SIEMENS

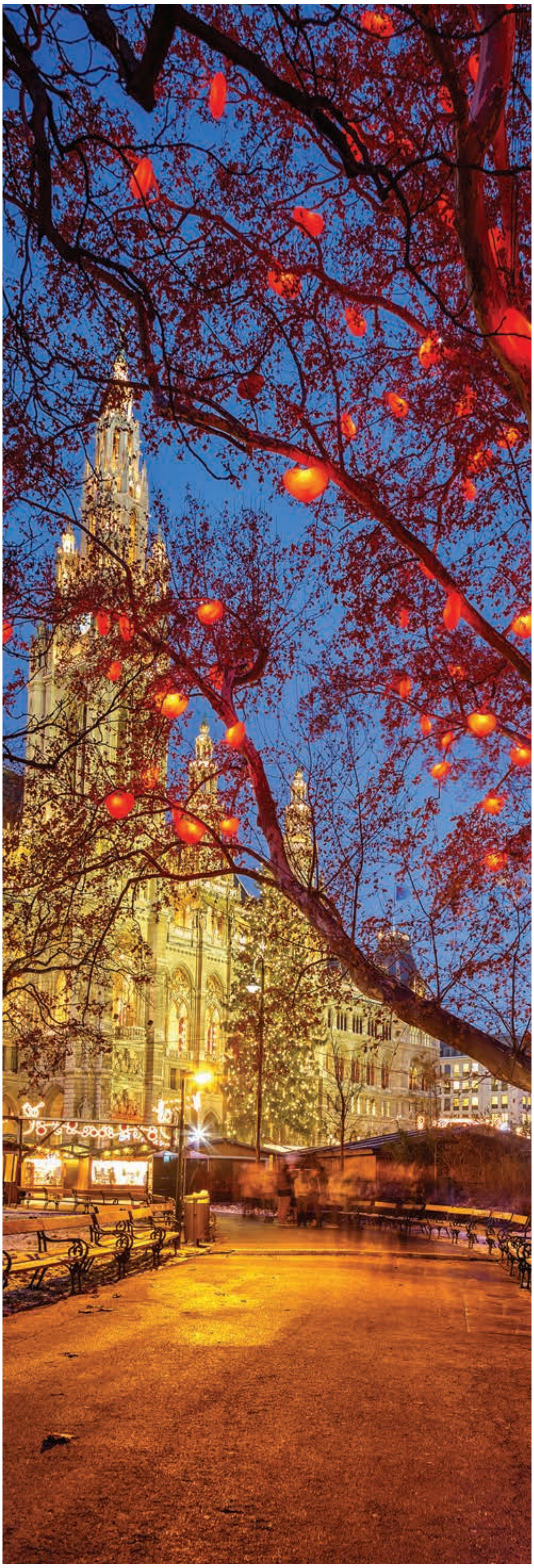
Vienna 2025

Comparing the benefits of Vienna's infrastructure choices

Siemens Report - October 2014

Siemens Centre of Competence Cities – Urban Development

Vienna has set 2025 as the ambitious target year for the city to implement major infrastructure technologies in order to meet its environmental and economic targets. This study quantifies the benefits of over thirty building, energy and transport technologies and makes recommendations of which infrastructure solutions the city should be prioritising in the run up to 2025.



Results from the study show that...

- **Vienna is cost efficient but mitigation must be accelerated:** This study tested some of the technologies in Vienna's KLiP I and II programmes and found that these solutions are cost effective in reducing CO_2 eq. levels and improving air quality. However, the city will need to implement more of these intensive carbon reduction technologies if it is to meet its 2030 targets.

- **Vienna can meet its 2030 targets by 2025:** An investment of €8 bn over the next decade is needed to implement a set of technologies in the energy, building and transport sectors that can reduce CO_2 eq. emissions in Vienna by 9 Mt and add 85,000 full time equivalent jobs to the local economy.

- **Focus on transport:** Vienna should increase the implementation rates of transport technologies, which provide the most cost effective way to reduce CO_2 emissions and improve air quality. In this model, the city is currently achieving its reductions predominantly through building and energy technologies that are more expensive and do not improve air quality as effectively.

- **Implement cutting edge technologies:** Vienna has some untapped cost effective technology opportunities to meet its CO_2 mitigation targets. In the energy sector, the city should continue its implementation of combined heat and power. In the transport sector, the city should invest in new cutting edge technologies such as intermodal traffic management applications, electric car and electric taxi solutions. These are win-win cost effective solutions that tackle CO_2 emissions, improve air quality and increase local jobs.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Introduction

Vienna stands at the forefront of sustainable development in the world. Global rankings regularly highlight Vienna's performance in terms of connectivity, mobility, and reduction of carbon emissions. The city however is constantly striving to test the cost efficiency of its current infrastructure solutions and explore new, more effective technologies that will help it meet it environmental targets.

Over the last 12 months, Siemens has worked with a group of selected experts of the City of Vienna to compare the environmental and economic benefits of some of the city's more traditional technologies such as wall insulation and double glazing with more cutting edge technologies such as intermodal traffic management and e-Taxis that Vienna is considering implementing in the future. These technologies were split into three scenarios each representing their stage of implementation in the city. The first scenario, called Vienna First, uses current technologies that are in an advanced state of implementation and that will continue to be implemented in the city towards 2025. These are the type of technologies that were included in Vienna's very successful KLiP I, carbon mitigation programme. The second scenario, Vienna Accelerated, takes some of the city's existing technologies that it wants to rapidly increase implementation rates. The final scenario, Vienna Experimental, is an experimental set of technologies that the city wants to test in the next decade.

Using Siemens' proprietary City Performance Tool (CyPT), the group of experts of the city was able to compare the opportunity costs of choosing one technology over another in the run up to 2025 in meeting its CO_2 targets. The CyPT further helped the city experts to identify win-win solutions that simultaneously improve air quality and add the greatest number of local jobs at the lowest cost to the city.

This report seeks to identify these win-win technologies and quantify their benefits to the city over the next eleven years. It will first summarise progress that has been made in Vienna since 1990 in reducing its CO_2 emissions and identify sectors where the city could be doing more. The second section will outline the methodology and the model that was used in the study and the implementation rates used for each of the technologies. The main findings section will quantify the benefits of each technology and recommend which sectors and which technologies Vienna should be investing in the next decade.

In 1999, the City Council of Vienna adopted KLiP I, the city's climate protection programme. KLiP I was constituted of 241 individual measures. The 10–year programme reached its target of cutting its emissions of CO_2 equivalent by 2.6 Mt in 2006—three years early. By 2008, Vienna had reduced its emissions by 3.1 Mt of CO_2 equivalent[1], surpassing its initial target.

In 2009, the climate protection programme was renewed for another ten years (KLiP II) proposing 385 individual measures and an objective or reducing CO_2 emissions by a further 1.4 Mt.[2]

These new measures are grouped in five themes: energy generation; energy use; mobility and urban structure; procurement, waste management, agriculture and forestry, environmental protection; awareness raising and public information.

By 2011, in comparison to 1990, Vienna had reduced its greenhouse gas emissions by 3.7 Mt. This represents a reduction of 21% per capita and 10% in absolute figures[3].

While KLiP III (2020-2030) is already being discussed, Vienna announces its ambition to reduce greenhouse gas emission by 35% by 2030, and by 80% by 2050.

