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Madrid 2020 – 2030

Cleaner air for a city of citizens

City Performance Tool – April 2017

Cities will be at the heart of achieving the government's Vision 2030.

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Executive Summary

Madrid is prioritizing social development and bringing it on a par with investment to boost the local economy and remaking itself for its citizens. Its most recent budgets have seen increases of 80% in cultural projects, nearly 250% in equality and employment policies and a 15% increase in the education budget. This is a deep commitment for the city; putting social development on the same level as economic development. This report continues in this spirit with a focus on Madrid's environmental development, specifically its short term goal to improve air quality and longer term goal to reduce its greenhouse gas emissions.

Environmental development progress is already being made. Madrid has recently implemented some of the world's most stringent air quality measures. When, air pollution levels breach the city's identified limits, Madrid will continue to impose vehicle bans within its central area. Longer term solutions to tackle the problem of air pollution are being planned, and this report will test several of the identified actions and inform decision makers on the relative carbon and air quality benefits.

Key Findings

Madrid 2020: Cleaner Air for a city of citizens, looks at an integrated way to deal with local air pollution in the short term and deliver carbon emissions reductions in the longer term.

Key findings of the analysis include:

1. Madrid has a real aim to deliver more results, faster and they have identified a short term, 20% carbon emissions reduction by 2020. Achieving this high reduction level over a short period of time means that Madrid will have to take bold actions. This analysis has determined that Madrid should deliver a plan that incorporates some form of city tolling, to reduce the numbers of cars actually being driven, incentivize a transition towards cleaner vehicles, such as electric buses (eBus) or compressed natural gas buses (CNG), and provide information to drivers on how to operate and drive their cars most efficiently, that this ambitious target can be met.

   These technologies were found to be the most effective for Madrid, but the total emissions reductions will be dependent upon how much of the technology is actually utilized, i.e. the take-up rates of technology. If Madrid were to deliver the tolling program and mandate that its entire bus fleet is comprised of either CNG or eBuses, and incentivize a high proportion of taxis and 10% of the general public to switch to electric vehicles, then Madrid could also meet its 2030 carbon emissions target aiming between reductions of 30% to 40%

2. City tolling is by far the most impactful solution modelled in this study delivering over 10% savings in CO_2, PM_{10} and NOx pollutants. City tolling is also the most cost effective solution delivering maximum emissions reductions at a lower cost than the rest of the technologies analyzed.

3. Coupled with achieving its 2030 CO_2 reduction target, the city must deal with the short term air quality challenge. This study has found that if the city concentrates on just four solutions, city tolling, alternative fuel buses, e-Taxi and eco-driver training, that it has considerable powers over, then PM_{10} and NOx levels could be reduced by 20% and 25% respectively.

Introducing the City Performance Tool (CyPT)

European cities stand at the forefront of sustainable development in the world. Global rankings regularly highlight their performance in terms of connectivity, mobility, and reduction of carbon emissions.

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} levels, improve air quality and add new jobs in the local economy.

The model takes over 200 data inputs from Madrid's transport and energy sectors, which includes the electricity generation mix and travel modal share. The model measures the impact of technologies on the city's CO_{2eq}, PM_{10} and NOx baseline, with CO_{2eq} accounting performed at scopes[1] 1, 2 and 3 levels for the energy and transport sectors.

The model also tests the performance of each technology on two economic indicators. Firstly, the total capital investment required to implement the technology together with the operational costs until 2025. Secondly, the model calculates the total number of jobs that could be created in the local economy.[2]

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

Starting with the city's population, electricity mix, kilometers traveled via public and private transport the model estimates the future impacts of technologies along the following three drivers:

1. **Cleaner underlying energy mix:** Shifting the energy generation mix from non-renewable to renewable energies (e.g., photovoltaic) and/or improving the efficiency of the current, fossil fuel, sources (e.g., Combined Cycle Gas Turbines)
2. **Improved energy efficiency:** Replacing existing technologies with more energy efficient technologies. For example replacing traditional street lighting with LED and/or demand oriented street lighting
3. **Transport Modal shift:** Modeling changes in the modal split of the city. For example by creating a new metro line, a city potentially moves passengers away from high-emitting cars into the Metro.

[1]The GHG Protocol further categorizes these direct and indirect emissions into three broad scopes:

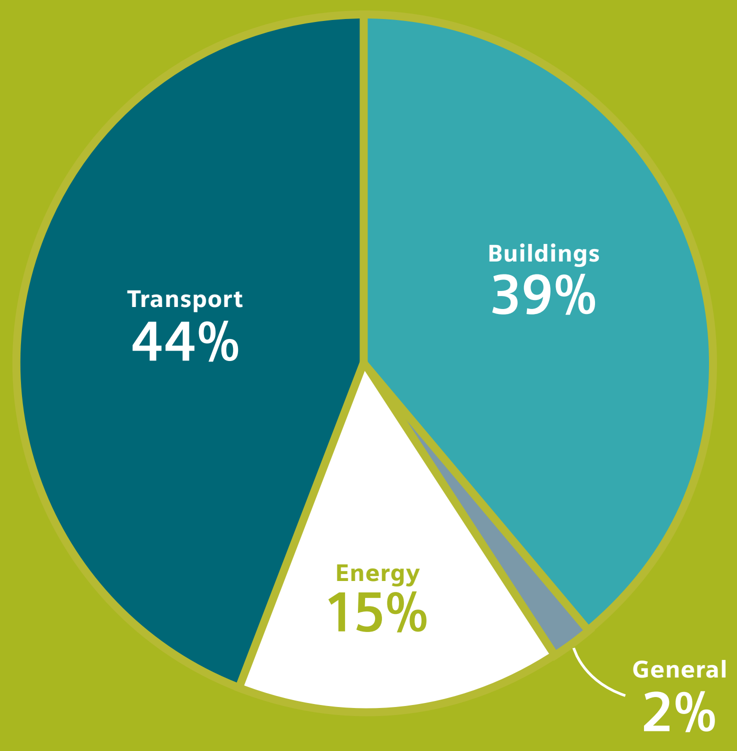
Scope 1: All direct GHG emissions.

Scope 2: Indirect GHG emissions from consumption of purchased electricity, heat or steam.

Scope 3: Other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities (e.g. T&D losses) not covered in Scope 2, outsourced activities, waste disposal, etc.

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

Figure 1: Number of data points by Sector



CyPT model has 350 data points, for Madrid we didn't consider Building Technologies sector that accounts for 150 data points.

Buildings

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

General

- Population
- Geographic Size
- Emissions targets

Energy

- Electricity mix
- Heating mix
- Emissions factors for fuels

Transport

- Annual passenger miles
- Freight ton miles
- Length of road network
- Length of highway network
- Length of highway network
- Bus, BRT, Street car, Metro, Commuter/Regional Rail, Taxis, Bicycles, Cars
- Etc.

Madrid's Transport Emissions

With a surface area of 606 km^2, Madrid covers less than 1% of total country land, yet it is home to nearly 7% of the total country population. As the nation's capital, Madrid wants to be an example of sustainable growth to the rest of the country, and it has been implementing a range of pollution mitigation initiatives since 2006.

Madrid's current emissions profile is unlike most cities where Siemens has carried out CyPT analysis because transport in Madrid is responsible for a far higher proportion of carbon emissions than in the other cities. This means that Madrid can impact a far larger proportion of its carbon emissions through transport. This is a positive point for Madrid as city government often has a stronger role in local transport than in other sectors and there is a greater opportunity to identify positive actions that the city could take.(Table 1).

A large part of Madrid's transport emissions are a result of its having a high level of private car use. One other negative effect of high car ridership is poor air quality. Madrid's air pollution problem is now so urgent that the city has experienced days in both 2015 and 2016 where air pollutants exceeded the permitted levels set by the European Union's Air Quality Directive. The problem was so severe that Madrid's leadership thought it was necessary to ban car traffic in the city center on the worst days. It's now a common sight to see a cloud of air pollutants covering the city. The problem is visible, and it is shaping public opinion. The local government sees that action must be taken and they are willing to make the bold decisions needed.

