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Siemens CyPT Seoul 2020

Transition toward sustainable city of Seoul: Infrastructure technology analysis

Siemens Cities Center of Competence Asia

Seoul is well on its way to becoming a more energy independent city meeting its objectives in the One Less Nuclear Power Plant and the Seoul Sustainable Energy Action Plan.
Our study has modeled the impacts of some unprecedented investments in 46 transport, buildings and energy technologies that deliver over 23% greenhouse gas savings by 2020. This is by far the most rapid emissions reductions in any city that the CyPT model has been deployed.

Executive Summary

When it comes to progress in reducing greenhouse gas emissions amongst megacities, Seoul leads the way. In just two years, between 2012-2014 the city managed to reduce energy consumption by 2 million TOE and 10 million tons of greenhouse gas by 2020, compared to 2005. The city has even greater ambitions and has engaged with Siemens' City Performance Tool (CyPT) to identify further savings through the deployment of new transport, energy and building technologies. Transition toward sustainable city of Seoul: Infrastructure technology analysis provides an in depth analysis of the greenhouse gas savings for each of these technologies. Overall Siemens tested the performance of over 46 infrastructure technologies. The report does not argue that all technologies will be implemented simultaneously but it gives a basis for the city to compare the efficiency of each technology. The report also showcases infrastructure technologies that have been deployed in global cities that are striving towards a more independent and greener energy future.

This report has found:

1. By mobilising its public investment and private capital, the city of Seoul can reduce its greenhouse gas emissions by an unprecedented 23% in just six years from the period 2014 to 2020.
2. Through the CyPT, Seoul is modelling a green transport revolution with planned public investments in metro lines, BRT lines, E-buses and the introduction of a city tolling network. Our model estimates over 2.4 Mton of greenhouse gas savings arising from these investments or 4.9% reductions of total citywide emissions adding nearly 1.5 million full time equivalent jobs to the local economy.
3. In the buildings sector, the replacement of commercial and residential lights and technologies that optimise the use of spaces and automate functions can deliver nearly 3.6 Mton of greenhouse gas savings or 7.6% of citywide emissions.
4. In the energy sector, accelerating Seoul's current investments in renewable energy installations (such as solar photovoltaic etc.) and increasing distributed energy through a combined heat and power system will add nearly 2.8% of savings by 2020
5. Furthermore, by enhancing the implementation rate to maximize the impact of different infrastructure levers, there are more emission reduction potentials in 2025 for a lower carbon and more sustainable Seoul.

Introducing the City Performance Tool

In the space of five years, between the global climate summits of Copenhagen-COP 15 and Paris-COP 21, cities have led the way in reducing emissions both within their boundaries and outside of their direct emission scopes. One megacity in particular, Seoul, has achieved major reductions in part due to a response from events in 2011 when the city faced major blackouts and questioned its reliance on nuclear energy due to events in neighbouring Japan. The city started in earnest to undertake an energy transition - one of the world's most ambitious.

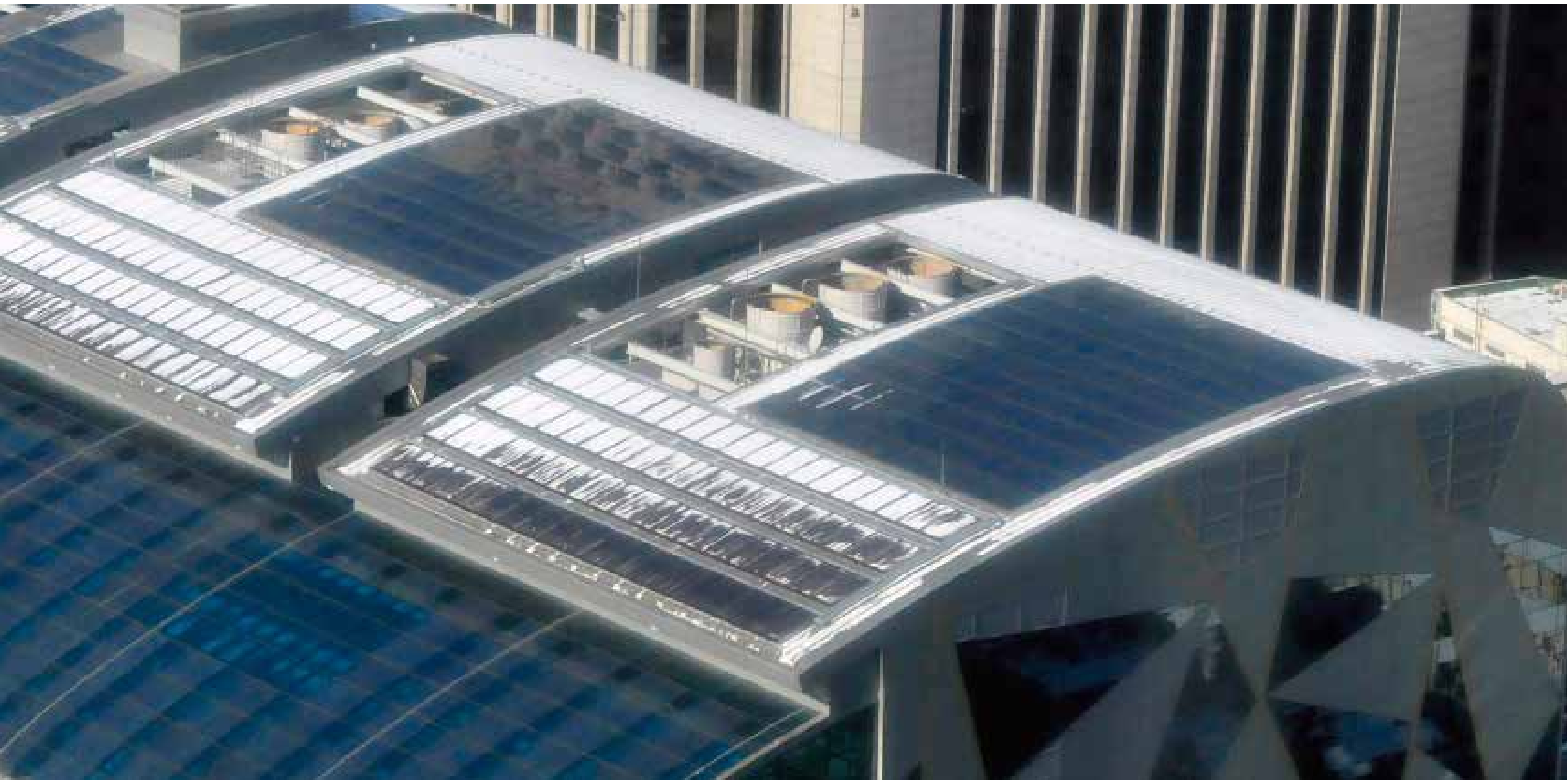
To help cities make informed infrastructure investment decisions in such energy transitions, Siemens has developed the City Performance Tool (CyPT) that identifies which technologies from the energy, transport and building sectors best fit a city's baseline in order to mitigate CO_{2eq} levels, improve air quality and add new jobs in the local economy.

The CyPT compares the performance of over 70 technologies, with only 60% being Siemens technologies. This provides the city to compare the impact of non Siemens mitigation solutions with Siemens technologies, such as wall insulation and double glazing.

The model takes over 350 inputs from Seoul'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. How high this is and how it is split between the transport and buildings sector depends on how people use transport and building space and how the city generates its electricity and heating.

As soon as the DNA is calculated we estimate the CO_{2eq} emissions and PM10 and NOx levels. The model measures the impact of technologies on the CO_{2eq}, PM10 and NOx baselines of the city with CO_{2eq} accounting performed at scopes 1 and 2 levels for the building and transport sectors. This means that we have taken into consideration both the emissions that are occurring within the city boundaries but also those to generate the relevant energy powering the technologies. The city of Seoul performs greenhouse gas accounting at scopes 1 & 2 for buildings and scope 1 for transport. This explains the small discrepancy between the CyPT baseline, which is slightly higher than Seoul's. Scope 3 emissions that look at the energy required to feed the electricity and heating generation in the city have been excluded[1]. The model also tests the performance of each technology on two economic indicators. Firstly, the total capital investment needed to deliver the technologies. Second, the total number of gross 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. 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.

[1]Seoul is following the Greenhouse gas calculation guidelines for local government from Ministry of Environment.



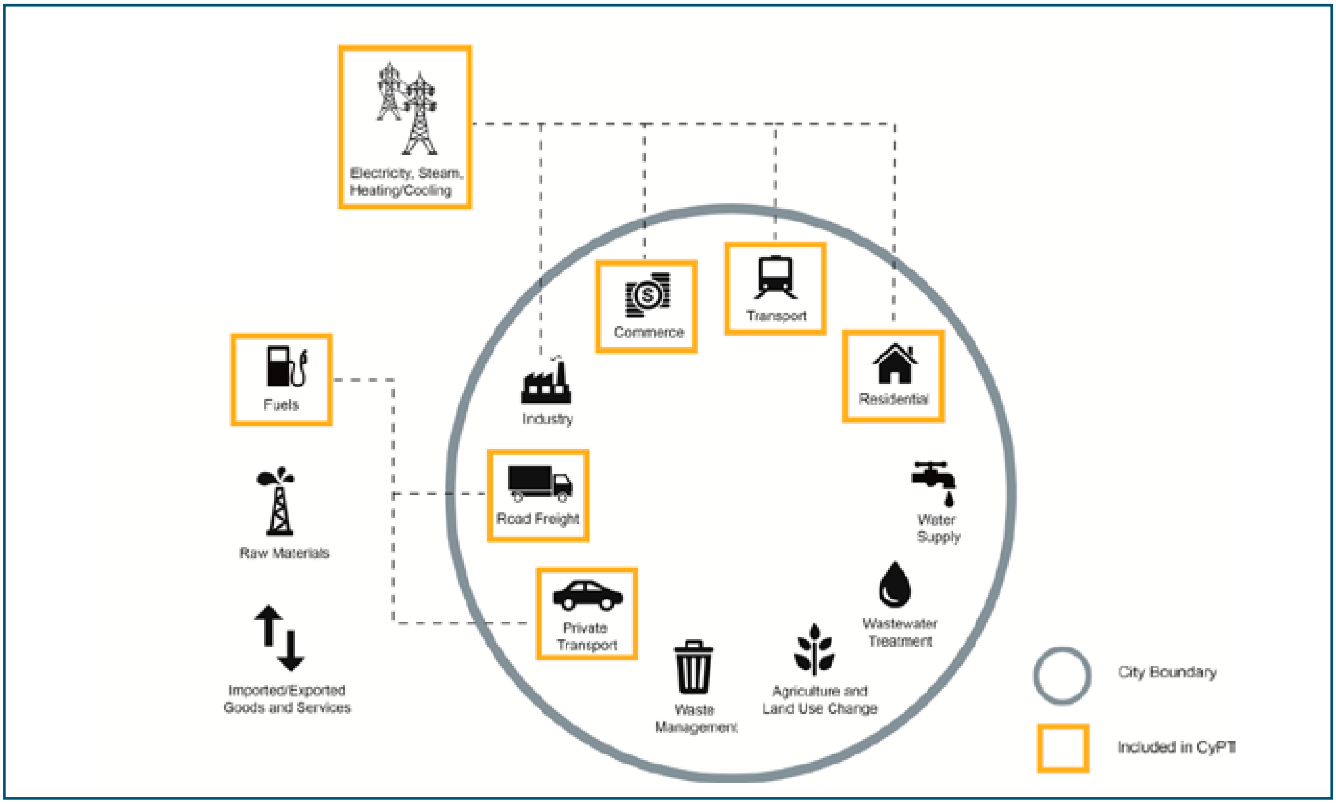


Figure 1: Scope 1 and 2 emissions captured in this study. Icons are for indicative purposes only

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

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

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

The model has so far been used in cities such as Adelaide, Copenhagen, Helsinki, London, Nanjing, San Francisco, Shenzhen and Vienna with each city identifying infrastructure solutions that best fit the city's energy demand and production characteristics.