To support these programmes, the city launched Smart City Vienna, a long-term initiative whose aims are to promote and foster a "smart city" approach towards Vienna's development. Vienna's approach towards "smart city" is very holistic and includes three main themes: the development of sustainable resources (energy, transport, infrastructure, building efficiency); innovation (education, economics, R&D); and quality of life (environment, health, social inclusion).

Vienna's progress: The KLiP programmes

Through their programmes KLiP I and II, and their long-term "Smart City" initiative, Vienna has started addressing carbon emissions and sustainability regarding the three sectors—building, energy, transport—addressed in this white paper.

In terms of energy, KLiP I proposed three programmes fostering the development of district heating (Öko-fernwärme), energy production from renewable energies (Öko-Strom), and combined heat and power (Cogeneration), which is one of the technologies that will be tested in the model. While the percentage of energy produced through district heating stagnated from 1990 to 2007, the proportion of renewable energy more than doubled, going from providing 4.9% of Vienna consumption in 1990, to 11.4 in 2007.

In terms of buildings, KLiP I proposed five main programmes to increase housing energy consumption and reduce its production of GHG. Among these programmes, Thermoprofit, which aimed at optimising the thermal insulation of 220,000 homes – again another solution that will be tested in the model.

1. City of Vienna (2012) Findings of the Austrian Energy Agency's progress report. Vienna.
2. ibid
3. ibid

The KLiP programmes

KLiP I's transport chapter is by far the most ambitions, with no less than 16 programmes. The measures set out in KLiP I ranges from increasing the amount of areas limited to 30 km/hour (Lebenswerte Stadt), policies encouraging Vienna residents to walk (Gut zu Fuss im Wien), increasing the percentage of journeys made by cycling (Kommt Zeit — kommt Rad), the development of car sharing (Mobilitätsverbund) and carpooling (CarPooling), or the development of alternative energies for cars (Bio.Elektro)[4]. A number of these new car solutions will be analysed in this study.

KLiP II amplifies Vienna's effort towards reducing their GHG emissions, proposing 37 sets and 385 individual measures. These include setting new targets for existing programmes such as district heating, the development of renewable energies, improving building insulation and the development of further cycle lanes. New measures are also implemented, such as pedestrian-friendly traffic lights, underground lines extensions, facilitating different transports intermodality and interoperability, the development of energy-saving trams, the implementation of hybrid and electric powered buses. Some of these technologies have been chosen in this study and tested against other infrastructure solutions that the city could be exploring.

4. City of Vienna (1999) Klimaschutzprogramm Wien. Vienna.

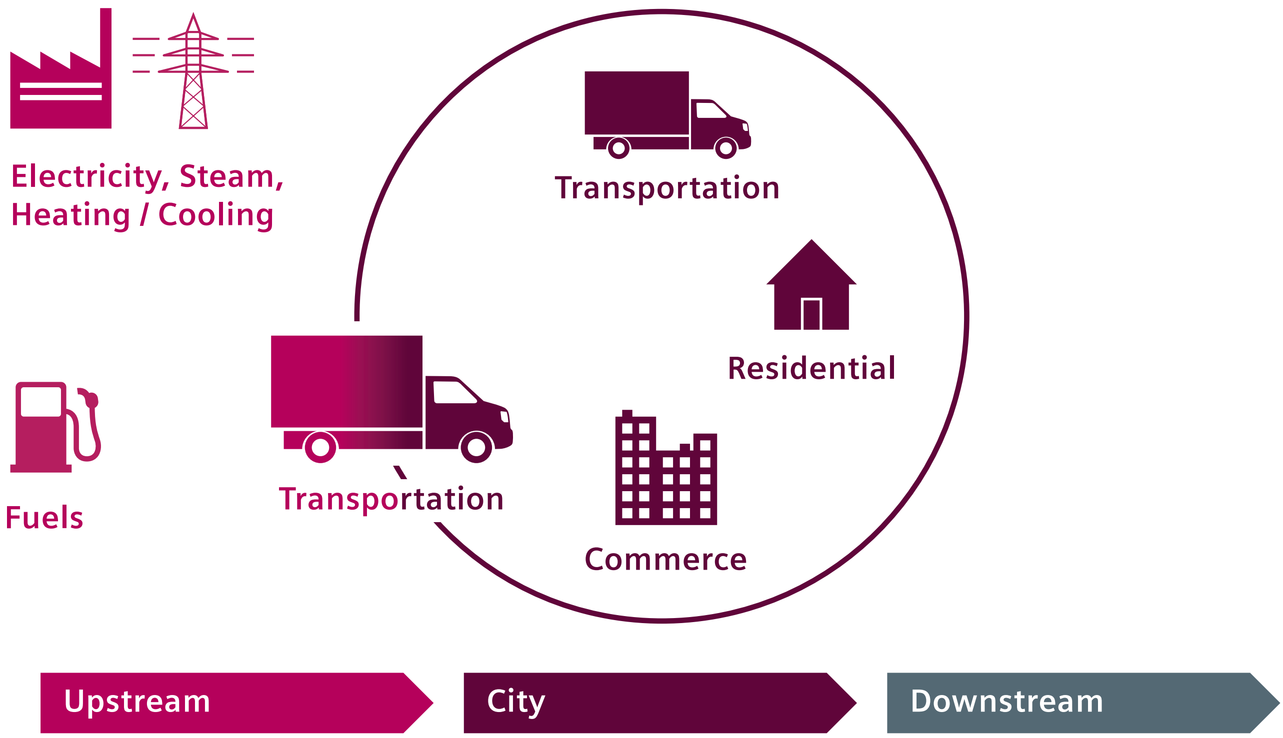
	KLiP I	KLiP II
Residential Wall Insulation	Yes	Yes
Residential Glazing	Yes	Yes
Commercial Wall Insulation	Yes	Yes
Commercial Glazing	Yes	Yes
LED Street Lighting	No	Yes
ATO Metro	Yes	Yes
Hybrid Electric Cars	Yes	Yes
Intermodal Traffic Management	No	Yes
CNG Cars	Yes	Yes
CHP	Yes	Yes
Residential Efficient Lighting	No	No
Home Energy Monitoring	No	No
Commercial efficient Lighting	No	No
Demand Oriented Lighting	No	No
Building Efficiency Monitoring	No	Yes
Building performance Optimisation	No	Yes
Demand Controlled Ventilation	No	No
Metro New Line	No	No
Bike Sharing	Yes	Yes
Electric Buses	No	Yes
Plug-In Hybrid Electric Cars	No	Yes
Intelligent Traffic Light Management	No	No
Photovoltaic	Yes	Yes
Home Automation	No	No
Heat Recovery	No	No
Hybrid Electric Bus	No	Yes
Electric Cars	No	Yes
Electric Taxis	No	Yes
Intelligent Street Lighting	No	No
Electric Cars Sharing	No	No

Figure 1: A large proportion of the technologies tested in the model form part of Vienna's previous and current climate plans

Methodology

Siemens has developed the City Performance Tool (CyPT) to understand the extent to which green technologies from the transport, building and energy sectors improve CO_2 and air quality (measured in PM_{10} and NO_X level reductions) whilst driving local job creation. The tool relies on proprietary Siemens data on the environmental performance of actual technologies currently being implemented by cities across the world. The CyPT also includes non-Siemens technologies to allow both the company and the cities to compare a full spectrum of solutions from diverse technology sectors.