Last December, the new city government participated in The Sustainable Innovation Forum (SIF15) during the Conference of Parties (COP21) in Paris. It was at this event that the Madrid's new mayor, Manuela Carmena and Councilor for the Environment and Mobility, Ines Sabanes, announced new environmental targets for Madrid

	Aarhus	Copenhagen	Helsinki	Madrid
Transport related emissions	24%	20%	32%	41%
Buildings related emissions	76%	80%	68%	59%

Table 1: Buildings and Transport related emissions split in European cities where Siemens has carried out CyPT reports. Madrid stands out because of its higher transport emissions share

Targets:

- 20% CO_2 reductions by 2020 and 40% by 2030
- 35% reductions of total carbon emissions.
- 10% reduction of final consumption in energy
- 20% reduction of emissions linked with transport
- 25% reduction of energy use in public and government buildings

Increase public transport ridership

The city council has created a number of programs, strategies and plans to achieve these targets and try to make Madrid a more sustainable city:

The APR plan

The Residential Priority Areas (APR) were created to avoid creating more air pollution in certain areas of the city by restricting car use. Currently Madrid has four APRs within its municipal boundaries including: APR Letras, APR Embajadores, APR Opera and APR Cortes. Car entrance to these APR areas is monitored by cameras and license plate recognition softward to immediate check the environmental performance of a specific vehicle.

The Park & Commute initiative

Madrid has created around 27,000 parking spaces within its Park and Commute program. It is proposing to create 12 new locations just outside the city on the perimeters of the M-30 and M-40 highways. These new parking spaces will be located within walking distance to public transport stations. Overall, the park & ride program has the following targets:

- Reduce public transport journey times, and ensure that it is faster for most people to travel by public transport rather than private carLocate all spaces within a 3 to 4 minute walking distance of a public transport station or hub.
- Public transport should deliver a frequent service with only a 5-10 min waiting time between trains or buses.

The SER regulated parking initiative

The Regulated Parking Service aims at better managing, regulating and controlling parking in certain sections of the city's public roads, in order to streamline and harmonize the use of public space and parking vehicles.

In Madrid, there are two kinds of parking spaces; green spaces, where only local residents of a particular neighborhood can park at all hours, and a limit of 2 hours for all non-local vehicles and blue spaces where all vehicles are allowed to park but with a four hour limit.

Plan to renew taxi fleet

Madrid recognizes the need to upgrade the local taxi fleet to cleaner vehicles, and that this upgrade needs to be accompanied by some form of financial incentive to make the transition less of a financial burden. The city is preparing a program and a budget to help the taxi drivers replace their vehicles with more efficient hybrid or electric cars. The new vehicle's emissions will not be able to exceed 80 grams of CO_2/km. The program will provide rebates to the taxi drivers, of between €1,000 and €6,000, dependent upon the emissions levels of the new vehicles.

Shared Bicycles

BiciMAD, is Madrid's new shared public bicycle program. . It provides 100% electric bicycles, which are clean, healthy and a sustainable method of transport. This service is available for all citizens and visitors to the City of Madrid. The service includes 1,560 electric bikes distributed across 123 stations.

eCar Sharing – Emove and Car2go

There are now two private electric car sharing services, and Madrid is very supportive of their efforts to incentivize cleaner cars and to actually reduce the number of cars in the city.

As these cars are 100% local emissions free, drivers are able to park anywhere in the city for free.

The two companies have more than 800 cars already and more than 100.000 users in Madrid.

CyPT Baseline

We modeled over 7Mt of transport related CO_{2eq} emissions for Madrid in 2015, which make up over 40% of the city's overall greenhouse gas emissions. The predominant share of these emissions (6Mt) originates from private vehicles, with taxis and buses making up just under 800Kton. This emissions footprint is not surprising given that 62% of the total 23 billion passenger kilometers travelled in Madrid every year is by car.

Although the city's transportation modal split is dominated by private car use, over 30% of annual passenger kilometers in the city are taken by public transportation through the city's regional trains, metro and buses. Taxi use, motorcycles and bicycles make up the remaining 5%.

Madrid's high proportion of car usage is also behind the air pollutant levels in the city. Figures 4 & 5 show that over 80% of both PM10 and NOx pollutants are attributed to car trips in and around the city.

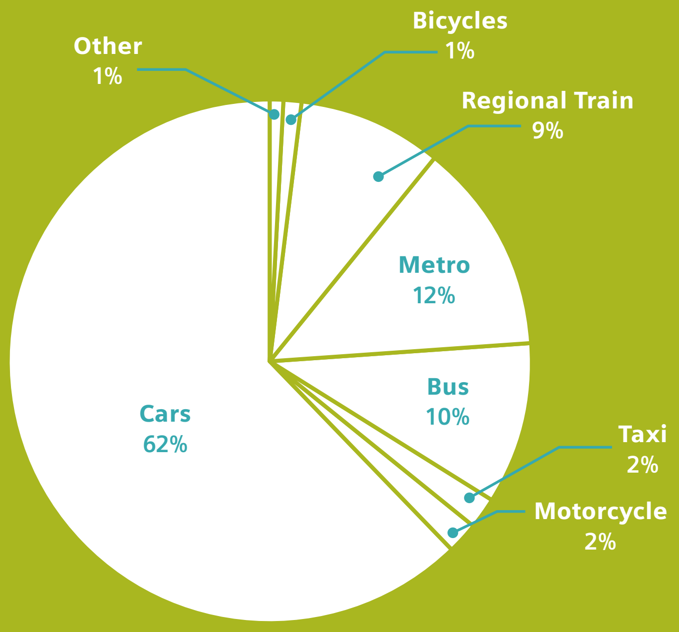


Figure 3: Madrid's transportation modal split as a percentage of annual passenger kilometers travelled

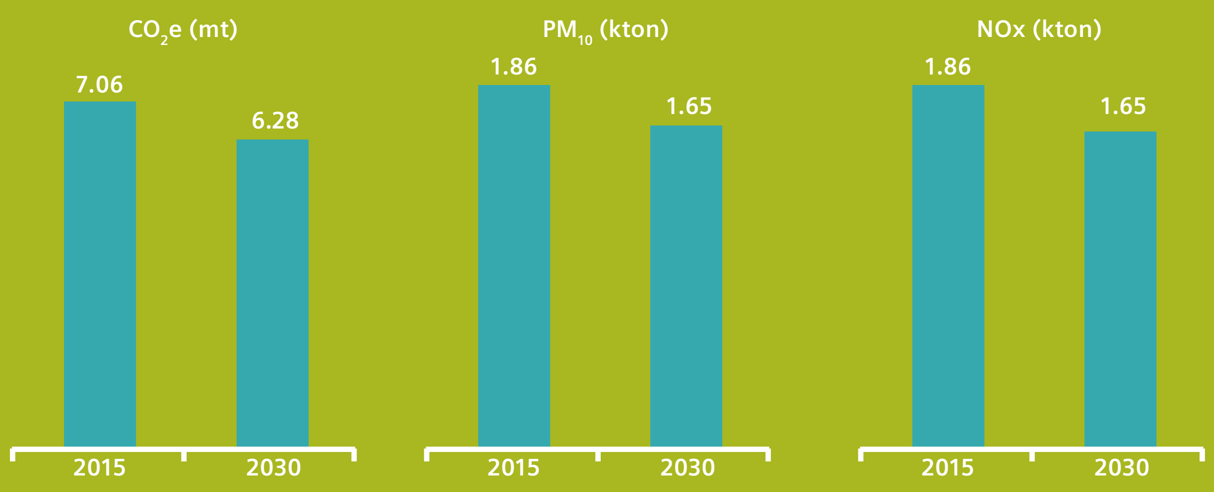


Figure 4: Madrid's transport emissions in 2015 and the estimated business as usual transport scenario in 2030. The estimated emission reductions are due to the city's planned transport investments, which are independent of the technologies modeled in this study