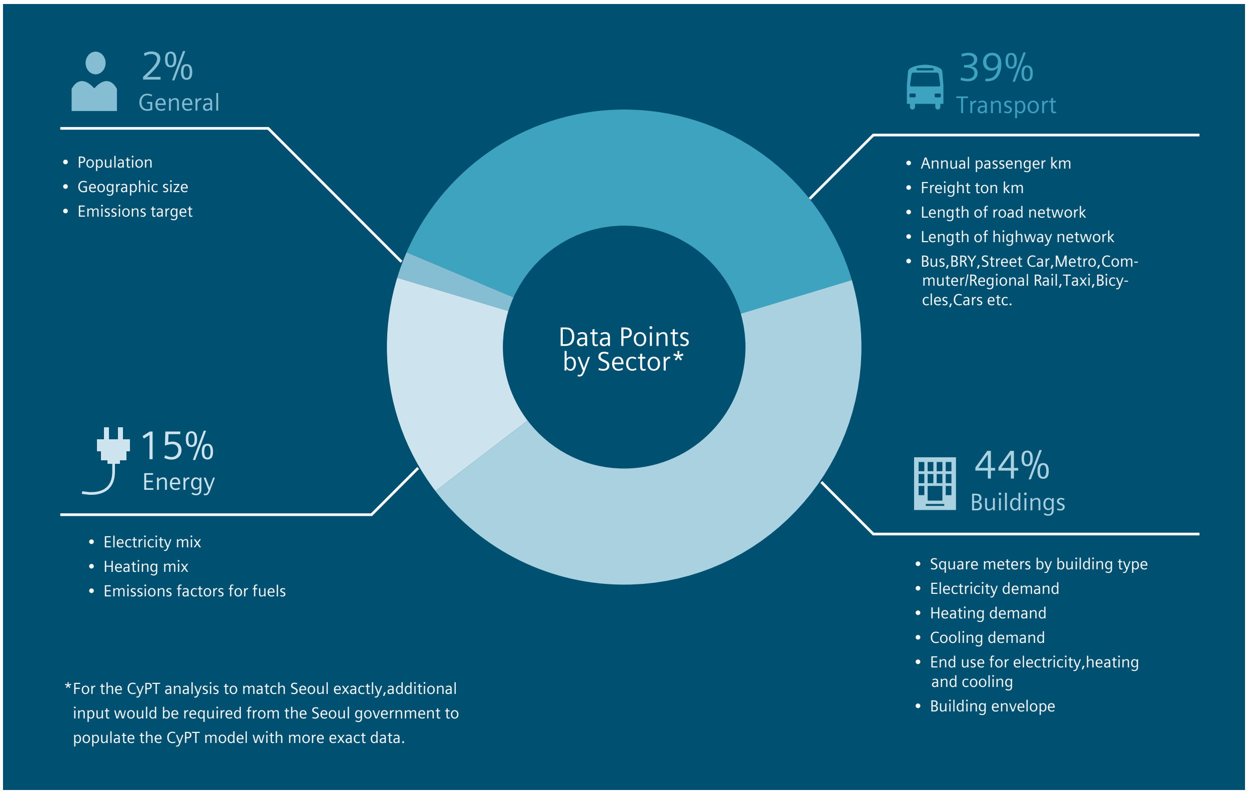
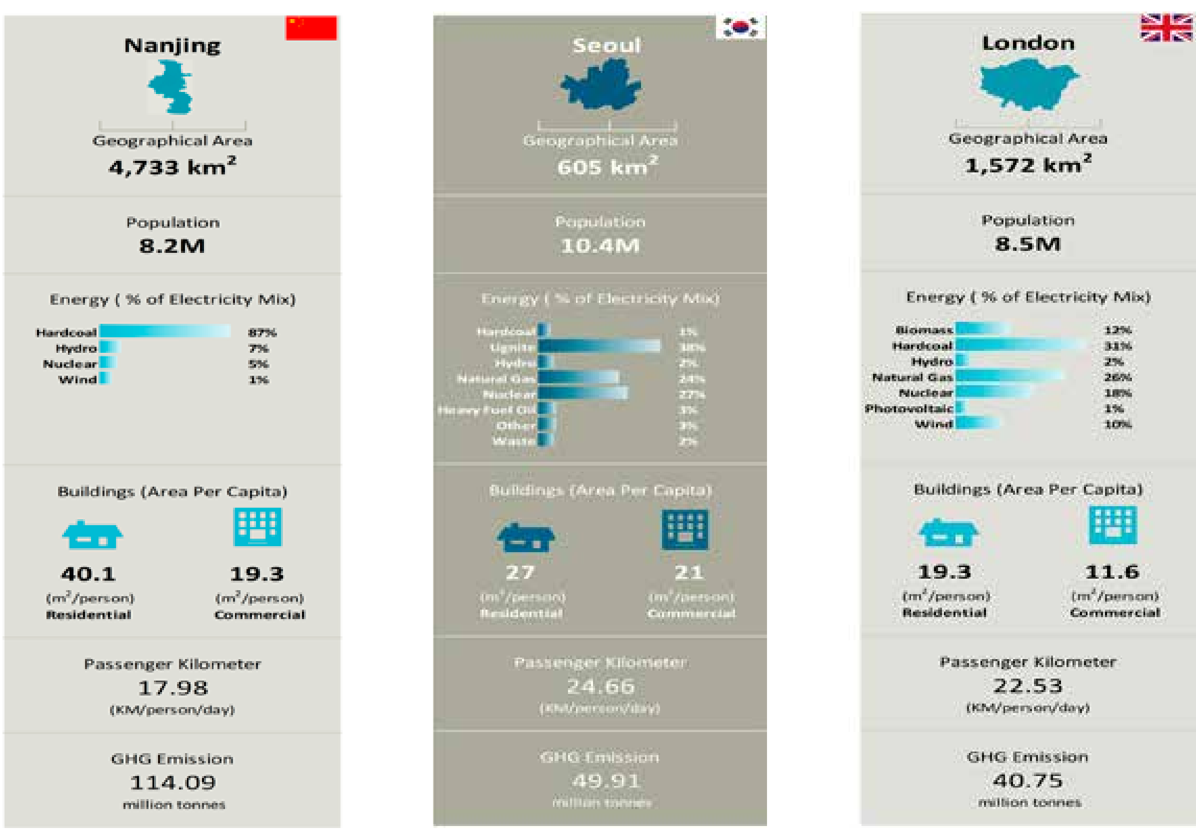


Figure 2: Percentage of data points by sector used in CyPT model

Seoul’s Climate Plan

Three events focused Seoul’s attention on energy and resilience. A heat wave in 2011 lead to spikes in electricity demand and widespread blackouts across South Korea. Also in 2011 the tsunami and subsequent Fukushima nuclear disaster in Japan built opposition to nuclear energy across South Korea. Whilst the election of Seoul’s current mayor Won-Soon Park in 2011, provided a civic leader with a background in environmental activism (Lee, et al. 2015). These events led the city to undertake an important energy transition that was delivered as fast as it was planned due to the very strong bonds that existing between the public, private and civic sectors in Seoul and South Korea as a whole.



A significant portion of clean energy has already been used in Seoul in terms of electricity mix. Due to most of the industry set-up are out of the city boundary, the total GHG emission is much less than the other developing cities in Asia.

Seoul's position as an international leader in addressing climate change has been built on exactly this strong relationship with the city's businesses and industries but also between the city's citizens and the national government. What is unique about Seoul's success in executing environmental policy is the level of engagement across these levels. Since 2012, energy policy has been defined by public facing programs, first in the "One Less Nuclear Power Plant" (OLNPP) program, and now in the "Seoul Sustainable Energy Action Plan" (SSEAP).

One Less Nuclear Power Plant

One Less Nuclear Power Plant is the flagship energy policy launched in April 2012 by Seoul Metropolitan Government to respond to climate change and energy crisis in the aftermath of the Fukushima nuclear accident and the nationwide rolling blackout in 2011.

The main target of the One Less Nuclear Power plant was to cut energy consumption by 2 million TOE, which is equivalent to the capacity of one nuclear power plant, mainly by directly engaging citizens in energy-saving and renewable energy generation. This target was exceeded in June 2014, six months ahead of schedule, as Seoul reduced the city's energy consumption by 2.04 million TOE. Significant achievements include:

Energy generation

Seoul Metropolitan Government attracted around 400 billion won in private capital to generate electricity from clean renewable sources.This will supply power 300,000 households. 63.5 billion won out of the total private investment was used to establish 3,756 photovoltaic power generation systems with the combined capacity of 69 MW.

Energy efficiency

Seoul implemented Building Retrofit Program (BRP) on 20,000 buildings by offering loans with ultra-low interest rates of 1.75% and adopting a first-invest-return-later approach. Moreover, 6.79 million energy-efficient LED bulbs were introduced by Seoul. In particular, Seoul replaced 430,000 conventional bulbs in all 243 subway stations in the city with LED ones with the full financial support by the Korea Finance Corporation.

Energy-saving

The Eco-Mileage program, which incentivizes citizens' energy-saving actions, saw its membership increase to 1.7 million, prompting energy-saving behaviors both at households and businesses. The Eco-Mileage program won the 2013 UN Public Service Award in the category of"Fostering participation in public policy decision making through innovative mechanisms."