Figure 2: CO_2 eq. emissions that are measured in the CyPT model



Model

The model takes over 300 inputs from Vienna's transport, energy and buildings sectors, which include the energy mix of electricity generation and transport modalities and typical energy, travel and building space demand. Siemens assembled a baseline for the energy, buildings and transport sectors of the city that was verified by Vienna's experts before the model was run.

The model relies on the city choosing the implementation rate of technologies and measures the impact of these technologies on the CO_2 eq., PM_{10} and NO_x baselines of the city. CO_2 eq. accounting is performed at scopes 1, 2 and 3 levels for the building and transport sectors as is shown on figure 2.

The model also tests the performance of each technology on two economic indicators. Firstly, the total capital investment to implement the technology together with the operation costs to operate and maintain the system until 2025. Secondly, the model calculates the total number of jobs that will be created in the local economy. These include installation, operation and maintenance jobs, which are calculated as full time equivalent jobs of 1760 hours. Manufacturing jobs are not accounted because some of these technologies may be produced outside the city's functional area, with no local benefits to the economy.

Workshops

Out of a possible list of 36 technologies, the city of Vienna decided to test 31 technologies that were relevant to the city. This narrowing down of technologies was carried out in two separate workshops that brought together city planners from the energy, urban development, planning and climate departments with experts from Siemens' urban development and corporate technology teams.

Methodology

Baseline

Without the implementation of any technologies, Vienna's annual Greenhouse Gas Emissions are 9.8 Mt of CO_2 eq., their PM_{10} emissions are 2.1 kt/a while Vienna's NO_X emissions stands at 21.1 kt/a. With a population of 1,741,275 in 2014, Vienna's GHG per capita emissions are 5.63 tons of CO_2 equivalent.

The modal split of transportation relies heavily on cars and subway. Cars represent 37.4% of the journeys (person kilometers) while subway accounts for 27.8% of journeys. Altogether, public transports (city, regional and interregional trains, subway, tram, bus and bus rapid transit) account for 49.8% of the journeys in Vienna. Cycling and walking respectively account for 3.3% and 5.4% of the modal split, or 8.7% altogether. The personal transportation demand for Vienna is 6,688 million person/km per year, while the freight transportation demand is 4,242 thousands of tons per kilometer per year.

The electricity energy mix of Vienna relies heavily on natural gas, as it represents 76.2% of the energy used in the city. Nuclear and coal are inexistent, while renewable energies account for 16.62% of Vienna's energy mix. The breakdown of renewable energies is 0.02% for photovoltaic energies, 0.2% for power generation from wind, 2.7% from biomass and the renewable energies' lion's share for hydropower with 13.7% of Vienna's total energy mix.

When it comes to the building sector, Vienna includes over 800,000 households with average occupancies of two people per household. An average of 39.9 m^2 of residential space is taken by each inhabitant, and 19.2 m^2 per capita is needed on average for non-residential buildings. As of today, the total residential electricity demand is 33.07 kilowatt hour/m^2 per year, and 87.53 for non-residential demand.

Some of the key figures from this baseline that was collected by Siemens and verified by Vienna's experts are include in figure 3.

Energy	
Natural Gas	76.2%
Heavy Fuel Oil	6%
Hydropower	13.7%
Biomass	2.7%
Windpower	0.2%
Photovoltaic	0.02%
Total renewable energies	16.62%

Transport	
Urban personal transportation demand of city per year [person/km per year]	6,688,249,911
Walking	5.4%
Bicycle	3.3%
Interregional Train	3.9%
City Train	0.45%
Subway	27.8%
Tram	9.49%
Bus Rapid Transit	2.51%
Bus	5.66%
Taxi	4.06%
Car	37.45%
Freight transportation demand of city per year, road and rail [tonnes/km per year]	4,242,399,000
Freight Lorry	81%
Freight Rail	19%

Buildings	
Households [count]	838,430
Number of persons per household	1.99
Area of residential buildings per inhabitant [m^2/inhabitant]	39.88
Total electricity residential demand in baseline [kilowatt hour/m^2 per year]	33.07
Area of non-residential buildings per inhabitant [m^2/inhabitant]	19.2
Total electricity non-residential demand in baseline [kilowatt hour/m^2 per year]	87.53

Figure 3: Key figures from Vienna's baseline

Methodology

Lever choices and implementation

The CyPT implementation and lever choices are organized around three scenarios: Vienna First, Vienna Accelerated and Vienna Experimental. The levers and their implementation rates were selected and adjusted during workshops organized by Siemens with Viennese City officials. The scenario "First" models the technologies, which are already being implemented by the city of Vienna. Vienna Accelerated looks at technologies that are in the process of being implemented in programmes such as KLiP II or being currently considered by Vienna. Finally Vienna Experimental explores technologies that the city wants to investigate further before it considers them for implementation in the city.

The 31 technologies are distributed between three sectors: building (13 levers), transport (16 levers) and energy (2 levers). For each lever three implementation rates are available and the city chose a rate that it considered feasible to deliver in the run up to 2025. These levers and their relevant implementation rates are shown in figure 4.

The three scenarios rely significantly on building levers, as their implementation rates are much higher. Thus, for Vienna First and Vienna Accelerated all the building levers are at their maximum implementation rates. In contrast transport lever implementation rates are low.

Vienna First

Lever	Implementation		
Increases CHP Contribution	10% of mix	20% of mix	30% of mix
Residential Wall Insulation	1% of stock/ year	3% of stock/ year	5% of stock/ year
Residential Double / Triple Glazing	1% of stock/ year	3% of stock/ year	5% of stock/ year
Commercial Wall Insulation	1% of stock/ year	3% of stock/ year	5% of stock/ year
Commercial Double / Triple Glazing	1% of stock/ year	3% of stock/ year	5% of stock/ year
LED Street Lighting	30% replacement	70% replacement	100% replacement
Metro – Automated Train Operation (ATO)	30% of lines	70% of lines	100% of lines
CNG Cars	20% replacement	50% replacement	70% replacement
Hybrid Electric Vehicles	20% replacement	50% replacement	70% replacement
Intermodal Traffic Management	30% of users	70% of users	100% of users

Selected rate

Vienna Accelerated

Lever	Implementation		
Photovoltaic Power Generation	10% of mix	20% of mix	30% of mix
Residential Efficient Lighting	3% of stock/ year	5% of stock/ year	8% of stock/ year
Residential Home Energy Monitoring	3% of stock/ year	5% of stock/ year	8% of stock/ year
Commercial Efficient Lighting	3% of stock/ year	5% of stock/ year	8% of stock/ year
Commercial Demand Oriented Lighting	3% of stock/ year	5% of stock/ year	8% of stock/ year
Commercial Building Efficiency Monitoring	1% of stock/ year	3% of stock/ year	5% of stock/ year
Commercial Building Performance Optimisation	1% of stock/ year	3% of stock/ year	5% of stock/ year
Demand Controlled Ventilation	1% of stock/ year	3% of stock/ year	5% of stock/ year
Metro – New Line	1 line	2 lines	3 lines
Urban Bike Sharing	3/1000 people	7/1000 people	10/1000 people
Electric Bus	20% of fleet	70% of fleet	100% of fleet
Plug-In Hybrid Electric Car	20% replacement	50% replacement	70% replacement
Intelligent Traffic Light Management	30% of lights	70% of lights	100% of lights