Break-down of Madrid's Greenhouse Gas Emissions from transportation

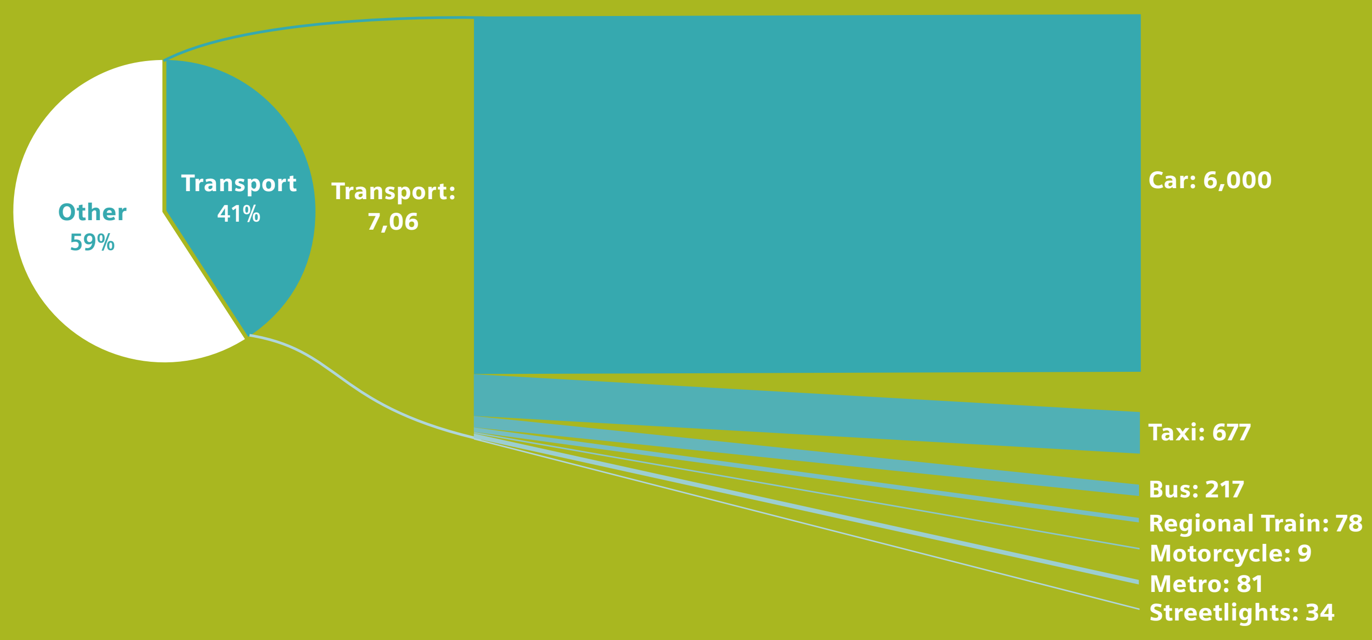


Figure 5: Greenhouse gas emissions in Madrid for the year 2015, which is used as the baseline in this study. Over 85% of transport related emissions originate from cars.

Breakdown of Madrid's PM_{10} and NOx emissions from transportation

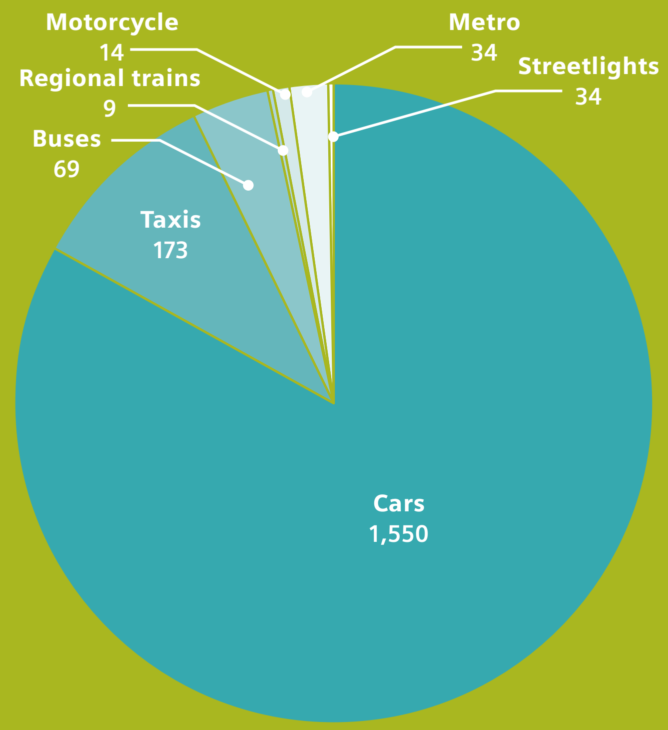


Figure 6: PM_{10} emissions in Madrid for the year 2015, which is used as the baseline in this study. Over 83% of transport related PM_{10} emissions originate from cars.

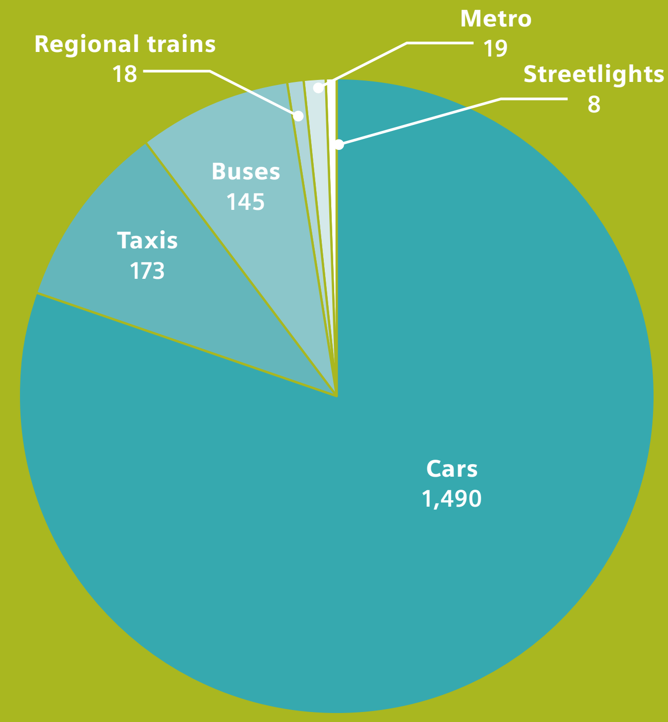


Figure 7: NOx emissions in Madrid for the year 2015, which is used as the baseline in this study. Over 80% of transport related NOx emissions originate from cars.

CyPT Scenarios

We tested the environmental performance of transport scenarios through four possible transportation futures in Madrid. The first scenario looked at a flagship Park and Commute project that the City of Madrid is designing that will shift transport demand from cars to trains.

The second scenario included the Park and Commute scheme from Scenario 1, and combined it with a City Tolling initiative. The tolling initiative is planned to reduce car use within the city boundaries by 20%, by charging drivers to enter the city.

The third scenario builds on the first two and adds take-up of cleaner vehicles across the city. Finally, scenario 4, models all of the aforementioned technologies with a cleaner electricity mix that benefits from a higher proportion of electricity from renewable sources.

Scenario 1

Park & commute

Scenario 2

Scenario 1 +

City Tolling

Scenario 3

Scenario 1 + 2 +

Cleaner Vehicles

Scenario 4

Scenario 1 + 2 + 3 +

Cleaner Electricity

Overall ten technologies were modeled, as outlined in the table below. Implementation rates were also assumed for each technology. Looking at these solutions in more detail, five out of the ten technologies can be deployed by the city itself. The remaining five technologies rely on households, businesses and utility companies to provide the investment:

1. Park & Commute: The city is proposing to build park and commute infrastructure in key locations within a short walking distance from train stations around Madrid's ring road. There are currently 27,000 parking spaces within the city, and this proposal will add a further 9,500 spaces across 12 new locations. These new locations will be just outside of the city on the perimeters of the M-30 and M-40 highways, far away from the congested city center. In the CyPT model, we have calculated that the 17,000 spaces will be utilized at 80% capacity with one vehicle occupying a space throughout the day assuming a typical morning and evening commute. This level of utilization will result in a 0.5% change in travel demand from car to trains.

2. City Tolling: Siemens modeled a system of city tolling based on Automatic Number Plate Recognition technologies (ANPR) that record and charge vehicles that enter and leave a central ring around the city. Based on the performance of other city tolling initiatives in cities such as London, a 20% decrease in car use was assumed.

3. New Vehicles: A number of the technologies modeled in this study involve the replacement of city buses and private vehicles.