These initiatives have engaged both the public and private enterprises to identify opportunities for investment and reductions in energy consumption, utilizing solutions at both the macro and the micro scales. The success of this approach can be seen in the numbers. Between 2012 and June 2014, the OLNPP program saw the target reduction of 2 million TOE consumption exceeded 6 months ahead of schedule. As a consequence, Seoul city has also earned a significant reputation and recognition as a global green city toward sustainability.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The current SSEAP has an equally ambitious plan to increase the city's electricity self-reliance rate to 20% and further reduce energy use by 4 million TOE by 2020. In assessing the baseline emission in Seoul, CyPT model has taken into account the city's status-quo, including population, electricity and heating mix, total building area and energy consumption of different building categories, distribution of different type of vehicles, impacts from national policies and behavior changes (such as forecast on modal share and power mix).

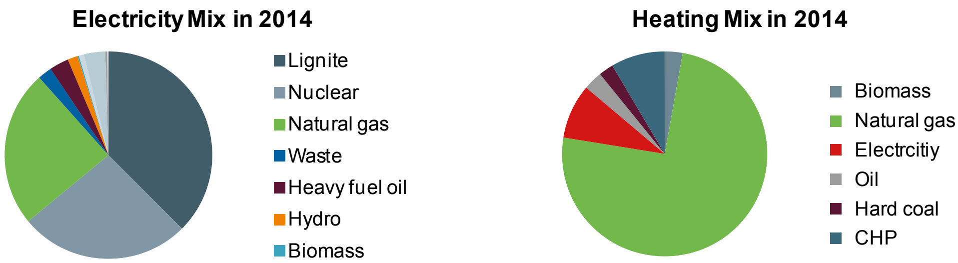


Figure 3 : Electricity and heating mix in baseline

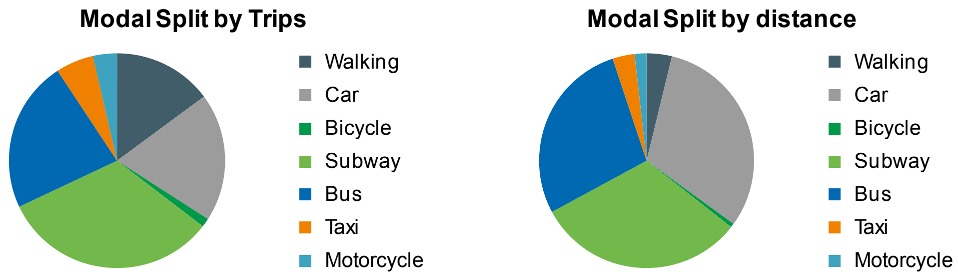


Figure 4 :Transport modal split in baseline

According to our calculations, the city's greenhouse gas emissions amounted to 49 Mton of CO_{2eq} in 2014, which is used as our baseline. This is composed of 37.4 Mton of CO_{2eq} and 11.6 Mton of CO_{2eq} from the buildings and transport sectors respectively.

With electoral support and buy-in from business and investors, the OLNPP scheme was launched with 400 billion won (334 million USD) in private capital to target some of these emissions. This was used to support programs that generated enough electricity from clean renewable sources for 300,000 households. For example 63.5 billion won (53 million USD) financed 3,756 photovoltaic power generation systems, equaling 69 MW of production. This was combined with feed-in tariffs subsidized by the Seoul Metropolitan Government. Such programmes were influential because they targeted residential buildings - one of the largest sources of emissions in the city as shown in figure 3.

Achieving this energy transition is important as Seoul is still relying on a national electricity mix that is based on carbon intensive lignite (37.5%) and gas (24.4%). Nuclear which makes up 26.5% of the mix is deemed high risk following events in the region in 2011. Similarly, heating in the city is predominantly derived from boiler systems making up 75% of the mix, with district networks on combined heat and power generation only making up 8% of the mix.

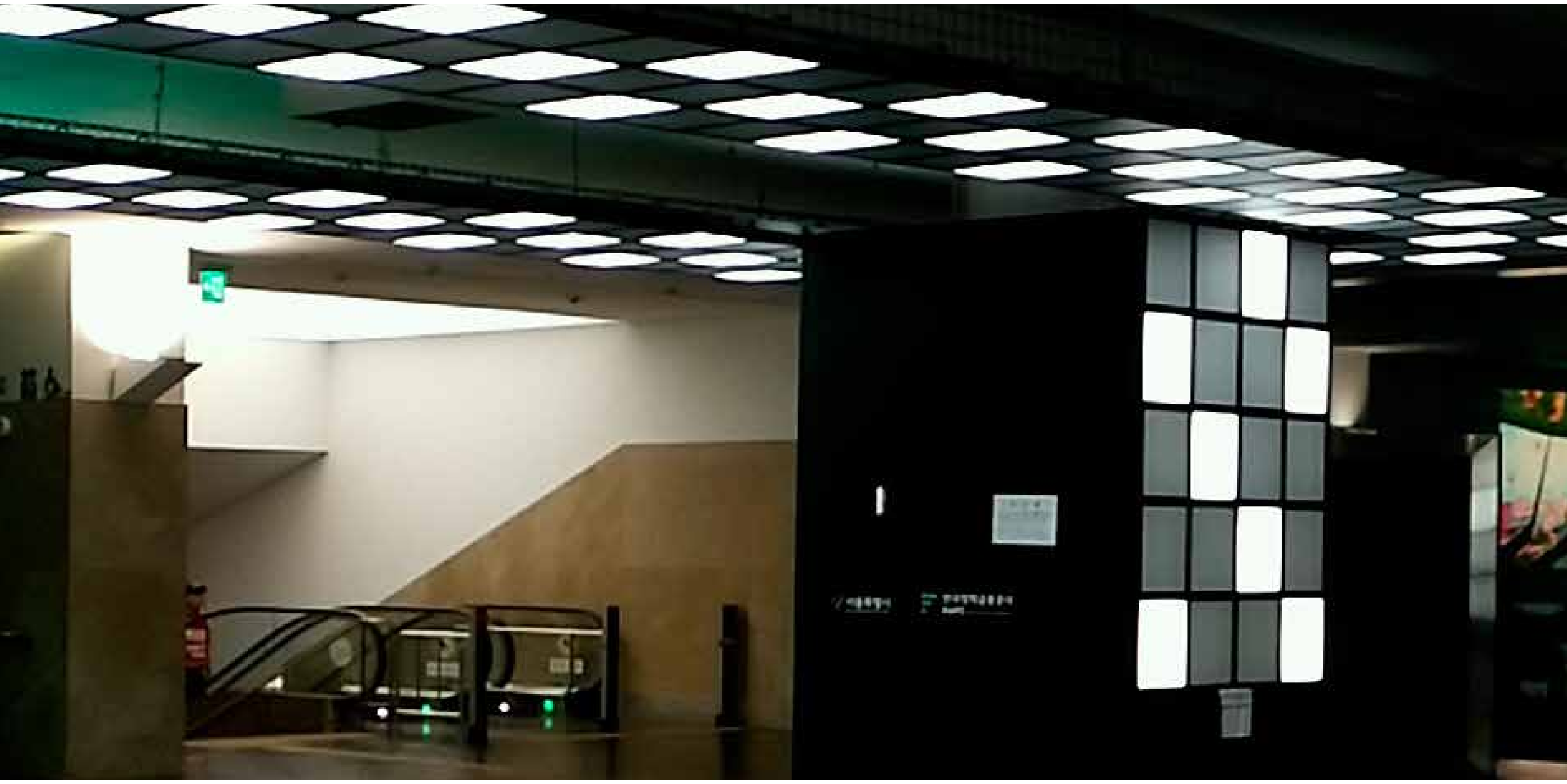
The Seoul Metropolitan Government also supported energy efficiency by financing an extensive building retrofit program. Offering loans at 1.75% (2015) interest from 2.0% (2013), 20,000 buildings were able to be retrofitted. Seoul City changed 12.97 million energy-efficient LED bulbs through an LED replacement program.

The diversity of initiatives under the OLNPP program allowed reductions to be spread across sources. The first phase, OLNPP's energy-saving programs achieved the greatest cut in energy consumption at some 910,000 TOE, while energy efficiency and generation projects pushed down the total energy consumption by 870,000 TOE and produced energy of 260,000 TOE.

OLNPP policy was designed to respond to energy-related concerns at the local, national and international scale. Addressing concerns about energy consumption, national grid resilience and climate change respectively (Lee, et al. 2014). The social and moral dimensions captured by OLNPP, combined with the reductions delivered, has led to the latest “Seoul Sustainable Energy Action Plan” (SSEAP) moving forward with significant ambition and public support (Patterson, 2015).

Between 2003 and 2015, Seoul increased its solar power capacity to 105 MW, enough to power 34,000 households. Other funding streams have been opened up going forward, to support this proven technology. As a part of the SSEAP, the Solar Power Generation Citizens' Fund for the purpose of transforming citizens from energy consumers to energy producers has secured the construction cost of 8.25 billion won (6.9 million USD) from 1,044 individuals to establish 4.24 MW of solar panel generation.

Other projects are delivering examples of energy reduction, efficiency and generation that seek to provide practical solutions. As a part of Urban Smart Grid Projects, the energy Energy Self-Sufficient Village program, including Shipjasung Village and Dongjak Hyundai Apartmenet, installed 662 of latest IoT smart metering and solar power generation with energy capacities of 43kw, which is generating 50 Mwh electricity per year. These lighthouse projects, with small and medium size energy efficient houses for public rent, continue to present a demonstrable output of the SSEAP.



The “Improve Eco-mileage Program” continues to engage with Seoul stakeholders who are active in reducing their energy use.Providing a 830,000 TOE saving between 2012 and December 2015. 1,706,000 members of the program, made up of both households and businesses, have implemented voluntary energy conservation measures. Seoul’s metropolitan government provides energy consultants to help these participants determine the best way to save energy. Points are earned according to the amount of energy saved and can be redeemed as discounts on eco-friendly products or public transport vouchers.

Considering the future plan of electricity mix and target for improved modal share in transportation, our calculation shows that the emission in Seoul will be reduced accordingly.

The next section looks at some of the technologies in the City Performance tool that the city wants to test further.

Technology choices

Once Seoul's baseline was calculated, a workshop was held in the city that brought together some of the key municipal stakeholders. This included participants from the transport, energy and public works departments. The aim of the workshop was to determine the implementation rate for the most relevant technologies for Seoul in policy terms in the run up to 2020.

The workshop was structured in 2 hours long exercise where the participants were given the following pieces of information:

1. Seoul's CO_{2eq} emissions baseline, split between buildings and transport so that participants were made aware of the higher emission sources.
2. The effective implementation rate of technologies in the model - that is the implementation that we are modeling minus the current deployment of that technology in the city

Figure 5, shows the number of participants that selected a particular technology and the implementation rate suggested by the group, reflecting the technical levers which are highly concerned and matched with current city policy and masterplan. There were six technologies that were unanimously chosen in the workshop. These included four transport technologies: new metro lines, electric cars and electric car sharing schemes as well as a low emission zone in the city. There were two energy technologies photovoltaic panel solar installations as well as combined cycle heat and power generation in a district network.