Vienna Experimantal

Lever	Implementation		
Residential Home Automation	1% of stock/ year	3% of stock/ year	5% of stock/ year
Commercial Heat Recovery	1% of stock/ year	3% of stock/ year	5% of stock/ year
Hybrid Electric Bus	30% of fleet	70% of fleet	100% of fleet
Train – Automated Train Operation (ATO)	30% of fleet	70% of fleet	100% of fleet
Electric Cars	20% of fleet	50% of fleet	70% of fleet
Electric Taxis	30% of fleet	70% of fleet	100% of fleet
Demand Oriented Street Lighting	30% of lights	70% of lights	100% of lights
Electric Car Sharing	1/1000 vehicles	2/1000 vehicles	3/1000 vehicles

Figure 4: List of technologies and implementation rates that the city of Vienna decided to model in the CyPT

1. Vienna's cost-effective solutions

Assuming that the technologies chosen in the Vienna First scenario are indicative of technologies that the city has been implementing since 1990, the city has explored the most cost effective ways to improve air quality and reduce carbon emissions. When the three scenarios were compared in terms of carbon emissions per cost of investment over their lifespan, Vienna First technologies were by far the most cost effective, saving 22 kg of CO_2 for every euro of investment. This compares very well with the Vienna Accelerated and Vienna Experimental technologies that save 7 kg of CO_2 and 5 kg of CO_2 respectively.

The very same technologies in the Vienna First model are also the most cost effective at improving air quality and reducing PM_{10} levels, saving more than four times more PM_{10} particulates per € of investment spent over their life time.

Figure 5 shows these scenario comparisons together with the number of jobs that each of these set of technologies are adding to the city economy. Again, the Vienna First technologies return very good job figures with nearly 46,000 FTE jobs, compared to the 20,000 FTE jobs of the more experimental technologies. When these job figures are related to the CO_2 eq. savings, the traditional technologies create nearly 8,000 jobs per megatonne of CO_2 eq. savings compared to 6,000 jobs for the Vienna Experimental technologies.

These results suggest that the city has already explored those technologies that provide environmental benefits at the lowest cost to the tax payer.

Results & Analysis

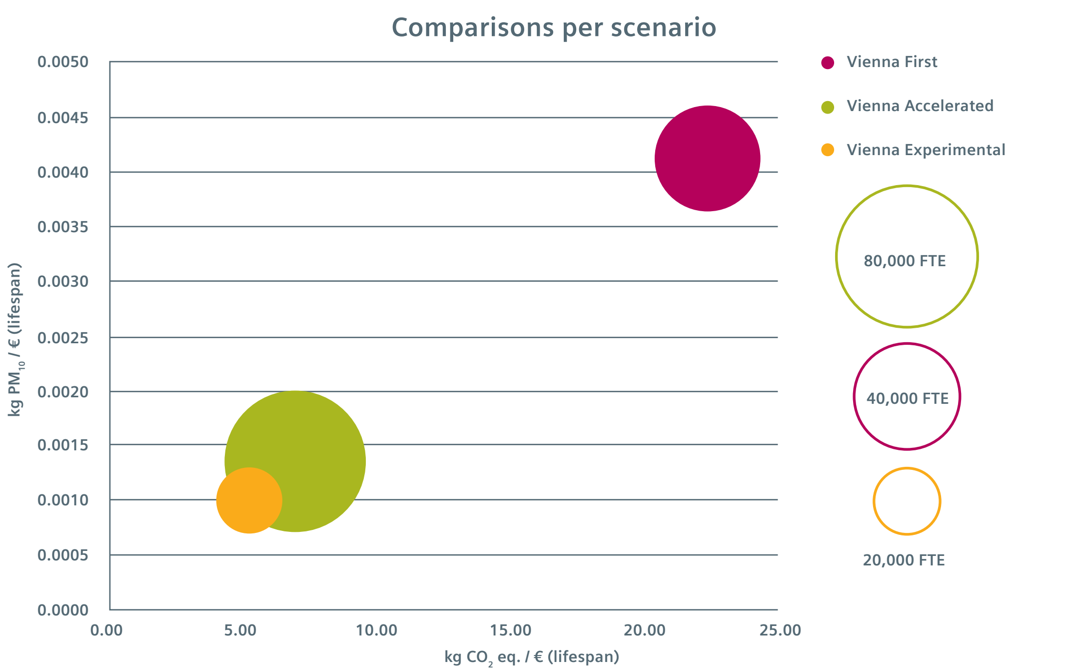


Figure 5: CO_2 and PM_{10} improvements per € of investment. The size of the bubble refers to the number of full time equivalent jobs created

When unpacking the mitigation per investment potential of individual technologies, it is clear that the city is taking advantage of the good returns of wall insulation and Combined Heat and Power that provide 8 kg CO_2 eq. and 36 kg CO_2 eq. for every euro of investment spent. These were key initiatives in Vienna's KLiP I and KLiP II programmes.

Results & Analysis

However, new cost efficient technologies such as intermodal traffic management can be explored further. Intermodal traffic management smart phone applications, which help users decide which mode of transport to take to minimise their CO_2 eq., can save up to 140 kg of CO_2 eq. for every euro of investment, when all users follow the application's suggested trip choices. Figure 6, shows the CO_2 eq. reductions to cost ratios compared to wall insulation, which is set as a benchmark. Technologies on the light red side of the diagram are more cost effective at lowering CO_2 eq. emissions than wall insulation which was one of the most important actions in the KLiP I programme.

Although the cost efficiencies of intermodal traffic management look encouraging, it does not necessarily mean that in the short and medium term, these technologies will be able to meet the ambitious emissions targets of the city. As we will show in the next section some of these cost effective solutions are affordable but do not reduce CO_2 levels sufficiently. Their CO_2 eq. savings / € ratio may be good but the total CO_2 savings are insufficient.