4. Cleaner Electricity: The final set of technologies modeled in this study involve cleaning up the electricity mix that feeds into the city through implementing wind power and solar photovoltaic solutions. Current planned investments to 2030 already

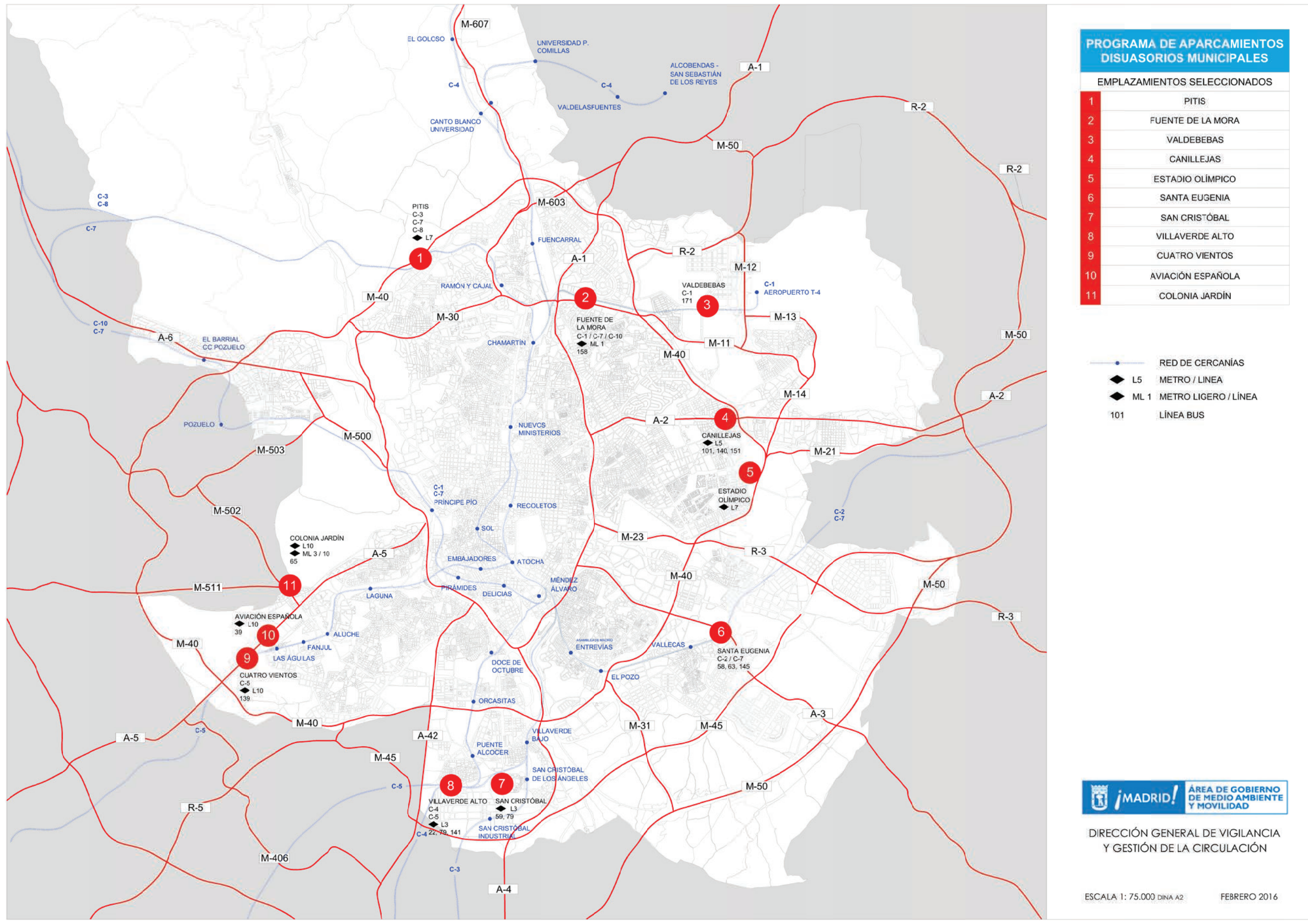
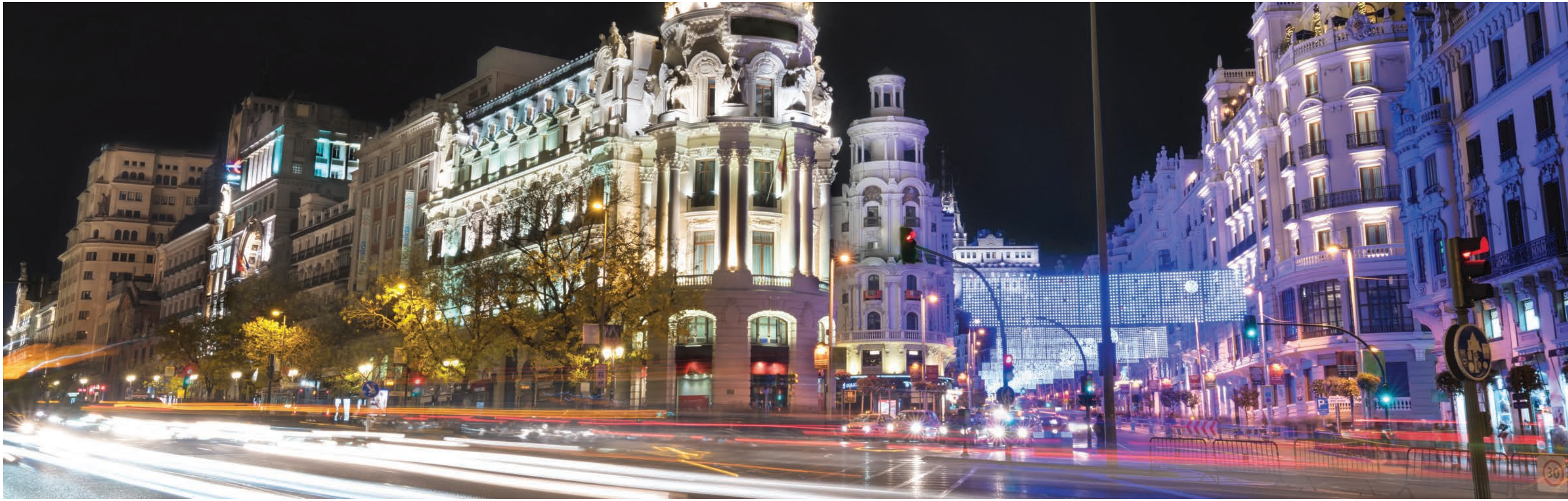


Figure 8: Map showing location of new parking facilities next to transit stops in the junction of major roads and the M-30 and M-40 ring roads



Scenario	Technology lever	Unit	2030 Business as Usual	2030 CyPT Implementation rates	Effective Implementation rates
Scenario 1	Park and Commute	% change in travel demand from car to trains	0.0%	0.5%	0.5%
Scenario 2	City Tolling (20%)	% reduction in car traffic	0.0%	20.0%	20.0%
Scenario 3	cBus (30%)	% of fleet replaced	1.0%	30.0%	29.0%
Scenario 3	eCar (10%)	% of cars replaced	0.1%	10.0%	9.9%
Scenario 3	Plug-in Hybrid Car (10%)	% of cars replaced	0.3%	10.0%	9.7%
Scenario 3	eTaxi (70%)	% of taxis replaced	1.0%	70.0%	69.0%
Scenario 3	Eco Driver Training (30%)	% of drivers trained	0.0%	30.0%	30.0%
Scenario 3	CNG Bus (70%)	% of fleet replaced	41.3%	70.0%	28.7%
Scenario 4	Wind Power	% of electricity consumption	19.6%	25.0%	5.4%
Scenario 4	Photovoltaic	% of electricity consumption	4.6%	10.0%	5.4%

Table 2: Buildings and Transport related emissions split in European cities where Siemens has carried out CyPT reports. Madrid stands out because of its higher transport emissions share

About Siemens

Infrastructure is the backbone of a city's economy and urban development projects help to create a livable and sustainable smart city. With automated and intelligent infrastructure technologies, Siemens expertise is integrating hardware and software to improve quality of life, capacity and efficiency in metropolitan areas. Siemens established the Global Center of Competence Cities for Cities to specifically address the needs of urban planners and to enter into a structured dialogue and base lining assessment with urban decision makers.