Technology lever	Number of participants selecting lever	Suggested implementation rate till 2020	Suggested implementation rate till 2025	Unit
Residential - Wall Insulation	3	1%	2%	% of buildings covered/ year
Residential - Glazing	2	1%	2%	% of buildings covered/ year
Residential - Efficient lighting technology	2	1%	2%	% of buildings covered/ year
Residential - Home Energy Monitoring	2	1%	2%	% of buildings covered/ year
Residential - Home Automation	0	1%	2%	% of buildings covered/ year
Residential - Building Envelope	1	1%	2%	% of buildings covered/ year
Non-residential - Wall Insulation	3	1%	2%	% of buildings covered/ year
Non-residential - Glazing	2	1%	2%	% of buildings covered/ year
Non-residential - Efficient lighting technology	2	1%	2%	% of buildings covered/ year
Non-residential - Demand oriented lighting	2	1%	2%	% of buildings covered/ year
Non-residential - Building Efficiency Monitoring (BEM)	3	1%	2%	% of buildings covered/ year
Non-residential - Building Performance Optimization (BPO)	1	1%	2%	% of buildings covered/ year
Non-residential - Demand controlled ventilation	0	1%	2%	% of buildings covered/ year
Non-residential - Heat recovery	2	1%	2%	% of buildings covered/ year
Non-residential - Building Envelope	1	1%	2%	% of buildings covered/ year
Non-residential - Building Automation, BACS C	0	1%	2%	% of buildings covered/ year
Non-residential - Building Automation, BACS B	0	1%	2%	% of buildings covered/ year
Non-residential - Building Automation, BACS A	3	1%	2%	% of buildings covered/ year
Non-residential - Efficient Motors	0	1%	2%	% of buildings covered/ year

Non-residential - Room Automation, HVAC	0	1%	2%	% of buildings covered/ year
Non-residential - Room Automation, HVAC+lighting	0	1%	2%	% of buildings covered/ year
Non-residential - Room Automation, HVAC+blind	2	1%	2%	% of buildings covered/ year
Non-residential - Building Remote Monitoring (BRM)	0	1%	2%	% of buildings covered/ year
Electric buses	3	30%	50%	share of fleet replaced
Metro - new line	4	5	10	number of new lines
LED Street lighting	2	80%	90%	number of street lights replaced
Intelligent Traffic Light Management	0	70%	90%	% of network covered
Electric cars	4	3%	5%	share of car fleet replaced
Plug-in hybrid electric cars	1	3%	5%	share of car fleet replaced
Electric taxis	3	30%	50%	share of taxi fleet replaced
Demand oriented street lighting	0	20%	40%	share of street lights replaced
Electric car sharing	4	0.5 / 1000	1 / 1000	cars / 1000 inhabitants
Intermodal traffic management	0	70%	90%	Users as share of travellers
Bike sharing	0	1.5 / 1000	2 / 1000	bikes / 1000 inhabitants
e-BRT (Bus Rapid Transit) - New line	2	4	10	share of lines equipped
Car - Eco-Drive Training and consumption awareness	2	40%	60%	share of driving license holders trained
Metro - Reduced headway	1	180	120	peak-time headway [s]
Metro - Regenerative braking	0	30%	70%	share of lines equipped
Smart Streetlighting (LED & MSB dimming)	2	20%	40%	number of street lights replaced
Lorries/Trucks - Low emission zone	5	Euro 4	Euro 5	minimum EURO class standard to enter low emission zone
Car & Motorcycle - City tolling	0	10%	15%	reduction in road traffic
Wind	0	3%	5%	% of electricity mix
PV	6	4%	5%	% of electricity mix
Combined cycle gas turbine	4	10%	15%	% of mix
CHP	2	10%	15%	% of mix
Smart Metering	2	50%	70%	% of buildings fitted

Figure 5 : The 46 shortlisted technologies in the Seoul workshop. In dark green are technologies picked by the majority of the participants. Technologies in red were not selected but the results will also be accounted in the assessment.

Results

In the two years between 2012-2014, the city of Seoul managed to reduce greenhouse gas emissions by 2Mton. The city is already looking forward to the year 2020 and is implementing energy related technology programmes that would bring further savings.

The "Siemens CyPT Seoul 2020" scenario which includes 23 building technologies, 18 transport technologies and 5 energy technologies chosen in the workshop, can deliver a further 20% emission reductions in the city.

Buildings

Overall, the building technologies in Siemens CyPT Seoul 2020 delivered 13.6% reductions of building related greenhouse gas emissions or 7.6% of city wide emissions. The largest savings originate from building automation technologies delivering over 8.1% buildings related emissions reductions. These are less invasive mitigation solutions compared to building envelope retrofits that the city has yet to fully explore. One quick way for the city to start deploying such programmes is through clear incentives and targets to commercial building owners as is highlighted in the case of Melbourne and Chicago in Box 1. The city may opt to choose a stronger regulatory approach as in Tokyo's cap and trade scheme that created a marketplace for building emissions in the city.

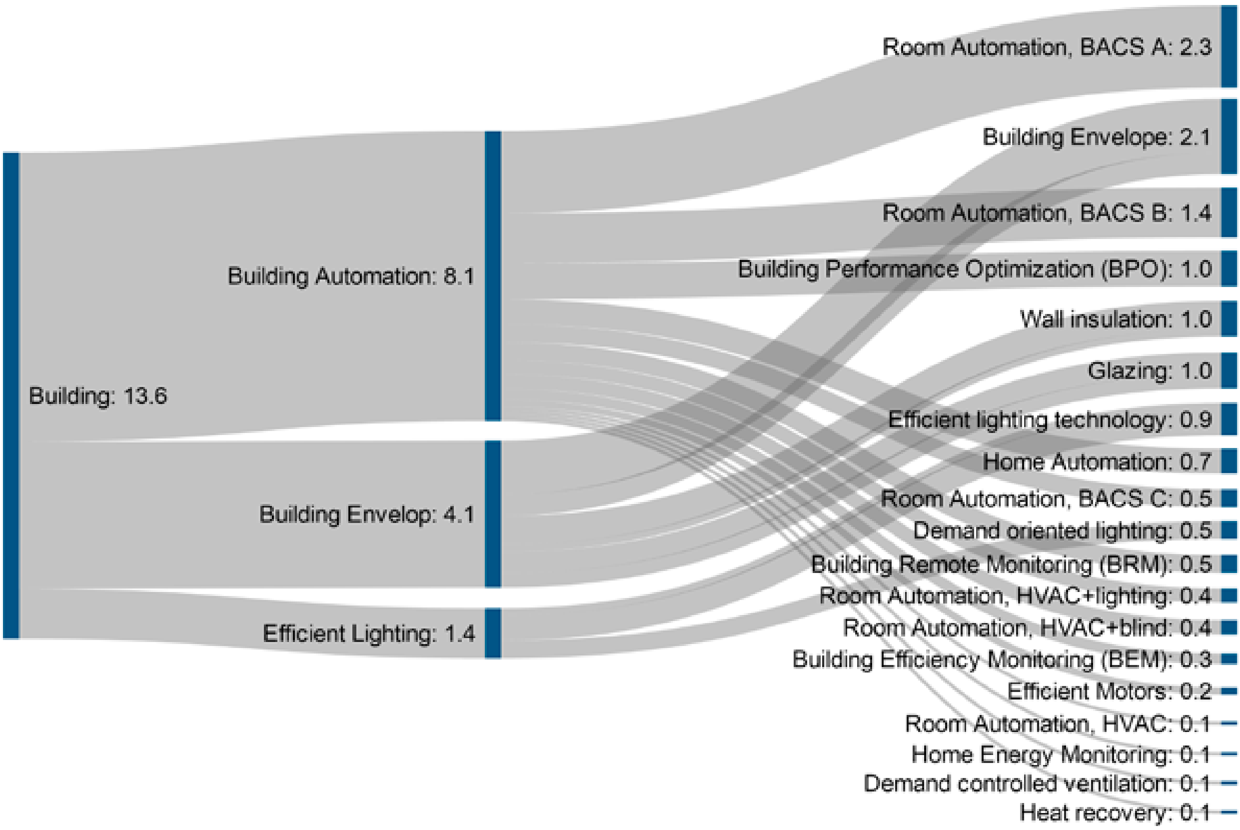


Figure 6 :%CO_{2eq} emission reductions for each building technology compared to overall building emissions.

By comparing the reduction in CO_{2e}, PM10 and CAPEX for specific technical levers in building sector, technologies of intelligent building automation are more cost effective, such as Building Performance Optimization, Building Remote Monitoring and Building Efficiency Monitoring. In addition, the implementation of building envelops levers (such as wall insulation and glazing) will also help to create more local jobs, and benefit for social and economic development.