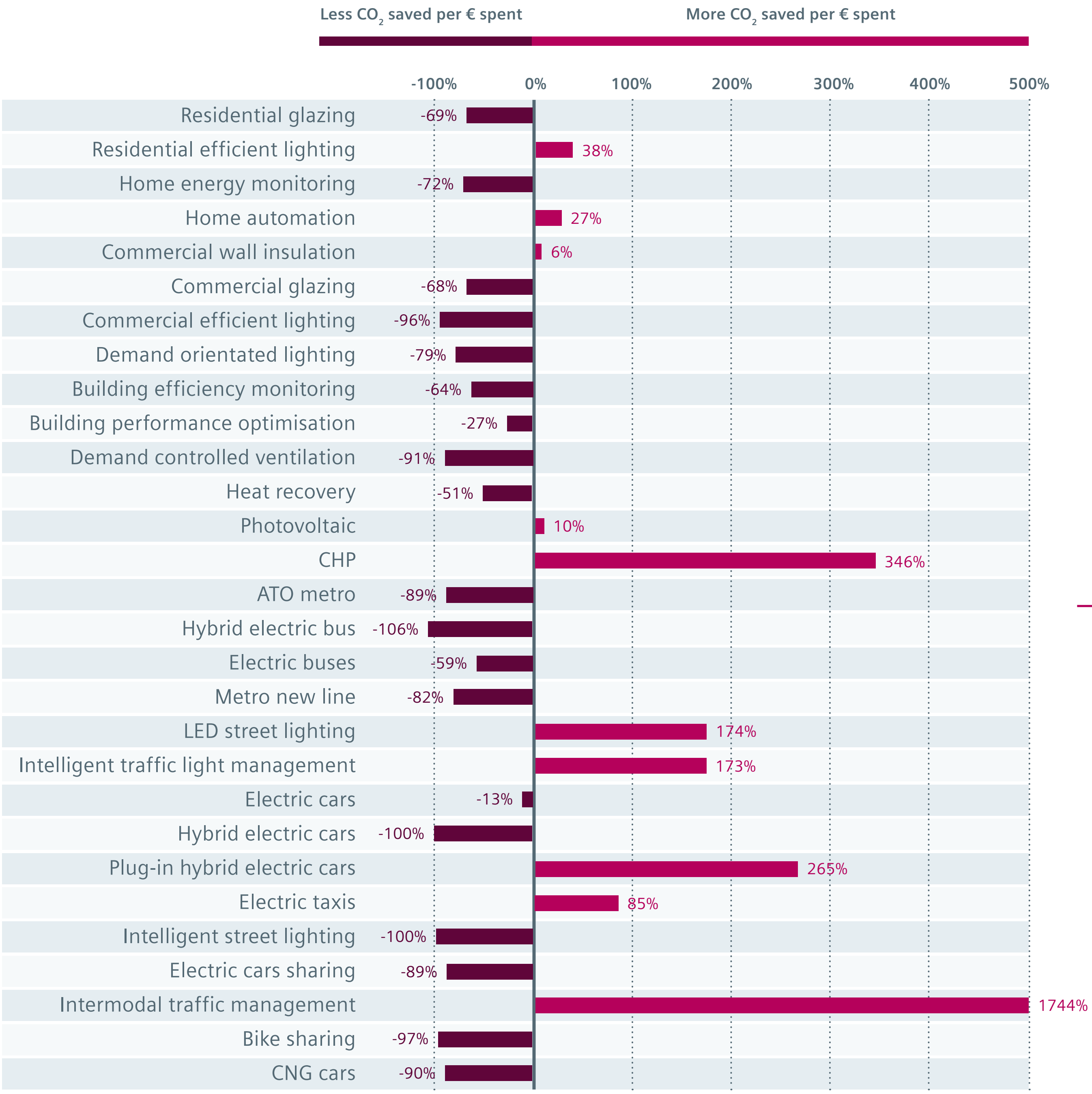


Figure 6: Comparing the CO_2 eq. to € ratio for technologies to the wall insulation ration benchmark, set at 100%

2. Vienna needs to implement more cost effective technologies if it is to meet its 2030 targets

Over the next eleven years, the traditional technologies in the Vienna First model will save 6 Mt of CO_2 eq. emissions which compares poorly with the nearly 10 Mt of CO_2 eq. emissions saved by the Vienna Accelerated technologies over the same period.

Figure 7, shows the reductions that the city of Vienna has achieved since 1990 and the potential reductions that can be achieved by the city choosing one of the three scenarios. If the city proceeds with the Vienna First technologies that are already at a high level of implementation, the city will achieve its 2030 emissions targets by 2033. It will fall short by three years. Because the CyPT model is very ambitious with the implementation rate of the technologies (as seen when comparing the CO_2 eq. savings of the scenarios with the savings achieved by the city since 1990), the city risks to delay its ambitious targets further if the rates of implementation are dropped when the city is delivering these technologies.

The more realistic scenario that the city can choose is the Vienna Accelerated one, where the 2030 CO_2 eq. targets will be reached by 2025. Again, the city needs to be realistic and allow for a drop in implementation rates for the targets to be achieved by 2030.

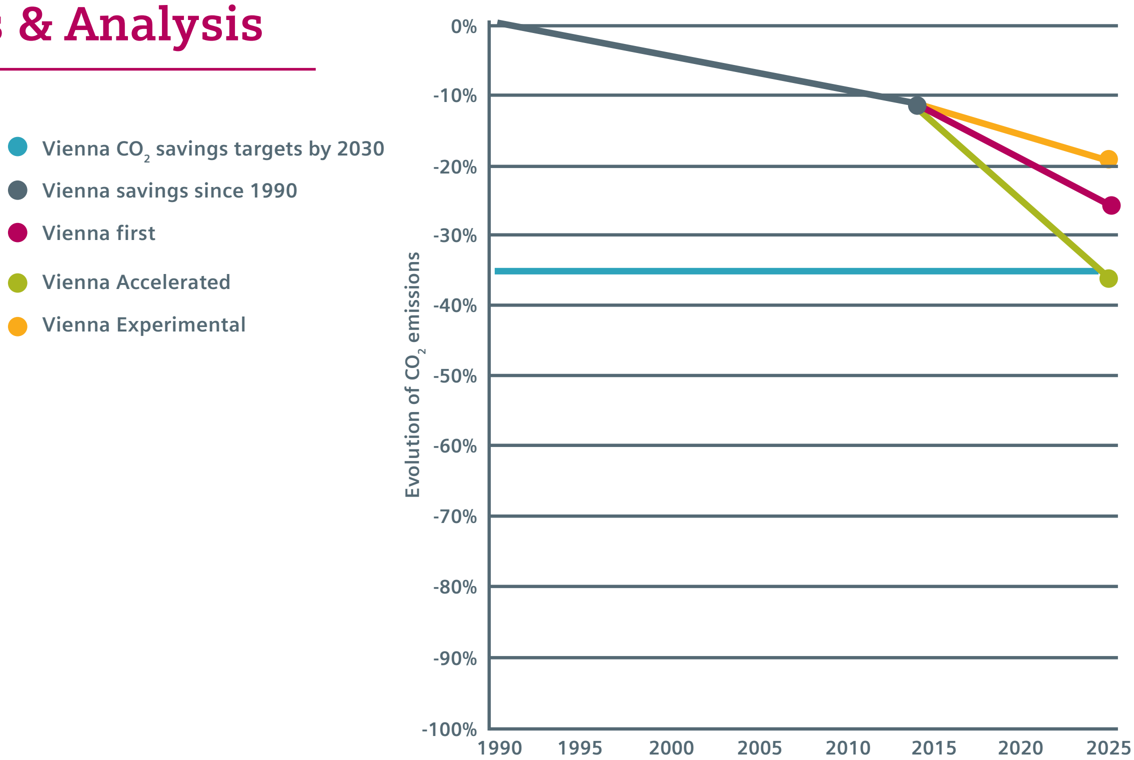
What are the technologies within each scenario that are driving these changes? Figure 8 (far right), shows the total CO_2 eq., PM_{10} and NO_X savings for each of the technologies in the three scenarios. In dark green are results with large benefits and in red those with poorer results.

Although the building technologies and combined heat and power in the Vienna First model deliver good CO_2 eq. savings, this is not enough to meet Vienna's targets. Ambitious technology implementations such as Photovoltaic cell installations – that drive the majority of savings in the Vienna Accelerated model need to be considered. Photovoltaic installations perform averagely in their CO_2 eq. savings to cost ratios as shown in figure 5, but produce large mitigation benefits. It is an expensive way for the city to meet its targets that it will need to consider.