CyPT Results

Greenhouse gas emissions

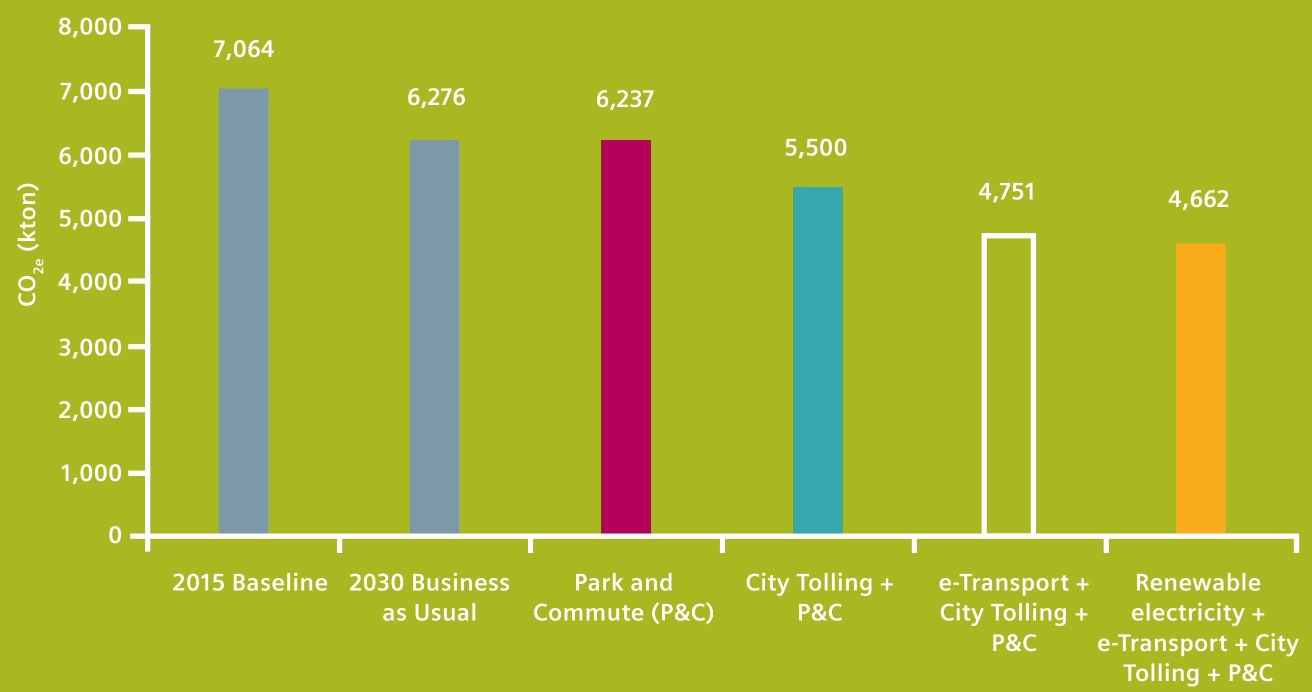


Figure 9: Emission reductions by scenario type. Madrid can achieve its target of reducing transport emissions by 20% by 2030 by delivering its current investments and adding either the city tolling or e-transport initiatives. Both the park and commute and renewable energy scenarios have lower impacts.

Carbon savings by technologies

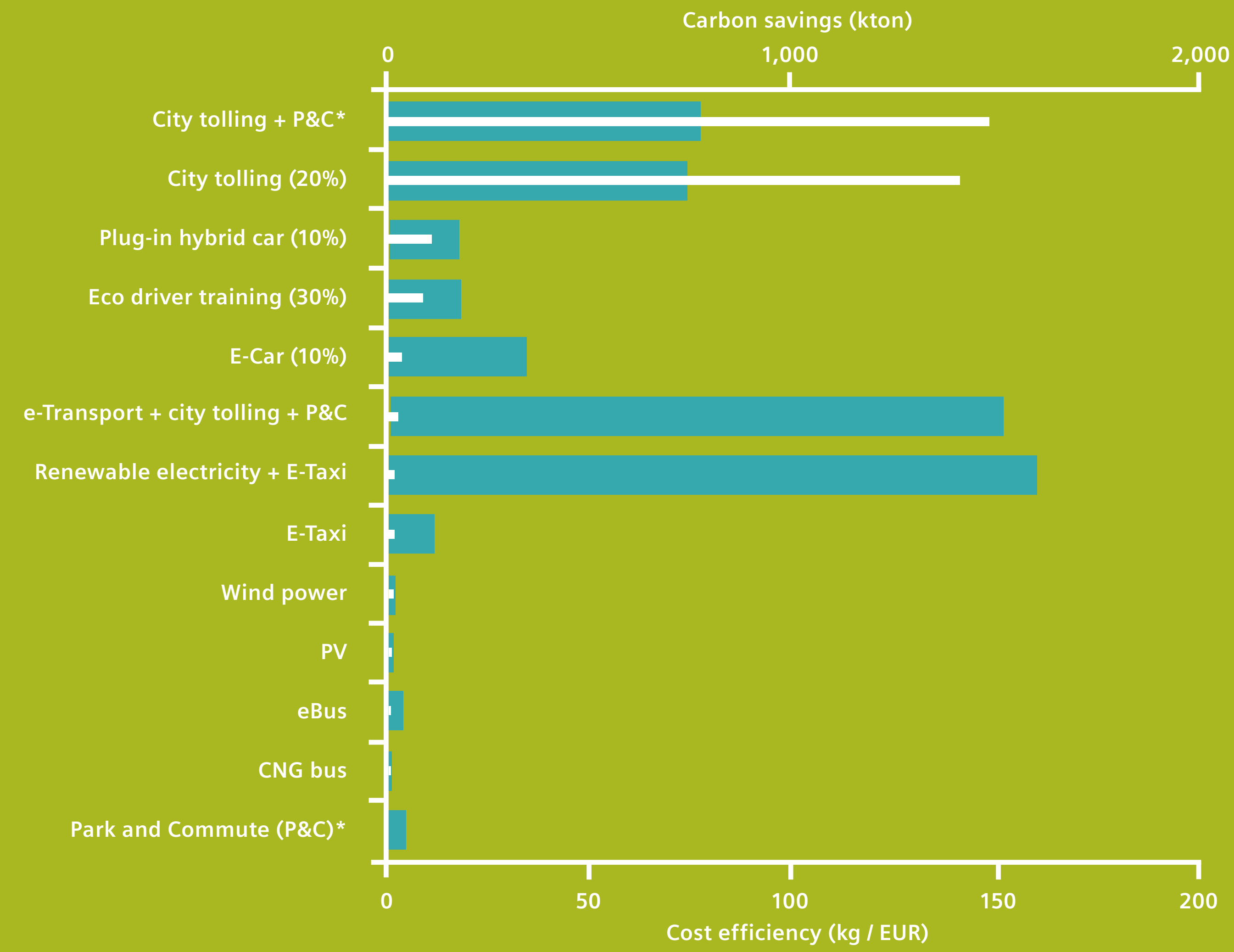


Figure 10: % CO_{2eq} savings for each of the transportation technologies modelled in the study. The % on the y-axis indicate the implementation rate

*) We have not calculated CAPEX for Park and Commute (P&C) solution.

Business as usual:

Without any investment in the CyPT technologies modeled in this study, transport related annual emissions in the city of Madrid will decrease from 7Mt in 2015 to 6.3Mt in 2030, a 10% decrease as shown in figure 9, as a consequence of assuming an increase of cleaner cars and fuel source on the next years. Although this is significant, it does still mean that there is a 10% shortfall in the city's target to reduce transport related emissions by 20% by 2030.

With further investments

Our study has shown that the city can achieve its 2030 target through delivering either of two options. The first option is to invest in a city tolling initiative with an aim to reduce car usage by 20%. The second option is to fully replace all buses with an alternative fuel sourced vehicle and a portion of the taxi and private car fleet with cleaner fueled vehicles. Compared to the 2030 Business as Usual scenario, city tolling provides another 11.8% CO_{2eq} emission savings and cleaner vehicles another 12%.

Looking at the performance of each of the technologies, city tolling is by far the most impactful solution saving over 12% of CO_{2eq} emissions in 2030. The next most impactful options include transitioning to cleaner vehicles and modifying driving styles to save energy use (eco-driver training). A combination of eco driver training and replacement of the city's current car fleet with eCars and plug-in hybrid cars could further reduce annual emissions by nearly 10%.

