possible techniques relative to baseline situation	Use high efficiency boiler HR107.
Baseline situation based on a reference technique	a) CR or VR boiler is present for base load (operating time is over 500 hours per year). b) High efficiency boiler HR100 is present for base load (operating time is over 500 hours per year).
Technical conditions	Retour water temperature of boiler may be lower than 55°C. High temperature systems (such as hot water systems or high-temperature radiating panels) prevent this sometimes. Draining condensation is possible.
Economical conditions	Limited insulation is present (indication: less than 40 mm insulation or year of construction of 1975 or earlier).
Applicable during an independent or natural moment?	a) Independent moment: yes, when gross floor area is less than 600 m². Natural moment: yes. b) Independent moment: No. Natural moment: yes.
Alternative recognized measures	Use heat from outgoing ventilation air to preheat the incoming ventilation air, with balanced ventilation.
Special circumstances	In buildings with minimal energy label C or in new buildings, date of construction from 2003 and after, which satisfy the EPC requirements of 2003, these measures are considered to have been taken.

Type of measure	Indoor and outdoor lighting
Number measure	9
Description measure	Prevent unnecessary use of lighting during recess or out of office time.
Possible techniques relative to baseline situation	Apply a timer switch.
Baseline situation based on a reference technique	Lighting is switched manually per room.
Technical conditions	NA
Economical conditions	NA
Applicable during an independent or a natural moment?	Independent moment: yes. Natural moment: yes.
Alternative recognized measures	NA
Special circumstances	In buildings with minimal energy label C or in new buildings, date of construction from 2003 and after, which satisfy the EPC requirements of 2003, these measures are considered to have been taken.

Activity	Indoor and outdoor lighting
Number measure	10
Description measure	Reduce installed capacity indoor lighting.
Possible techniques relative to baseline situation	Apply elongated fluorescent lamp (AG5) and adapters in existing fixtures.
Baseline situation based on a reference technique	Conventional fixtures with elongated fluorescent lamps (AG) are present
Technical conditions	NA
Economical conditions	NA
Applicable during an independent or a natural moment?	Independent moment: yes. Natural moment: yes.
Alternative recognized measures	NA
Special circumstances	In buildings with minimal energy label C or in new buildings, date of construction from 2003 and after, which satisfy the EPC requirements of 2003, these measures are considered to have been taken.

Type of measure	Indoor and outdoor lighting
Number measure	11
Description measure	Reduce installed capacity accent lighting.
Possible techniques relative to baseline situation	Apply a PL-lamp (traditional CFL) or a halogen lamp in the existing fixtures.
Baseline situation based on a reference technique	Incandescent lamp is present.
Technical conditions	NA
Economical conditions	NA
Applicable during an independent or a natural moment?	Independent moment: yes. Natural moment: yes.
Alternative recognized measures	NA
Special circumstances	NA

Type of measure	Outdoor lighting
Number measure	12
Description measure	Prevent unnecessary use of outdoor lighting, by only using lights when it is dark and switch of the lights during the night for a minimum time of 6 hours or use a movement switch.
Possible techniques relative to baseline situation	a) Apply a motion sensor, a twilight switch and a timer. b) Apply a twilight switch and a timer. c) Apply a twilight switch and a timer.
Baseline situation based on a reference technique	(a and b) a twilight switch and a timer are missing in outdoor lighting c) Automatic timer is missing in the commercial lighting (commercial lighting is on during the night).
Technical conditions	a) Lamps that light on quickly. (b and c) NA
Economical conditions	(a and b) Minimal 20 fixtures are present. (c) NA
Applicable during an independent or a natural moment?	a) Independent moment: yes, when minimal 50 fixtures are present. Natural moment: yes. (b and c) Independent moment: No. Natural moment: yes.
Alternative recognized measures	NA
Special circumstances	NA

Type of measure	Indoor and outdoor lighting
Number measure	13
Description measure	Reduce installed capacity of outdoor lighting.
Possible techniques relative to baseline situation	a) Apply Led-lights in existing fixtures. b) Apply sodium-lights lights in existing fixtures. c) Apply metal halide lights in existing fixtures. d) Apply sodium-lights lights in existing fixtures.
Baseline situation based on a reference technique	(a and b) Halogen lamp is present. (c and d) High pressure mercury light is present.
Technical conditions	NA
Economical conditions	NA
Applicable during an independent or a natural moment?	Independent moment: yes. Natural moment: yes.
Alternative recognized measures	NA
Special circumstances	NA

Type of measure	Indoor and outdoor lighting
Number measure	14
Description measure	Reduce installed capacity of commercial lighting.
Possible techniques relative to baseline situation	a) Apply LED-lights in existing fixtures. b) Apply fixture with elongated fluorescent lights (AG5). c) Apply LED-lights in existing fixtures.
Baseline situation based on a reference technique	(a and b) Incandescent lamp is present. (c) Halogen lamp is present.
Technical conditions	NA
Economical conditions	NA
Applicable during an independent or a natural moment?	Independent moment: yes. Natural moment: yes.
Alternative recognized measures	NA
Special circumstances	NA

Type of measure	Operating a combustion heating system (air emissions)
Number measure	15
Description measure	Apply energy-efficient heat generation of water.
Possible techniques relative to baseline situation	Apply gas-fired high-efficiency (HR) boiler.
Baseline situation based on a reference technique	Conventional (gas) boiler is present.
Technical conditions	Draining of condensation is possible.
Economical conditions	NA
Applicable during an independent or a natural moment?	Independent moment: yes, when gross floor area is less than 600 m^2. Natural moment: yes.
Alternative recognized measures	NA
Special circumstances	In buildings with minimal energy label C or in new buildings, date of construction from 2003 and after, which satisfy the EPC requirements of 2003, these measures are considered to have been taken.

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Global Center of Competences Cities
The Crystal
1 Siemens Brothers Way
Royal Victoria Dock
London
E16 1GB

For more information about this report, please contact:

Leo Freriks
Siemens The Netherlands
leo.freriks@siemens.com

Klaus Heidinger
Global Center of Competence Cities
email: klaus.heidinger@siemens.com

Elaine Trimble
Global Center of Competence Cities
elaine.trimble@siemens.com