The results in figure 8 also show how each of the technologies performs on the other environmental performance indicators. Taking the example of photovoltaic cells – PM_{10} contributions are actually increasing due to the manufacturing process of the panels. An alternative technology decision making process needs to be followed for Vienna to benefit simultaneously on all environmental and economic parameters. This will be explained further in section 4 overleaf. This report aims to identify those technologies that provide win-win solutions.

Results & Analysis

Figure 7: % reductions in CO_2 eq. levels for each of the three scenarios tested in the model



Lever name	CO_2 savings (kg PM_{10} eq.)	PM_{10} savings (kg PM_{10} eq.)	NO_x savings (kg NO_x)	Jobs (count)
Vienna First				
Residential Wall Insulation	1,159,439,112	50,352	855,677	13,215
Residential Double / Triple Glazing	1,168,325,943	16,867	862,236	10,444
Commercial Wall Insulation	342,892,299	26,845	254,501	3,690
Commercial Double / Triple Glazing	1,205,977,206	40,612	908,621	10,395
LED Street Lighting	19,422,113	1,300	20,175	3
Metro – Automated Train Operation (ATO)	18,503,203	1,237	19,201	780
Hybrid Electric Vehicles	155,215,689	154,756	1,271,837	0
Intermodal Traffic Management	386,323,029	97,787	936,169	20
CNG Cars	65,842,510	190,038	1,271,837	4,681
Increases CHP Contribution	1,411,372,347	47,663	-1,129,810	2,297
Vienna Accelerated				
Residential Efficient Lighting	358,488,082	50,352	428,130	0
Residential Home Energy Monitoring	120,085,897	16,867	143,415	242
Commercial Efficient Lighting	191,128,032	26,845	228,258	4,994
Commercial Demand Oriented Lighting	289,142,407	40,612	345,313	3,222
Commercial Building Efficiency Monitoring	269,315,285	19,387	238,901	1,565
Building Performance Optimisation	816,148,351	58,724	723,979	751
Demand Controlled Ventilation	12,771,477	1,794	15,253	88
Metro – New Line	705,065,353	138,215	1,693,719	37,983
Urban Bike Sharing	24,642,721	6,138	58,864	3,672
Electric Buses	47,143,996	-7,335	-3,195	4
Plug-In Hybrid Electric Car	678,083,394	182,087	2,202,807	543
Intelligent Traffic Light Management	16,471,068	5,406	74,368	30
Photovoltaic Power Generation	6,056,314,505	-180,426	5,012,792	29,517
Vienna Experimental				
Residential Home Automation	937,368,757	36,040	746,470	339
Commercial Heat Recovery	443,682,739	12,091	311,140	2,809
Hybrid Electric Bus	-13,180,185	-53,416	-1,552,787	1,288
Electric Cars	965,389,060	217,232	2,941,919	3,262
Electric Taxis	634,408,409	215,564	2,669,917	1,004
Demand Oriented Street Lighting	41,290	3	43	0
Electric Car Sharing	394,156,563	89,015	1,098,540	11,063

Figure 8: The environmental and job benefit performance of each technology in absolute numbers

3. Vienna should increase the implementation of transport technologies

When compared to building and energy technologies, the transport solutions tested in the model are able to deliver the greater reductions in CO_2 eq. emissions and PM_{10} emissions per unit of investment whilst adding more jobs to the local economy. This is shown in figure 9.

On average transport technologies are able to cut emissions by 56 kg of CO_2 eq. per euro invested compared to the 45 kg and 15 kg from the energy and transport sectors. If the limited technology choices in the model reflect the wider technologies being implemented in the city, the question would be why the majority of CO_2 eq. savings in the city are driven by the energy and building sectors?

Results from the model show that transport technologies only account for 10% CO_2 eq. reductions whereas the energy and building technologies account for around 20% CO_2 eq. reductions each up to 2025. This is predominantly due to the fact that the transport levers in the model have low implementation rates as shown in figure 4.

The city should continue to focus on transport solutions that provide more cost effective CO_2 mitigation potential and air quality improvements. In the next section, we will discuss which individual technologies the city should focus on moving forward to 2025.

Results & Analysis

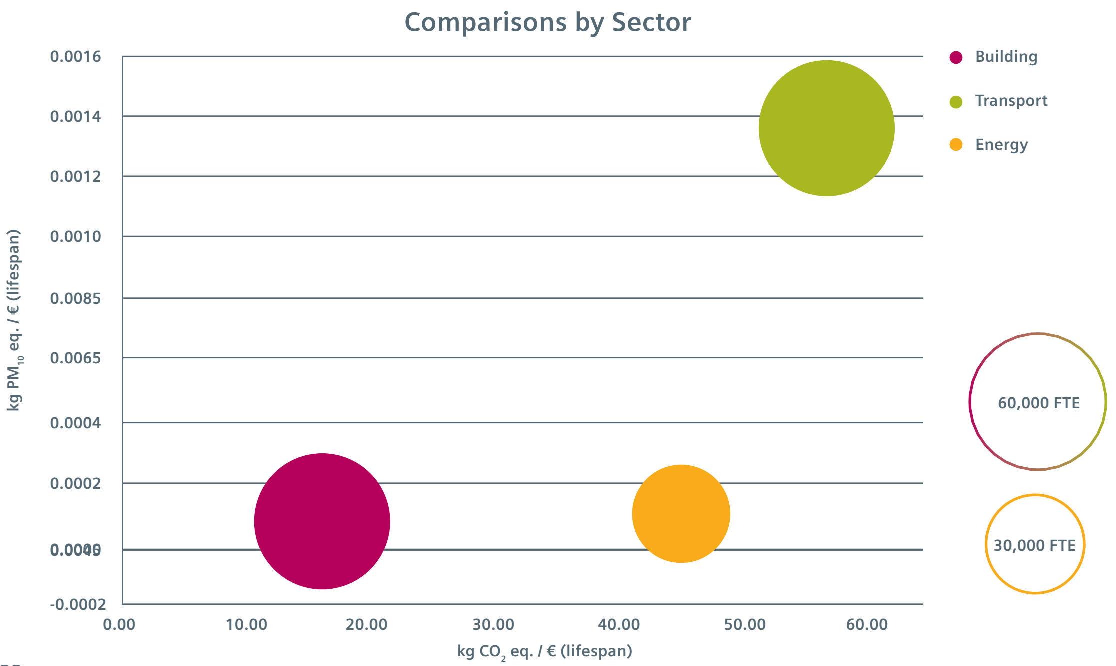


Figure 9: Transport technologies are more cost effective at improve air quality and reducing CO_2 eq. levels