Particulate matter 10

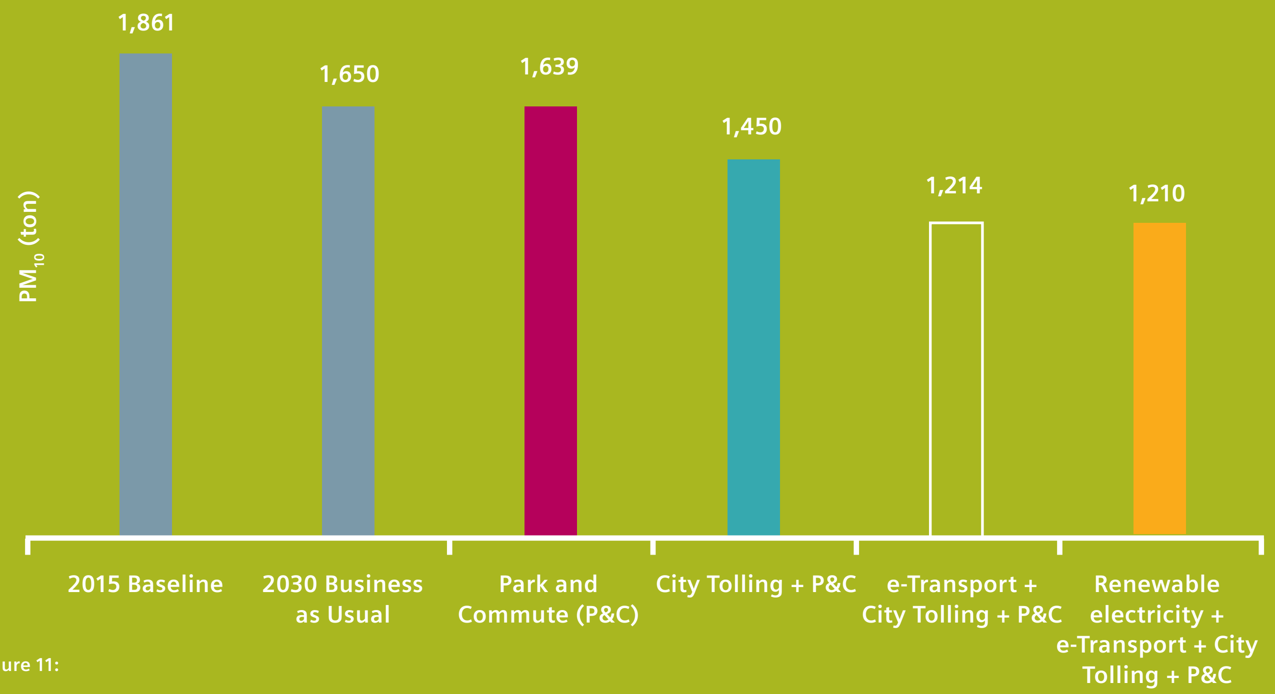


Figure 11:

Carbon savings by technologies

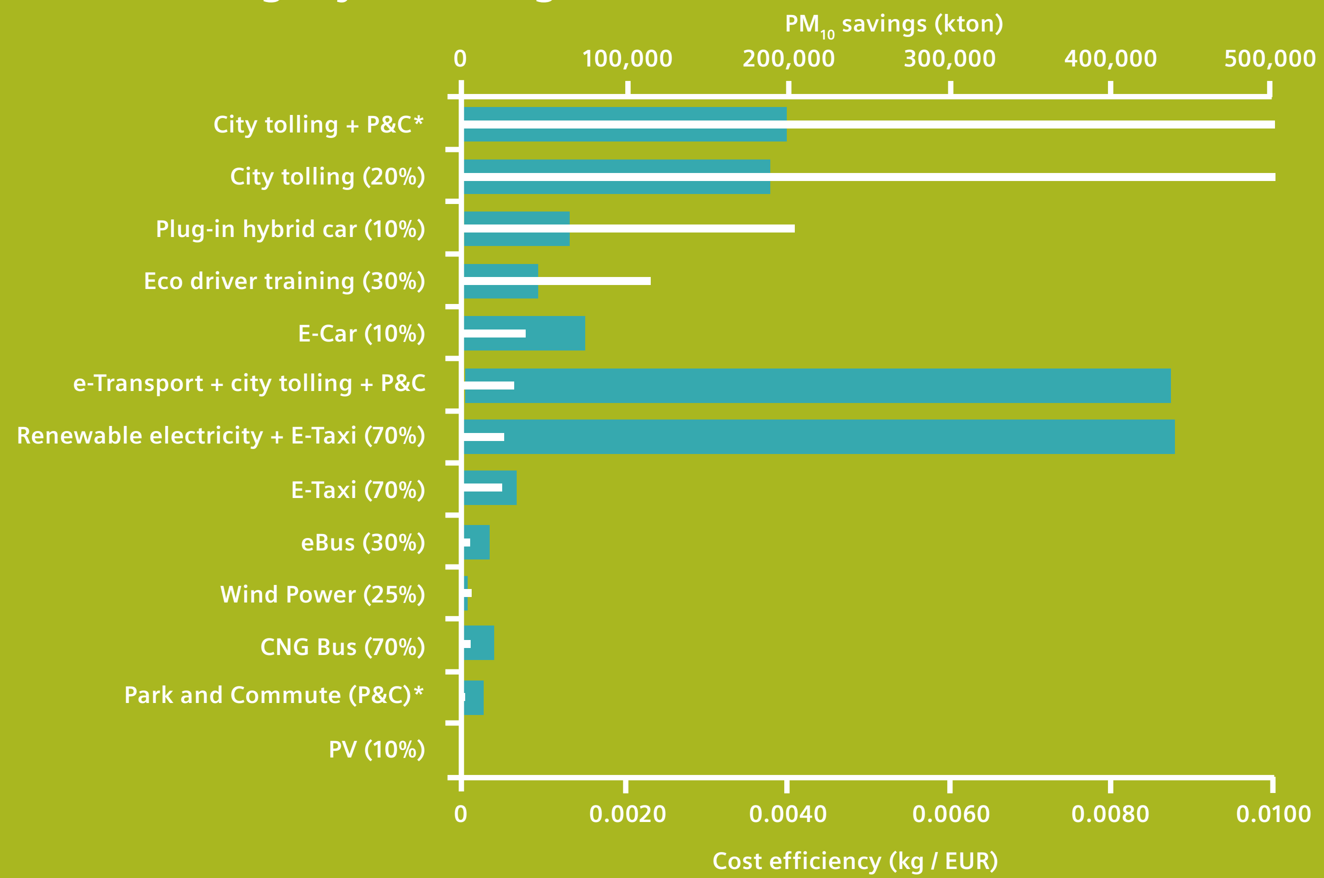


Figure 13: Performance of scenarios and individual technologies in terms of PM_{10} savings
*) We have not calculated CAPEX for Park and Commute (P&C) solution.

NOx

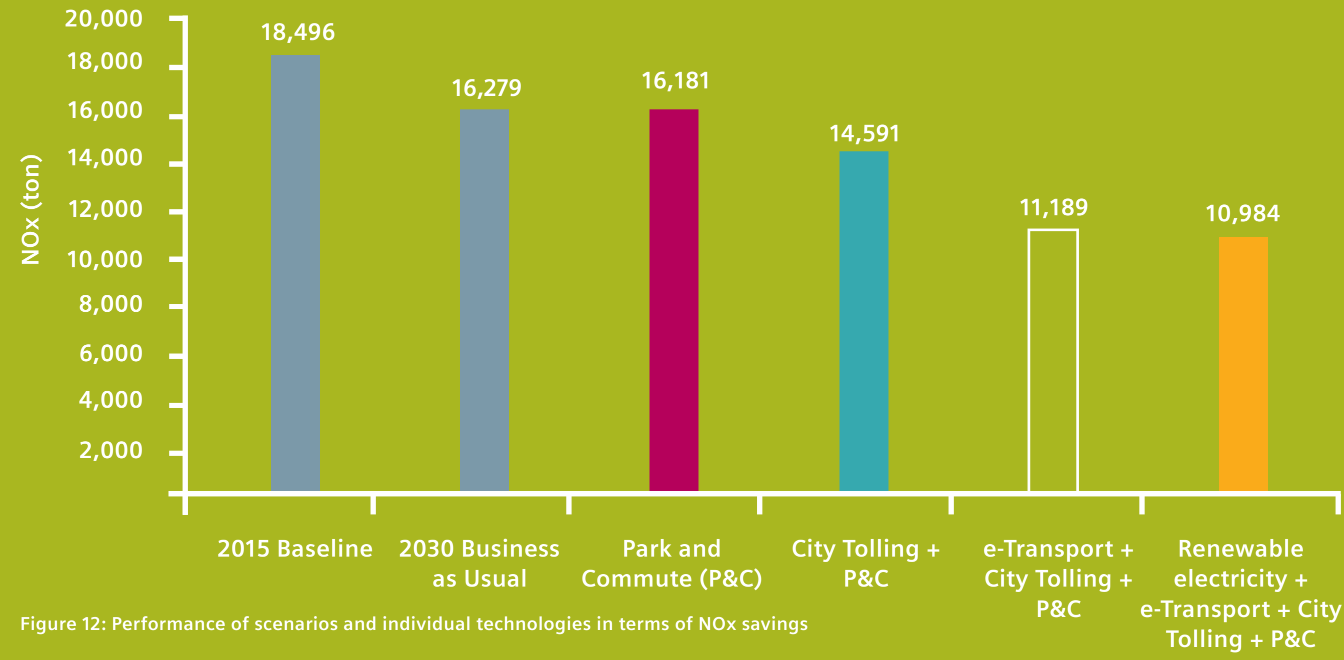


Figure 12: Performance of scenarios and individual technologies in terms of NOx savings