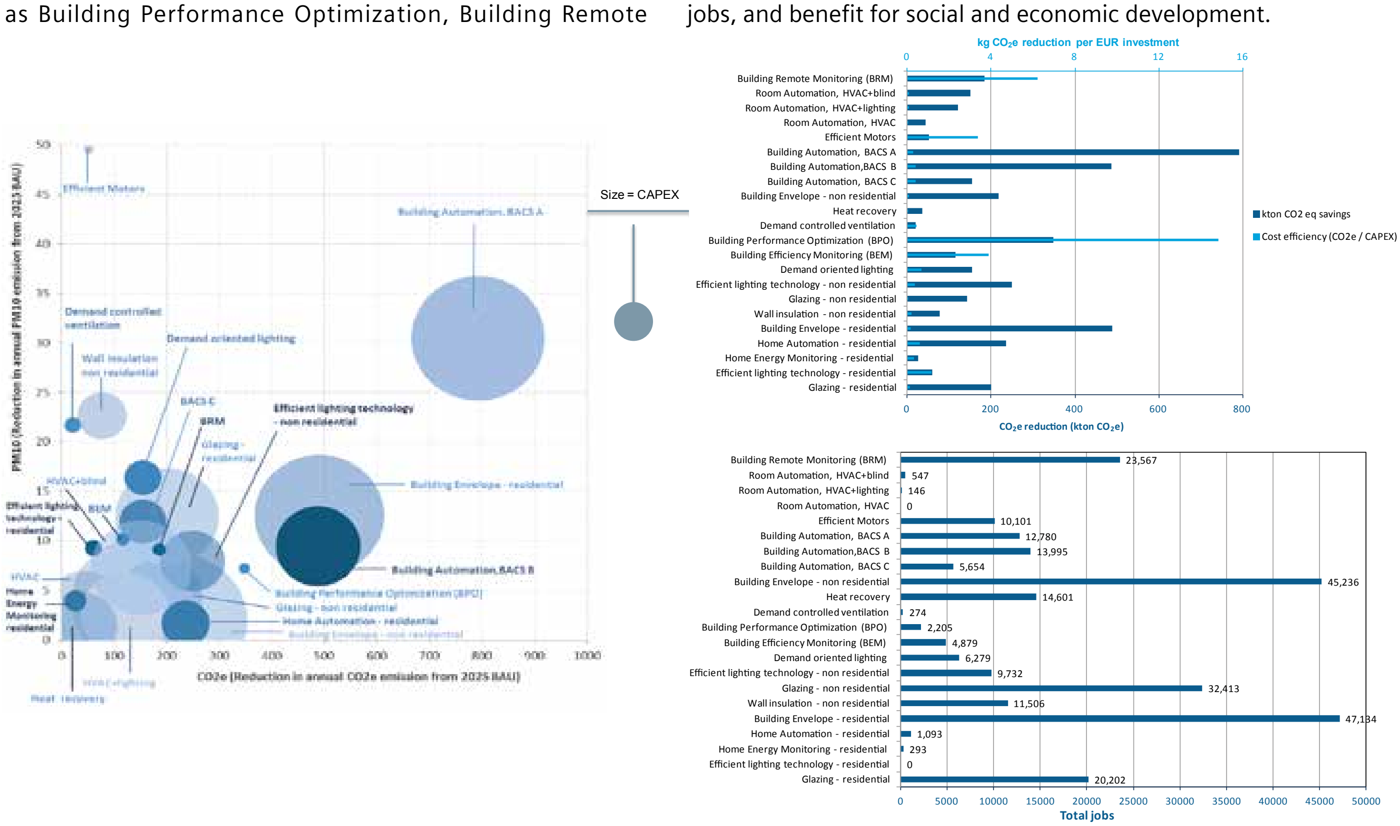


Figure 7 : Technology performance in cost efficiency and jobs

Box 1: Commercial Retrofit Programmes

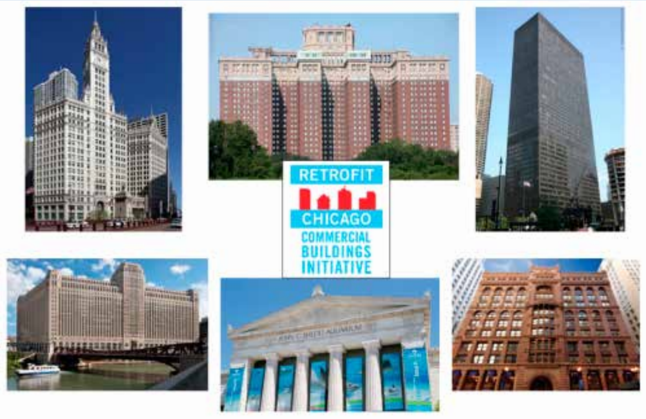
Melbourne – Sustainable Buildings Program

As Australia's fastest growing city, Melbourne has consistently embedded sustainability into its long-term development plans to ensure economically and environmentally responsible growth. In 2003, the City of Melbourne set an ambitious goal for the municipality of zero net emissions by 2020. To reach this goal, the City of Melbourne has therefore designed the 1200 Buildings Program to encourage the retrofitting of 1,200 commercial buildings – approximately 70% of the city's commercial building stock responsible for nearly 50% of Melbourne's CO_2 emissions. Although the program is voluntary, it provides building owners with significant incentives to retrofit their properties. Once a building has committed to improving energy efficiency by 38%, it has access to tailored advice for retrofitting; marketing activities and campaigns; and government-furnished financial incentives, including the program's key component, Environmental Upgrade Agreements (EUA). Based on similar legislation in other major cities around the world, the EUA is a finance mechanism developed to remove a number of barriers preventing building owners from accessing finance to improve buildings' energy and water efficiency.

Since its inception in 2010, the 1200 Buildings program has supported 10% of the building sector retrofit. Approximately 56 signatories (representing 5% of total buildings) have committed to promoting their efforts in retrofitting, and five buildings have used EUAs to access finance to retrofit, generating $5.6 million of investment and aiming to save 5,660 tons of carbon emissions and $491,000 in energy costs per year. If the 1200 Buildings program is successful, it will enable commercial buildings to improve their efficiency by approximately 38%, which would lead to the elimination of 383,000 tons of CO_2 each year. The program would also lead to a reduction in potable water use in the commercial sector by 5 giga liters – an important goal for a city with scare water resources and at risk from the impacts of climate change.

Retrofit Chicago - The Commercial Buildings Initiative

The City of Chicago has some of the most iconic buildings which showcase the city's strength in global business and innovative architecture. The Commercial Buildings Initiative is one of three components of Retrofit Chicago, a coordinated, cross-sector plan to bring energy efficiency improvements to municipal, commercial, and residential buildings throughout the city. Structured as a voluntary leadership effort, Chicago's Commercial Buildings Initiative aims to increase energy efficiency in commercial buildings larger than 200,000 square feet. By reducing energy use by at least 20% within 5 years, participants support the City of Chicago's private sector's commitment to increasing asset value, reducing operating costs, creating jobs, and lowering greenhouse gas emissions. In joining the program, participating buildings also commit to begin energy efficiency work within 6 months, track progress and share efficiency successes with the public, as well as serve as ambassadors to other buildings interested in increasing energy efficiency. When the program was launched in 2012, 14 buildings covering 14 million square feet of office and hospitality space joined the Commercial Buildings Initiative. This number has increased to 32 buildings and 28 million square feet since then. Program partners develop a participant value proposition that focuses on increased building asset value through reduced operating expenses and improved tenant attraction and retention. By providing technical support, access to financial incentives, public recognition, expedited permits and fee waivers, and peer-to-peer engagement and best practice sharing, the Commercial Buildings Initiative is achieving great economic and environmental benefits for the City of Chicago.



Tokyo – Cap-and-Trade Program

In 2006 Tokyo announced its aim to cut emissions by 25% from 2000 levels by 2020. As part of the strategy to achieve this goal, the Tokyo Metropolitan Government (TMG) focuses to reduce emissions from the city's new and existing building stock, implementing a cap-and-trade program for existing large commercial, government, and industrial buildings. Launched in 2010, the Tokyo cap-and-trade program is the world's first urban cap-and-trade program.

The cap-and-trade system sets out that buildings over a certain size to take action in reducing its emissions. The cap is fixed for reducing GHG emissions at 6% for the first compliance period (FY2010-FY2014) and 15% for the second compliance period (FY2015-FY2019). If a building reduces emissions beyond the cap, then it is eligible to sell "credits" to buildings unable to match those targets. Thus, a market for

GHG emissions is established, which produces the market-allocated distribution of a government-set level of emissions. In its first year of the program, 1,159 participating buildings in Tokyo exceeded expectations and reduced emissions by a total of 13%. Of the participating commercial buildings, 93% have now met the first compliance factor, and more than 70% have already surpassed the target for 2019. Because of the market mechanism the cap-and-trade program provides greater emissions reductions at a reduced cost to all participants. Moreover, energy efficiency efforts are now addressed jointly by tenants and building owners, which has led to greater public awareness of climate change issues.

The standout technology in the buildings sector is building automation, which provides intelligent sensors to reduce energy demand based on use in the electrical, mechanical and ventilation systems of buildings. Room automation technologies alone provide 2.3% savings in buildings related greenhouse gas emissions.

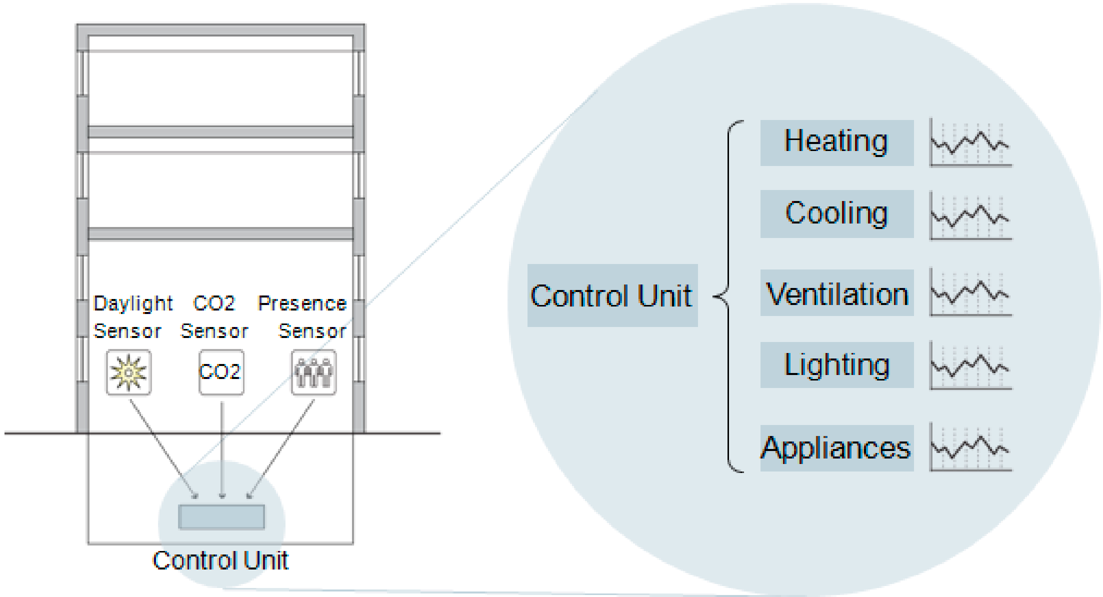


Figure 8 : In building automation, intelligent sensors feed data into a control unit that controls heating, ventilation and lighting.

Transport

Technical levers come in the transport sector will be able to deliver over 29% reductions in transport related emissions. The ten new metro lines and reduced headway through CBTC technology[1] will deliver more than 10% reductions in transport greenhouse gas emissions and add over 300,000 installation, maintenance and operation full time equivalent jobs. This is an unprecedented investment in metro expansion with few global precedents. In addition, relevant levers from E-vehicle and Intelligent Traffic Management will also contribute to GHG emission reduction significantly, such as City Tolling, E-bus and E-car Sharing.