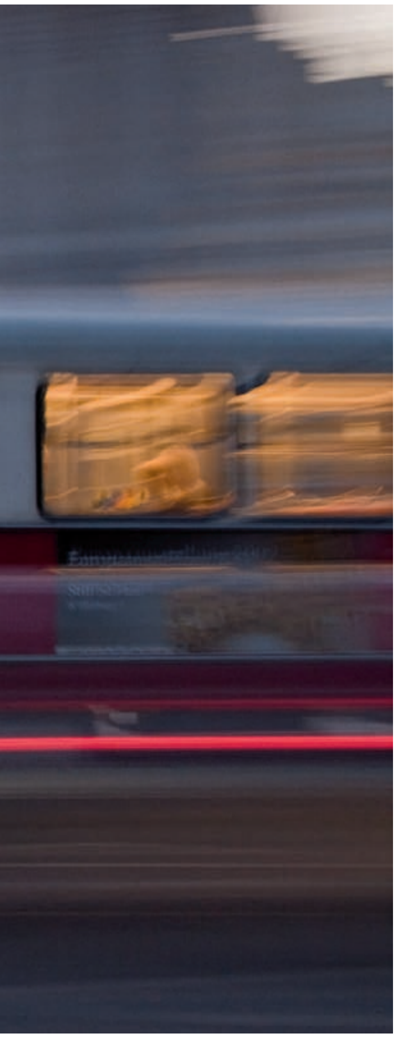
4. Identifying win-win technologies

We compared the performance of all thirty one technologies against the four key performance indicators in the CyPT model. Each technology was placed in a decile (from 1 to 10) based on its performance against the other thirty technologies. A technology placed on the higher decile would indicate, low costs, high job benefits, and large CO_2 and PM_{10} savings. Results from this comparison are shown in the next three pages. For each of the technologies, a spider diagram was plotted with a full spider diagram indicating high benefits on all four dimensions. The full list of spider diagrams is included in the next four pages subdivided by scenario type.

Using the spider diagrams that follow, and information on the cost effectiveness and absolute CO_2 eq. reductions as illustrated in figures 6 and 8, city planners can quickly identify the more relevant win-win technologies for the city.

Results & Analysis – Vienna First

Technologies in the Vienna First model can be subdivided into two types. Building technologies that are very good at CO_2 eq. savings and the creation of jobs, but having little effect on PM_{10} levels. On the contrary transport technologies in this scenario have high PM_{10} savings but low CO_2 eq. reductions. The stand out technology is combined heat and power with high CO_2 eq. savings, low cost and moderate PM_{10} savings.



Residential wall insulation

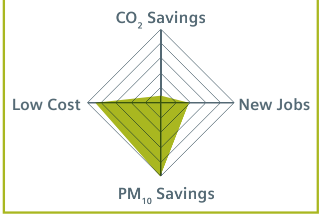
Residential glazing

Commercial wall insulation

Commercial glazing

LED street lighting

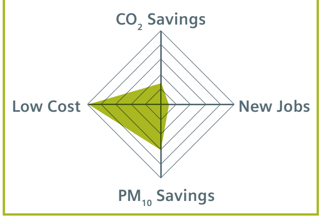
CNG cars



ATO metro

Hybrid electric car

Intermodal traffic management



Combined heat and power

Results & Analysis – Vienna Accelerated

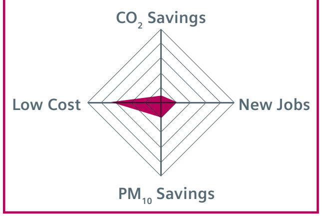
The more advanced building technologies in the Vienna Accelerated scenario have a poor overall performance compared to the other technologies in the model. Most of these technologies are low cost but their environmental and job returns are minimal on the implementation rates chosen by the city.

Amongst the transport technologies, a new metro line will have large impacts on PM_{10} and large job returns but at a high cost.

Residential efficient lighting

Home energy monitoring

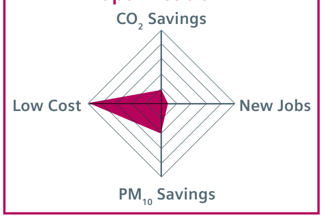
Commercial efficient lighting



Demand oriented lighting

Building efficiency monitoring

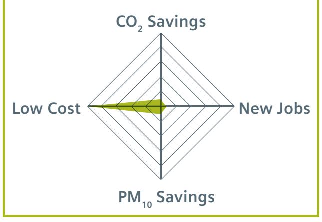
Building performance optimisation



Demand controlled ventilation

Intelligent traffic light monitor

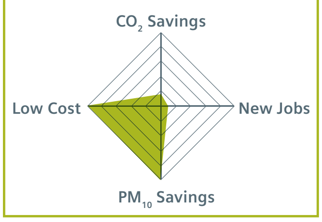
Bike sharing



Metro new line

Electric buses

Plug-in hybrid electric car

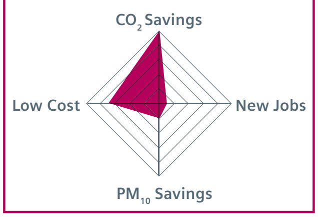


Photovoltaic

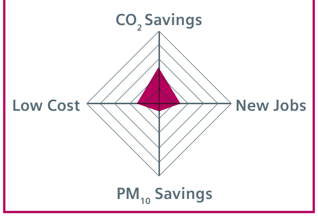
Results & Analysis – Vienna Experimental

Although the overall performance of the Vienna Experimental scenario is moderate, there are two stand-out technologies that are both environmentally and economically efficient. Electric cars and electric taxis stand out as comparably low cost technologies that provide large CO_2 savings and PM_{10} savings. Looking at the electric car implementation in greater detail, a 20% replacement of the city's car fleet to electric cars will reduce CO_2 eq. levels by 2.3% and PM_{10} levels by 4%, whilst creating over 3,000 FTE jobs in the city economy over the next decade. Figure 10 (overleaf), describes these technologies in greater detail with a summary of their key benefits to the city.

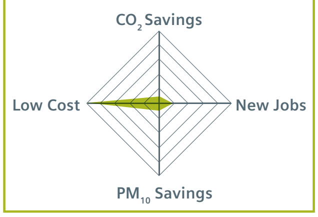
Home automation



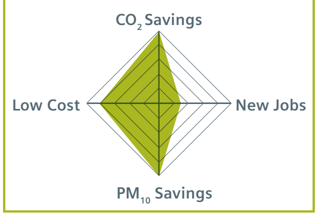
Heat recovery



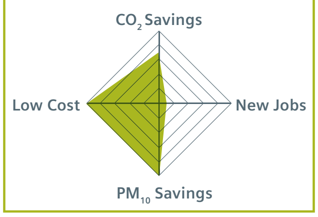
Hybrid electric bus



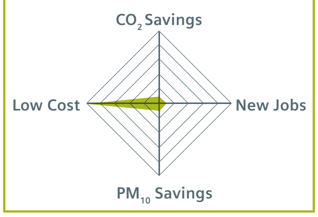
Electric car



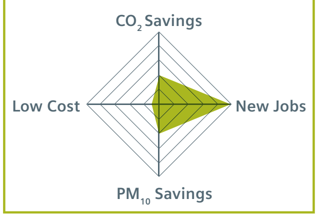
Electric taxi



Intelligent street lighting



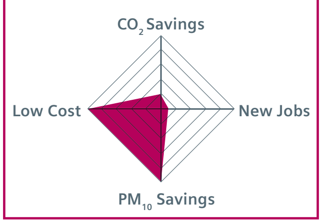
Electric car sharing



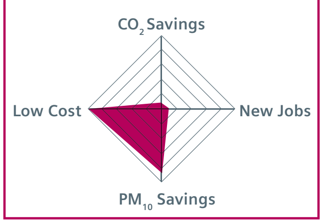
Comparing Vienna's choices in private cars

Vienna can promote the adoption of electric cars that have the greatest CO_2 mitigation potential because of the city's green electricity generation mix. Like most car technologies in the model, the benefits of PM_{10} reductions are considerable. Electric car sharing schemes will have a low impact because of the relatively short trips that are made in such vehicles.