Carbon savings by technologies

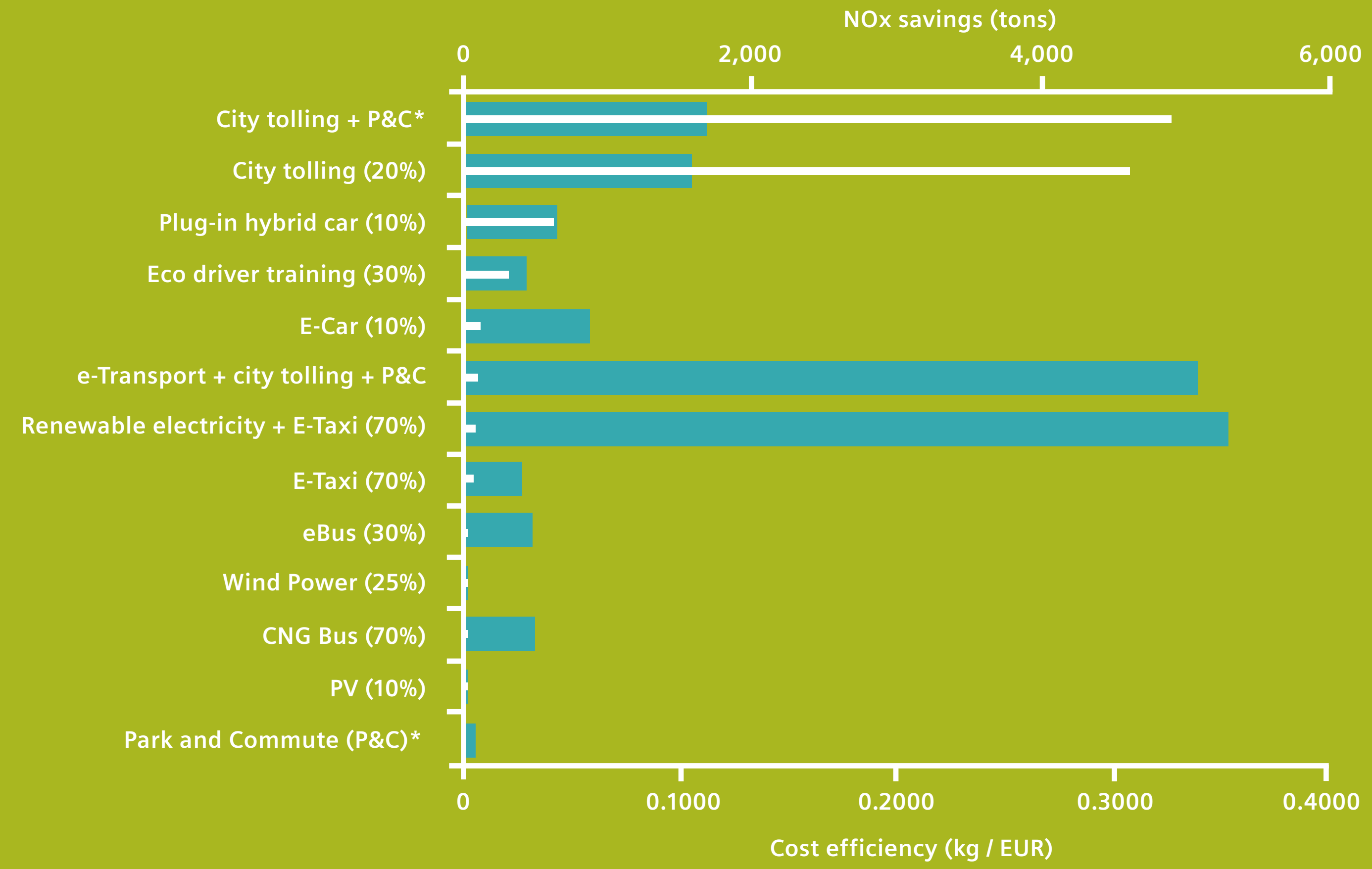


Figure 14: Cost effectiveness of transport technologies. The longer the grey bar, the more this technology reduces the relevant pollutant. The longer the orange bar, the more cost effective this technology is at reducing the pollutant in terms of capital invested by the city.
(*) We have not calculated CAPEX for Park and Commute (P&C) solution.

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Lever	GHG %	PM10 %	NOx %
City Tolling (20%)	11.8%	11.5%	9.8%
E-Car (10%)	5.5%	4.5%	5.4%
Plug-in Hybrid Car (10%)	2.8%	3.9%	4.1%
CNG Bus (70%)	0.1%	1.1%	3.1%
eBus (30%)	0.6%	1.0%	3.1%
Eco Driver Training (30%)	2.8%	2.8%	2.7%
E-Taxi (70%)	1.7%	1.9%	2.2%
Park and Commute (P&C)	0.6%	0.6%	0.6%
Wind Power (25%)	0.2%	0.1%	0.2%
PV (10%)	0.2%	0.0%	0.2%

Table 3: Performance of technologies across the three KPIs. % of Savings

How should Madrid prioritise the delivery of these technologies when taking into account the three key air quality performance indicators? Table 3 shows the savings for each of the technologies on the three KPIs modelled. In green are a set of five technologies that deliver good impacts across all indicators. City tolling is by far the most impactful solution delivering over 10% emissions savings for CO_{2eq}, PM_{10} and NOx.

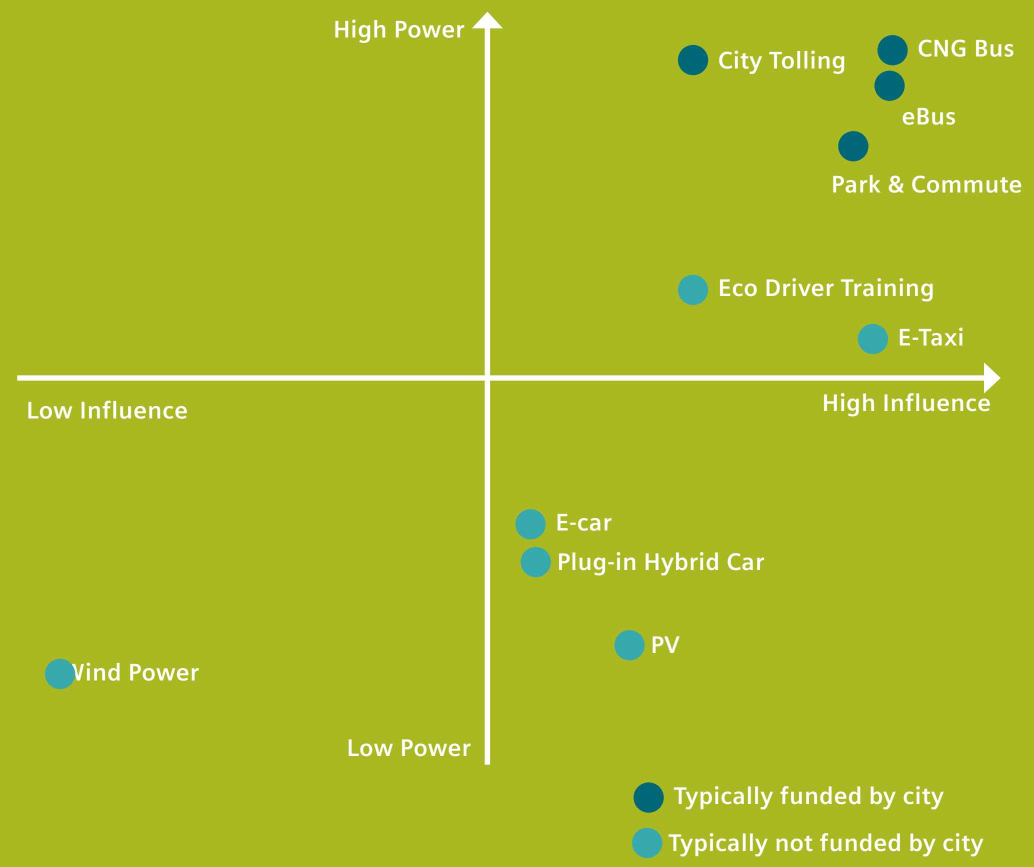
The Park and Commute initiative, although delivering very modest savings, should not be scrapped because it will reduce congestion and create transport options. The city should consider increasing the 9,500 parking spaces that were modelled in the study. This of course must be a temporary solution with more and more cars being replaced by public transportation commutes.