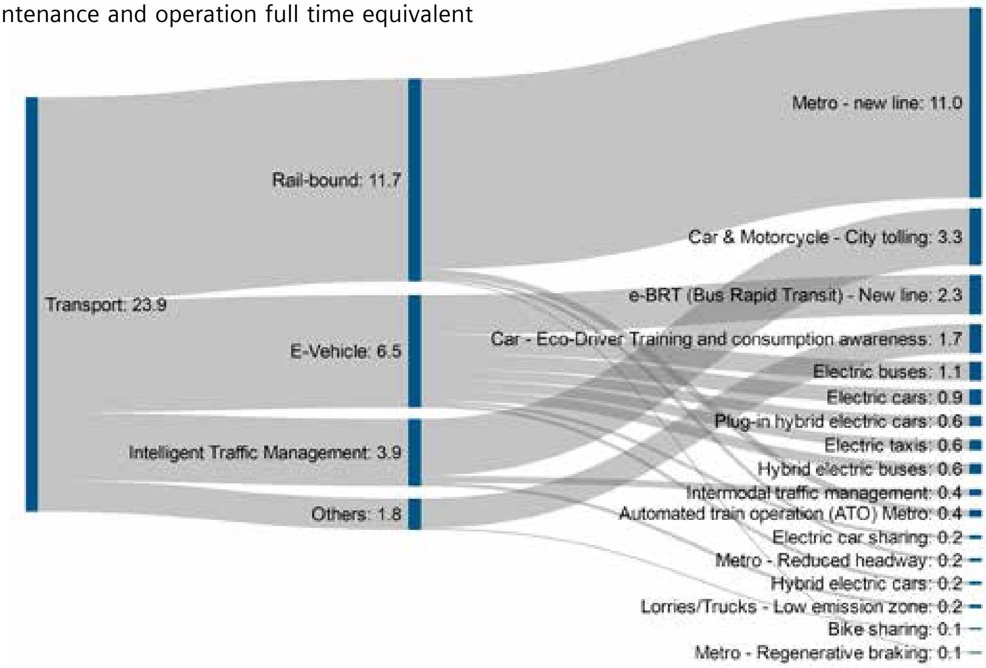


Figure 9 :%CO_{2eq} emission reductions for each transport technology compared to overall transport emissions.

[1]CBTC technology: Reduction of headway by introducing a rail automation system with moving block scheme. The lever increases the capacity of over utilized metro lines significantly. It induces a modal shift from other motorized mode to the metro system.

Considering the cost and overall performance in terms of CO_{2e} and PM10 reduction, the results show that technical levers from intelligent traffic management can produce relatively more reduction potential with limited investment, such as City Tolling, Intermodal Traffic Management and E-car Sharing etc. Meanwhile, Seoul city's ambitious plan in developing new metro lines will also provide significant amount of employments for its construction, maintenance and operation.

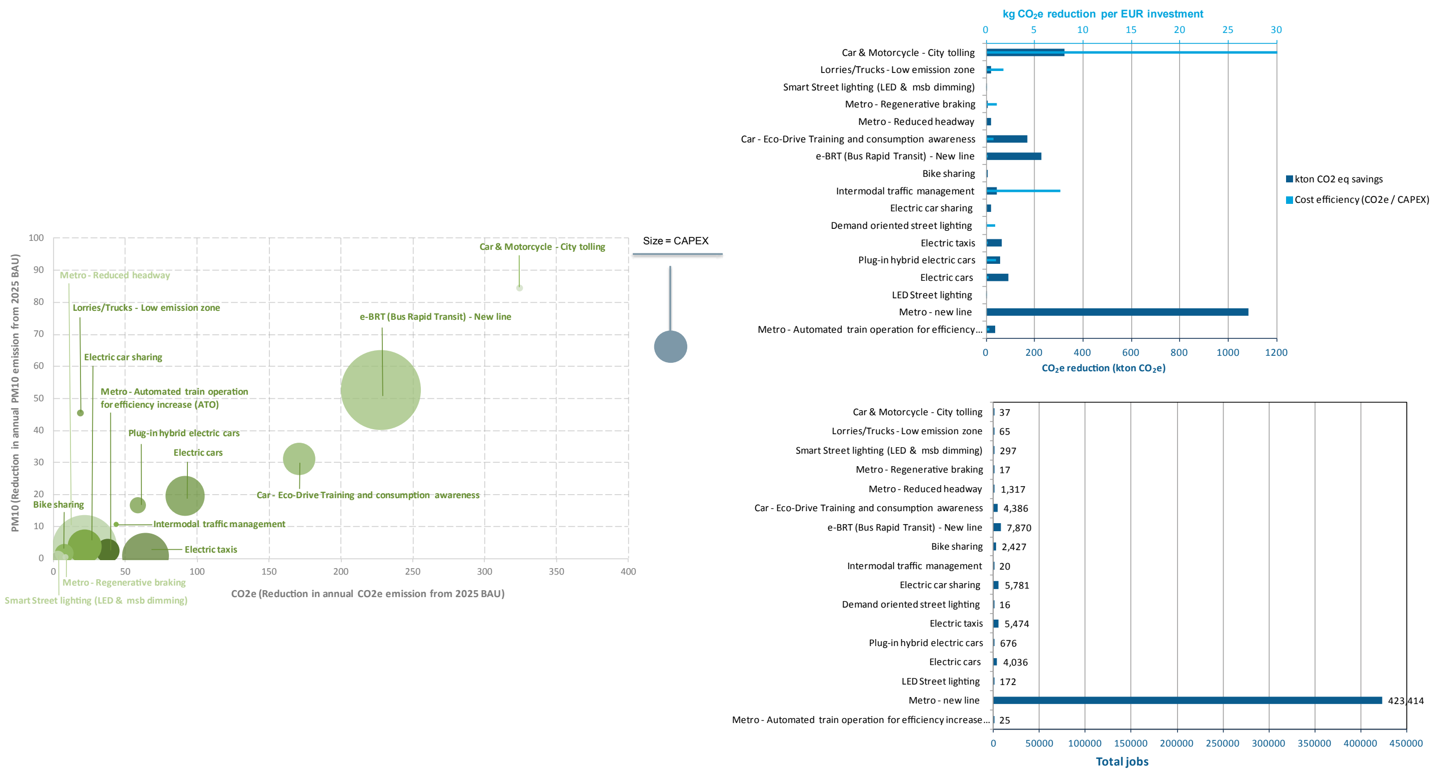


Figure 10 : Technology performance in cost efficiency and jobs

Box 2: Decreasing car use and increasing alternative car implementation in cities

London

The congestion charge in London is a daily levy imposed on drivers entering central London between 07:00 and 18:00 from Monday to Friday, excluding public holidays. Set at £5 at its inception in 2003, the charge has gradually increased over time, and as of June 2014 stands at £11.50 if paid in advance or on the day, or £10.50 for drivers that have registered for CC Auto Pay. The scheme makes use of purpose-built automatic number plate recognition (ANPR) cameras to record vehicles entering and exiting the zone. The cameras read car number plates and cross-reference them against a register of cars. Cameras can record number plates with a 90% accuracy rate through the technology. Drivers are able pay the charge in advance or on the day of travel. If they forget they can pay up until midnight the following day, but will incur a surcharge. Groups exempt from paying the congestion charge and those eligible for discounts include people with disabilities, residents living within the congestion zone, emergency services and breakdown recovery vehicles, taxis, and drivers of alternative fuel vehicles.

The congestion charge zone covers a large portion of central London. In 2007 the congestion charging zone was enlarged via the Western Extension, but this was revoked in 2011, returning the charging zone to its original size. Behind ticket and fare sales, congestion charge is the second biggest revenue generator for Transport for London bringing nearly € 300m of annual revenue. Revenue is generally earmarked to be spent on new bus investments in the city.

Rotterdam

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

San Francisco

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

The electrification of the city's transport fleet and introduction of e-cars provide further large savings to the city. Electric BRT and bus systems alone provide 5% transport related savings and deliver 14,000 full time equivalent installation, maintenance and operation jobs.

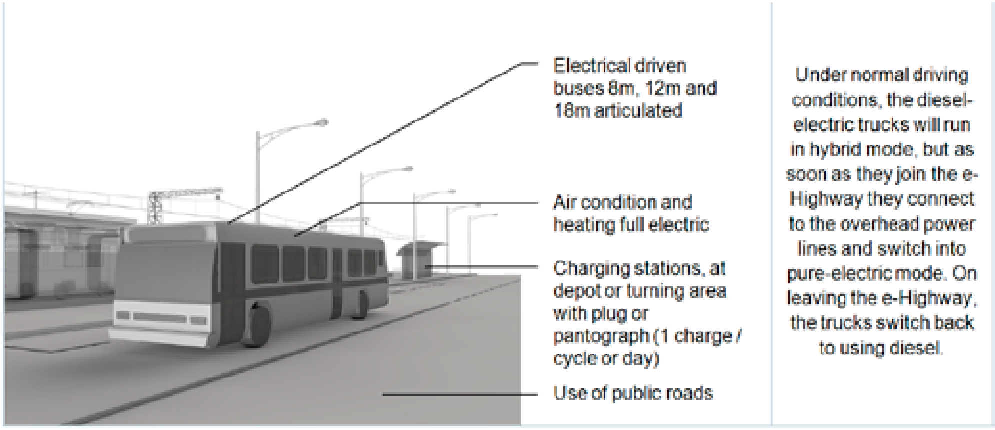


Figure 11 : Electric bus systems that can be charged through overhead lines or a plug-in option in the garage

Energy

Divesting away from its reliance on nuclear as well carbon intensive electrical power will provide clear economic and environmental benefits to Seoul. In 2020, the city can reduce citywide emissions by 3.4% through investments in new combined heat and power district energy systems as well as solar photovoltaic installations. Both these solutions provide large scale local capital investment in the very short space of six years adding nearly 100,000 local jobs.

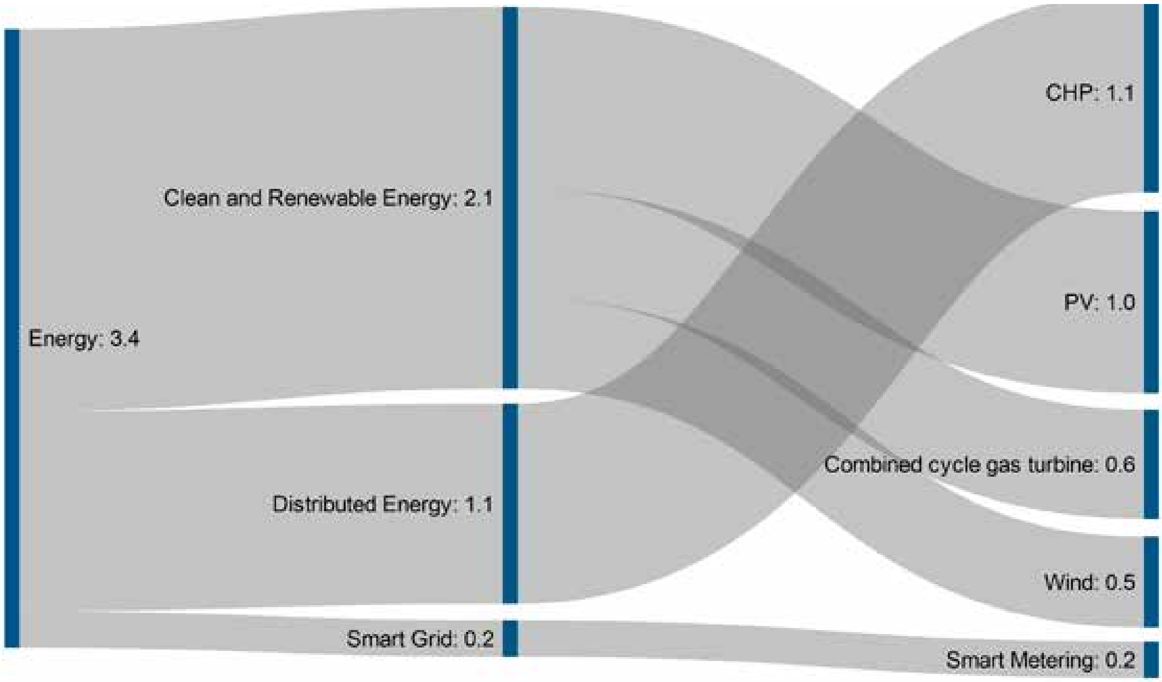


Figure 12 : % savings in CO_{2eq} for energy related technologies

The photovoltaic installations are perhaps the more ambitious energy project. We modeled this along the lines of Seoul's Solar City project that is mobilizing installations in both public buildings, schools and private buildings. Comparing the implementation cost and its performance in reducing CO_{2e} and PM10 emission, the results show that the application of CHP is more cost effective than the other levers.