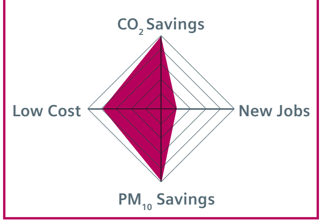
Plug-in hybrid electric car



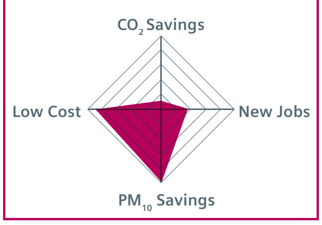
Hybrid electric car



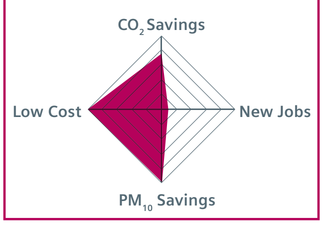
Electric car



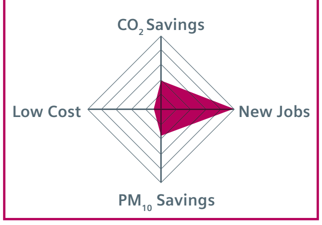
CNG cars



Electric Taxi



Electric car sharing



Results & Analysis – Technology roadmap

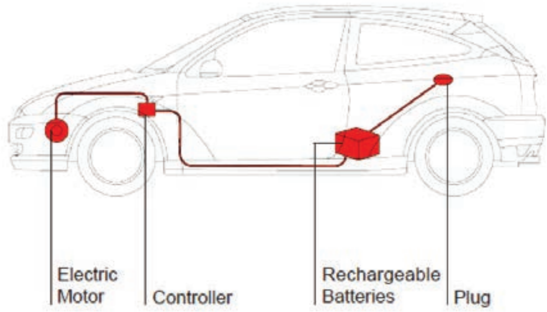
In the run up to 2025, there are five cost effective technologies that Vienna can continue or start to implement.

Residential wall insulation and combined heat and power, two traditional technologies that Vienna has implemented in its KLiP I and KLiP II programmes, should be continued in the next wave of KLiP III investments.

The city however should look to new technologies and specifically electric cars and electric taxis, which stand out as comparably low cost technologies that provide large CO_2 savings, PM_{10} and NO_x savings.

Finally, the city should consider supporting the development of intermodal traffic management applications. Although their overall effect on CO_2 eq. reductions is low, their very low up front investment cost provides affordable environmental opportunities for the city to consider further.

The e-car is powered by electricity and uses electric motors and motor controllers instead of internal combustion engines (ICE's) for propulsion. Battery electric cars are zero exhaust gas emission vehicles. A charging infrastructure is set up and a certain share of the vehicle fleet is replaced with battery electric cars.



Kg CO_2 eq. savings	965,389,060
Kg PM_{10} eq. savings	217,232
Kg NO_x savings	-1,129,810
Number of jobs created	2,941,919 FTE

An electric taxi is a taxi powered by electricity and uses electric motors and motor controllers instead of internal combustion engines (ICE's) for propulsion. The electric taxi derives all its power from rechargeable battery packs.

Kg CO_2 eq. savings	634,408,409
Kg PM_{10} eq. savings	215,564
Kg NO_x savings	-1,129,810
Number of jobs created	2,669,917 FTE

Figure 10: Description of electric car and electric taxi benefit technologies in Vienna

Conclusion

Over the last twelve months Siemens has worked with Vienna's experts to test the performance of technologies that the city has implemented in its KLiP I and KLiP II programmes. The city also wanted to test new technologies and compare their cost effectiveness of improving air quality and reducing CO_2 eq. emissions with more traditional infrastructure solutions.

Using Siemens' proprietary City Performance Tool, this report modelled over 30 technologies that Vienna's experts wanted to investigate. Through a series of workshops, the experts also provided a full baseline of emissions in 2014 and Siemens modeled the environmental and economic benefits when these technologies are implemented over the next decade.

Our findings show that Vienna has already explored some of the more cost effective solutions to reduce its CO_2 eq. emissions through the implementation of wall insulation and combined heat and power programmes in the city. However untapped opportunities remain with the city able to encourage the development of intermodal traffic management applications at a low budgetary cost.

More importantly, this report argues that market-ready win-win technologies such as electric cars and electric taxis can simultaneously drive environmental and economic benefits to the city and recommends an increased implementation of such transport technologies in the city.

Our findings show that Vienna has already explored some of the more cost effective solutions to reduce its CO_2 eq. emissions through the implementation of wall insulation and combined heat and power programmes in the city. However untapped opportunities remain with the city able to encourage the development of intermodal traffic management applications at a low budgetary cost.

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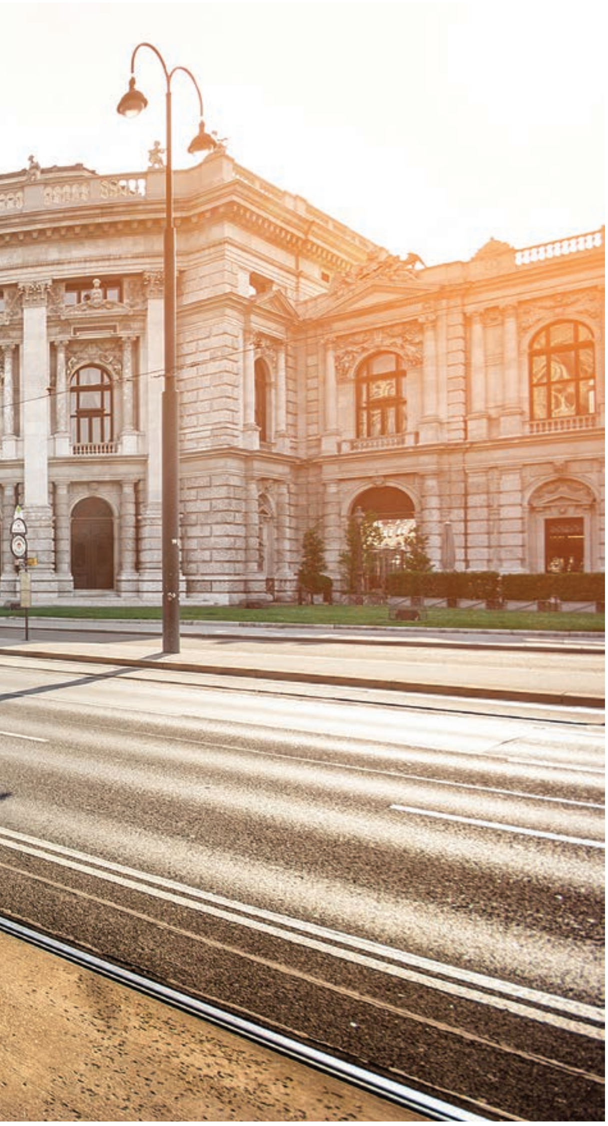


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