Although the alternative bus solutions provide moderately high NOx savings, the relative low modal split usage of buses in the city (see figure 2), makes these solutions less impactful. However, cleaner buses are a very noticeable action and cities should consider them in order to facilitate a wider change in perceptions.

Finally, although alternative energy sources may have large impacts on the carbon footprint of Madrid's building emissions it will not have a significant impact on transport emissions because very little of the transport rail system is electrified. However, should Madrid wish to comprehensively address air quality then the rail transport should be electrified and incentives such as the Commute and Ride program should be continued to entice people to use the rail system more often. This is important, as today only about 20% of annual passenger kilometres are travelled on the regional trains and metros.

Only 4 technologies improve air quality in 20% by 2020

Figure 15: Siemens analysis on the influence and power that the city has over the deployment of technologies. Power indicates a technology that will typically be funded by the city. Influence indicates a city's capacity to work with partners to deliver the solution. We assumed that the city will have full powers over new bus vehicle purchase, but have reduced on implementing city tolling which would require the buy-in of many stakeholders. Although the city has lesser powers over private vehicle purchases and driver training it will have more influence over planning regulations to allow the installation of rooftop photovoltaic panels compared to the heavy capital investment of wind power driven by utility companies.



Some of the world's climate leading cities have achieved large greenhouse mitigation gains by closely selecting the solutions that they have most power to deliver. Often known as the low hanging fruit, these are typically solutions that the city strongly regulates controls or finances.

For Madrid, although the 2030 targets are clear and realistic in terms of reductions in CO_{2eq} levels, the air quality pollutants are a more urgent priority that needs addressing today. In this study, we also looked at some quick win solutions that the city can start deploying and see benefits over the next few years to 2020.

We chose just four technologies based on their high potential to improving air quality as well as the relative power that the city has to deliver the solution. Figure 15 is an assessment of the power that a city has over public transportation, and its ability to influence or incentivise alternative car purchases. The four technologies that were modelled in this short term scenario all lie in the top right quadrant of the graph. This means that the city has the necessary powers to implement this technology or it has a strong ability to influence businesses and households to invest in the solution.

The results from this short term scenario show that the city can decrease PM_{10} and Co_2 levels by 20% and NOx levels by 25% compared to annual levels today. Technologies that sit in the later quarter of the list, along with alternatively fuelled vehicles can be supported by the city immediately through an number of initiatives. Box 1 introduces some international approaches to achieve this end.

Short term scenario	Unit	Implementation rates
ebus	Bus fleet	30%
Eco driver training	Drivers	30%
CNG Bus	Bus fleet	70%
City Tolling	Traffic reduction	20%

Table 4: Air quality improvements by 2020 through four technologies that the city has relatively high powers to implement

Case Studies – Car fuel alternatives

Oslo

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

Rotterdam

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

San Francisco

The City if San Francisco boasts more electric vehicles per capita of chargers-per-electric than any other city in the U.S. The availability of charging stations remains one of the main dissuading reasons not to purchase electric vehicles. .To address this concern, the City of San Francisco incentivizes people by facilitating chargers for the private sector, so that whoever wants to install one can do so without bureaucratic hurdles, while also facilitating state-level grants and a streamlined permitting processes. In addition, the state of California recently passed a building code mandating that a certain portion of new developments come pre-wired for electric vehicle chargers. San Francisco is also working on its own code, which will be see even stricter building rules that favor electric mobility. Moreover, the city installed three off-the-grid solar-powered charging station, which allow electric vehicle owners to pull up and charge their cars for free.

Conclusion: Delivering the change

This report has looked at ways that Madrid can reduce harmful air pollutants in a timely and realistic way. Today, transport emissions comprise over 40% of the city's emissions footprint. The vast majority of these emissions are related to car use, which is responsible for over 80% of CO_2, PM_{10} and NOx pollutants. For Madrid to meet its aim to empower its citizens socially and economically it needs to address its poor air quality.

Short-term 2020

- Madrid could meet its short-term emissions target by taking significant action today. This would mean that the city would need tackle the areas where it has considerable influence first, by significantly reducing traffic in the worst polluted areas potentially through a tolling mechanism. The city would need to fully convert is public fleet to alternative fuel vehicles and provide advice and training on how to drive cars in the most energy efficient way.
- As shown on figure 13, two of these technologies (city tolling and eco-driver training) are also a very cost effective way at reducing air pollutants. More importantly, these same two technologies provide the necessary long term benefits of CO_2 reductions as well as reducing air pollutants in the city in the short term over the next five years.
- Madrid must also in the very short term start to fully deliver its plan for eCars including publicizing the benefits of driving an eCar, such as free parking. The city must also ensure that eCar charging points are delivered across the city and into other parts of Spain as well. In the very short term when there are likely not be charging points across Spain it may make sense to first transition the city's car fleet to electric and to market specifically at two-car families, with the concept of having an electric City car.

2030 Target

- **Our findings show that it is possible for Madrid to meet its greenhouse gas emissions targets by 2030 irrespective of whether it was able to meet the ambitious 2020 target.**
- **Our business as usual has identified that a 10% carbon emissions reduction would likely naturally occur due to improved car performance.**
- **The remaining 20% to 30% of carbon emissions savings would need to be sourced by either delivering the tolling mechanism with a potential to reduce emissions by 20%.**
- **Madrid has another option to achieve the required savings through the transitioning of all public buses, 70% of taxi fleet and 20% of private car fleet to alternative fuelled vehicles.**
- **From an air quality perspective, the most impactful technologies are a city tolling mechanism, eCars, plug-in-hybrid cars, eTaxis and eco-driver training and information.**

Improving Madrid's air quality will require decisive action and a local infrastructure that can support eCars. Madrid's best options for improving air quality are first delivering some sort of a tolling mechanism to reduce the number of cars being driven within the city center. This decision will also positively impact local congestion and could speed the movement of buses across the city. The second key action is for the city to incentivize uptake of as many alternative fuel vehicles as it can. City action plus getting the people of Madrid to change how they move across the city by using more public transport or purchasing cleaner vehicles will have the most potential to clean Madrid's air and to make it truly a city for its citizens.

Appendix: Technology Glossary

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.

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.

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 PM_{10}, NOx. A fast charging infrastructure is set up The electricity used for charging is generated according to the general local electricity mix.

Plug in hybrid cars

Share of conventional combustion vehicles replaced by Plug-in hybrid electric vehicles at target year. Small combustion engine for base energy demand combined with an electric drive for acceleration and for brake energy recuperation. Energy demand is reduced due to a higher efficiency of the combustion engine, operating at optimum and brake energy recuperation together with related emissions.

CNG buses

Share of conventional combustion vehicles replaced by compressed natural gas vehicles. Reduction of local emissions PM_{10}, NOx. Energy demand is reduced due to a higher efficiency of the combustion engine together with related emissions.

Eco driving

Trainings on eco-driving techniques promote awareness about driver behavior, increasing average fuel economy for a city's car fleet.

Impact on emissions reduction: Impacts depend on car modal share. Reduction of energy demand per person kilometer results in related emissions reduction.

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.

Notes

Siemens can work in partnership with the government and cities to develop and deliver technology solutions across a wide range of sectors.

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:

Francisco Rincón
Siemens Spain
email: francisco.rincon@siemens.com

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

Macarena Vila-Onieva
Global Center of Competence Cities
macarena.vila-onieva@siemens.com