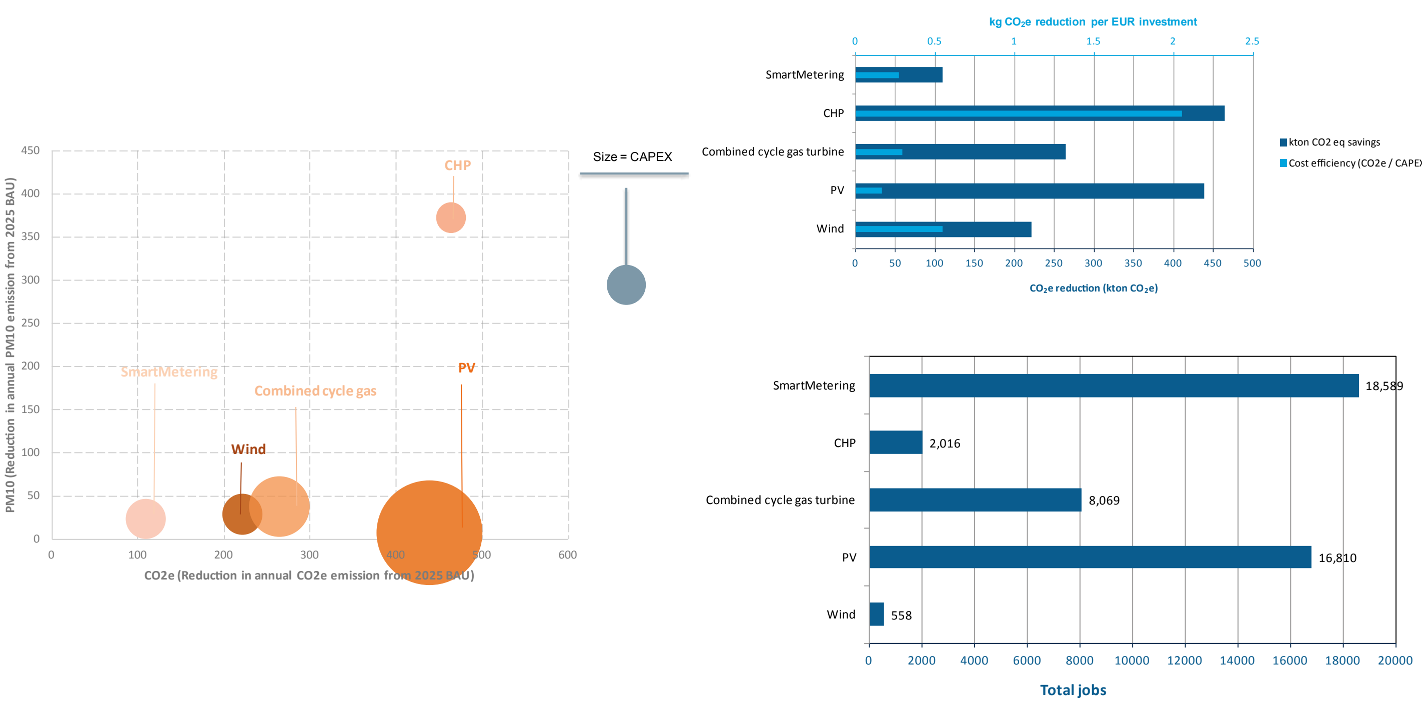


Figure 13 : Technology performance in cost efficiency and jobs

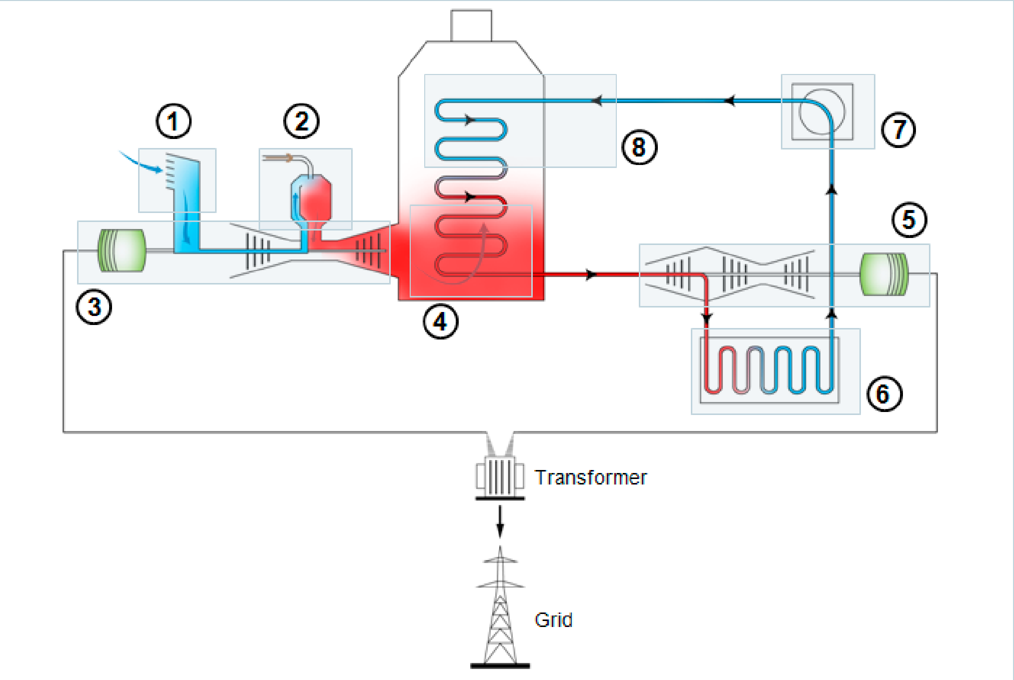
Box 3: Use of renewable energy

Solar City - US

SolarCity is a publically listed company in the US that pays and installs for the deployment of solar panels in homes and businesses. With recent aerial solar intensity mapping advances, the company can approach those areas and buildings with the highest potential output. Customers only pay a monthly fee for the service as long as they allow installation and access rights to their roof. Depending on local energy prices, the solar contract may often be lower than their existing monthly bill. By 2014, then company had an output of more than 2 gigawatts of deployed power.

Solar City delivers its service through two models called the Solar Lease and Solar PPA. In the former the monthly rate is predetermined and tied to a production output. In Solar PPA, the actual amount paid relates to actual demand. These options have allowed the company to both diversify its customer base but also reduce its risk profile with a steady minimum income reported to investors.

Another form of decentralized energy system for Seoul is combined heat and power (CHP) that is able to deliver heat and electricity reducing the reliance on national grid provision as well carbon intensive boilers in individual buildings. Interestingly the city of Copenhagen, which is one of the world's leading deployers of district energy, started investing in CHP following the 1970's oil crisis that pushed the city towards a more energy independent future. Similarly, Seoul's will to rely less on imported nuclear energy can help drive the momentum for a more energy independent future.



1. Fresh air enters the **air filter** and is sucked into the **combustion chamber**
2. Natural gas burns into the **combustion chamber** with the oxygen provided by the fresh air
3. Hot gases rush past and spin the **turbine** blades that turn the **generator** which produces electricity
4. Hot gases pass into the **steam generator** and boil water into steam (gases are exhausted via stack)
5. Superheated steam spins **turbine** blades that turn the **generator** which produces electricity
6. Superheated steam passes into the **condenser** that cools back into water
7. Cooled water flows to **filter unit** where it is cleaned
8. Cooled clean water returns to the **steam generator**

Reduces by up to 41% of CO_2 eq. emissions compared to average power generation worldwide

Figure 14 : Combined heat and power systems provide reliable decentralized heating and electrical power typically reducing emissions by 40%

Conclusion

Seoul is well on its way to becoming a more energy independent city meeting its objectives set out in the One Less Nuclear Power Plant and the Seoul Sustainable Energy Action Plan. This study has modeled the impacts of some unprecedented investments in 46 transport, buildings and energy technologies that deliver over 23% greenhouse gas savings by 2020. This is by far the most rapid emissions reductions in any city that the CyPT model has been deployed. Furthermore, by enhancing the implementation rate to maximize the impact of different infrastructure levers, further GHG emission can be saved in 2025 for a low-carbon and sustainable Seoul

The city will need to mobilize some major resources to achieve these goals. In transport, a very ambitious rail transit plan and intelligent traffic technologies were modeled showing the commitment that Seoul has in meeting its goals. The fixed infrastructure benefits are considerable with over 300,000 local jobs created from the new metro lines alone.

In the energy sector, the city can reduce its overall greenhouse gas emissions by 2% by continuing to deploy photovoltaic electricity generation and combined heat and power provision in new district networks. Such decentralized installations can make Seoul's electricity supply more resilient and less dependent on national or international imports.

Siemens' presence in South Korea can assist the Seoul City government to retrofit commercial buildings with intelligent building automation technologies that will deliver over 2.3% of CO_{2eq} reductions. In the transport sector, e-buses and e-BRT bus systems with on-board charging running on the city's cleaner electricity mix in 2020 can deliver over 4% reductions in transport related emissions. Finally Seoul can deliver resilient and secure off-grid energy through a combined heat and power network with total greenhouse gas savings of over 1% of citywide savings. In other words Siemens technologies alone can deliver nearly 4% of Seoul's citywide emissions in the next six years.


STAFF

Appendix I

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 (CH4) has a GWP of 25. Therefore, 1kg CH_4 * 25 = 25kg CO_2e.[2]

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.[3]

3. PM10

Particulate matter 10 (PM10) 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. PM10 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 PM10 include vehicle emissions, wood burning stoves and fireplaces, and dust from construction, landfills and agriculture.[4]

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 2,080 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.

[2]http://ecometrica.com/white-papers/greenhouse-gases-co$_2$-co$_{2e}$-and-carbon-what-do-all-these-terms-mean
[3]http://www.eea.europa.eu/data-and-maps/indicators/eea-32-nitrogen-oxides-nox-emissions-1
[4]http://www.arb.ca.gov/html/brochure/pm10.htm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Appendix II

Glossary

Building Levers		
Non-Residential	BACS Class B	Energy-efficient building automation and control functions save building operating costs. The thermal and electrical energy usage is kept to a minimum. It is possible to estimate the efficiency of a building based on the type of operation and the efficiency class of the building automation and control systems (BACS) installed. Energy Class B includes advanced building automation and controls strategies, such as demand-based operation of HVAC plant, optimized control of motors and dedicated energy management reporting. Reduction of CO_{2e}, PM10, and NOx are related to thermal and electrical energy savings.
Non-Residential	Building Efficiency Monitoring (BEM)	Building Efficiency Monitoring provides real-time measurement of energy consumption and environmental conditions within an EXISTING building, via a centralized monitoring system connected to a network of field devices (such as meters, switches and sensing devices). Standard energy reports are created to allow benchmark comparison with similar buildings to assess performance and highlight problems (e.g. kWh, CO_2, temperature). Offering monitoring services and performance reports creating awareness and transparency and enable continuous improvement and reduction of overall energy consumption. Reduction of CO_2e, PM10, and NOx related due to thermal and electrical energy savings.
Non-Residential	Building Performance Optimization (BPO)	Building Performance Optimization (BPO) is a range of services designed to increase the energy efficiency of an EXISTING building by implementing proven building control strategies otherwise known as Facility Improvement Measures (or FIMs). BPO can improve THERMAL and ELECTRICAL energy efficiency in a building in many ways; typically via improved HVAC technology, by adapting the building to suit usage profiles or providing information and analytics for operational personnel. Reduction of CO_{2e}, PM10, and NOx related due to energy savings.
Non-Residential	Building Remote Monitoring	Building Remote Monitoring (BRM) allows individual building performance to be measured and compared against benchmark values for similar building types or sizes. Energy experts are able to remotely analyze building energy usage, to detect problems and make proposals for improvements. Reduction of CO_{2e}, PM10, and NOx related due to energy savings.
Non-Residential	Demand controlled ventilation	With demand-controlled ventilation (DCV), the amount of air introduced into a space is matched to the actual demand and is ideal for areas with fluctuating occupancy such as open-offices, conference rooms and restaurants. CO_2 levels measured by air quality detectors identify periods of low occupancy and cause the fans to stop or reduce speed (at 50% air volume, the fan power is reduced by a factor of 8!). DCV also provides savings in heating and cooling, by adjusting set point temperatures (economy mode). Reduction of CO_{2e}, PM10, and NOx related due to electrical electricity savings.
Non-Residential	Demand oriented lighting	Demand-oriented lighting is based upon presence (or motion) detection: Lighting is switched 'on' when someone enters a given area and deactivates after a pre-defined period of time without movement. It is usually combined with daylight measurement. The largest energy savings can be achieved in buildings with fluctuating occupancy, and when combined with other lighting technologies, it can reduce the lighting energy use within a building by 20 to 50%. Reduction of CO_{2e}, PM10, and NOx related due to electrical energy savings.
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}, PM10, and NOx related due to electricity savings.

Building Levers		
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}, PM10, and NOx are related to electrical energy savings.
Non-Residential	Glazing	Applying double/triple glazed window made of two or three panes of glass and a space between them filled with air or insulating gases and reduces heat and noise transmission as well as solar gain from solar radiation through the window. Due to better window insulation less heating and cooling energy is needed inside the building. Reduction of CO_{2e}, PM10, and NOx related due to energy savings.
Non-Residential	Room Automation HVAC+lighting	Room Automation provides control and monitoring of heating, ventilation, and air conditioning within individual zones based upon demand, with options for automatic lighting. An in-built energy efficiency function identifies unnecessary energy usage at the room operating units, encouraging room users to become involved in energy saving, and different lighting scenarios can be programmed. Reduction of CO_{2e}, PM10, and NOx are related to thermal and electrical energy savings.
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}, PM10, 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}, PM10, and NOx related due to electricity savings.
Residential	Home Automation	Home Automation allows the automatic adjustment of heating, cooling, ventilation and lighting. The adjustment is based on environmental conditions and room occupancy, and it works by applying sensors and actuators as well as control units. Home automation reduces the energy demand of heating, cooling, ventilation and lighting.

Transport Levers		
Freight	E-Highways	Share of hybrid diesel-electric trucks and highways with overhead power lines at target year. As soon as trucks join the eHighway they connect to the overhead power lines and switch into pure-electric mode. Leaving the eHighway, the trucks switch back to using hybrid mode. Energy demand is reduced due to shift of transport to hybrid electric truck and electric transport together with related emissions.
Infrastructure	City Tolling	City tolling is a form of road pricing applied to a geographic area within a city. It would charge drivers for road use and pricing can be flat or dynamic based on distance and likely travel times. Charges could also be used to encourage cleaner vehicles or those that use a particular fuel type. The technology uses number plate recognition software and cameras.
Infrastructure	Intelligent traffic light management	Share of traffic lights, coordinated (green wave algorithms) - Management systems controls traffic speed and volumes and co-ordinates traffic lights to help maintain the flow. Reduced energy demand, fuel consumption and air pollution caused by traffic by reducing traffic jams, stop and go.
Infrastructure	Intermodal traffic management	Share of users integrated at target year equals to person kilometer considered to optimize capacities of the entire traffic infrastructure. 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.
Infrastructure	LED Street lighting	Share of low efficient street light replaced by more efficient light-emitting diodes (LEDs). Saving electricity together with related emissions. Additionally high reduction in maintenance due to longer lifetime (10 years versus 6-12 month) and possibility to dim the light depending on the environmental conditions.
Infrastructure	Low emission zone for vehicles	Share of the city's area, defined as a geographical area with restrictions for vehicles of certain off-gas emission standards.
Passenger	Automated train operation (ATO) Metro	Share of lines operated with ATO at target year: ATO controls or guides optimal throttle of engines, going optimal speed without violating the schedule. Reduced electricity demand per person km due to coasting. The saving potential correlates with the number of and distance between the stations. Reduction of CO_{2e}, PM10, and NOx related to lower electricity demand.
Passenger	Bike sharing	Number of sharing bikes per 1,000 inhabitants, offered at target year, which results in a shift from all other transport modes equally. The technology will lower energy demand per person kilometer of travel together with related emissions.
Passenger	BRT-Electrification	Share of the Bus Rapid Transport (BRT) bus fleet that is powered by batteries. Battery electric vehicles are "zero" exhaust emission vehicles. Electrification of these buses will reduce local emissions of PM10 and NOx. The technology requires the set-up of a charging infrastructure. The electricity, used for charging, is generated according to the general local electricity mix.
Passenger	e-Bus rapid transit new line (eBRT)	Share of Passenger Transport at target year provided by Bus rapid transit: a high performance public transport combining bus lanes with high-quality bus stations, and electrical vehicles. Faster, more efficient service than ordinary bus lines. Results in modal shift from private transport to public transport, shift from combustion engines and reduce energy demand per person km together with related emissions.

Transport Levers		
Passenger	Eco-Driver Training and consumption awareness	Frequent Training of car drivers to optimize driving behavior and increase fuel economy of fleet average.
Passenger	Electric buses	Share of the vehicle fleet operated by battery electric bus vehicles. Battery electric vehicles are "zero" exhaust emission vehicles. These vehicles will significantly reduce local emissions of PM10 and NOx. The technology requires set-up of charging infrastructure. The electricity used for charging is generated according to the general local electricity mix.
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 e-car and shift to non-vehicle travel, such as walking, cycling and public transport.
Passenger	Electric cars	Share of conventional combustion vehicles replaced by battery electric vehicles. Battery electric cars are "zero" exhaust emission vehicles. These vehicles will significantly reduce local emissions of PM10 and NOx. The technology requires set-up of charging infrastructure. The electricity used for charging is generated according to the general local electricity mix.
Passenger	Electric taxis	Share of conventional combustion taxi vehicles replaced by battery electric taxi vehicles. Battery electric vehicles are "zero" exhaust emission vehicles. These vehicles will significantly reduce local emissions of PM10 and NOx. The technology requires set-up of charging infrastructure. The electricity used for charging is generated according to the general local electricity mix.
Passenger	Hybrid electric buses	Share of vehicle fleet operated by 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.
Passenger	Hybrid electric cars	Share of conventional combustion vehicles replaced by 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.
Passenger	Metro - new line	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	Metro-Reduced headway	Reduction of headway by introducing a rail automation system with moving block scheme. The lever increases the capacity of over utilized metro lines significantly. It induces a modal shift from other motorized mode to the metro system.

Transport Levers		
Passenger	New Tram Line	Light rail systems (LRT) are lighter and shorter than conventional rail and rapid transit trains. LRT systems are flexible and can run on shared roadways or along dedicated tracks. These systems can be configured to meet a range of passenger capacity levels and performance characteristics. They can operate with high or low platforms, and consist of one or multiple carriages. Trams can be equipped with braking energy storage systems to further reduce energy demand.
Passenger	Plug-in hybrid electric 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.

Energy Levers		
Distribution	Smart Grid for Monitoring and Automation	Increased network performance with intelligent control - Optimization of decentralized energy resources – economically and ecologically. Possibility for bidirectional energy flow, Reduces technical and non-technical grid losses in distribution and corresponding reduced energy generation and related emissions.
Distribution	Smart Metering and demand response	Implementing smart meter devices and a meter data management system providing detailed information about how much energy is consumed at which place which allows demand response and reduction of non-technical losses.
Generation	Photovoltaic	Share of electricity provided by Photovoltaic at target year changing the energy mix and its related emissions provides cleaner electricity for buildings and electric powered transport modes.
Generation	Wind power	Share of electricity provided by wind power at the specified target year. This technology effectively changes and electricity mix and it provides cleaner electricity for buildings and electric powered transport modes.
Generation	CHP	Share of heat supplied at target year changing the energy mix for heating and its related emissions - provides cleaner heat for buildings.
Generation	Combined Cycle Gas Turbine	Share of electricity provided by combine cycle gas turbine operated at target year changing the energy mix and its related emissions due to combination of gas and steam cycle provides cleaner electricity for buildings and electric powered transport modes.
Transmission	Network Optimization	A well-structured, secure and highly available electricity supply infrastructure. Reduces grid losses; Resulting in less energy generation and related emissions to provide the demanded energy at customer side.
Transmission	Power System Automation and optimized network design	Optimal combination of substation automation and change of voltage levels, power system structures, equipment (lines, transformers), change of disconnecting points, etc. in order to reduce (non-)technical losses, guarantee fast power system restoration after a fault in the network and simplified network operations.


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