The City Performance Tool-How Cities Use LCM Based Decision Support

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Abstract This paper presents the City Performance Tool (CyPT) approach, a LCA-based methodology for sustainable infrastructure decision support. The work presents an outside-in view about the methodology, details about the underlying LCA models and its implementation into a tool. The results for three different cities will be presented and a general conclusion for the use of LCM-based decision support from a business perspective will be given.

1 Introduction

All over the world, cities are shaped by profound forces: their population, their technologies and their infrastructures. Even today, these forces collide and urbanization and climate change will spur dramatic changes in metropolitan areas. Cities need to pave the way for constant evolution: digital technologies are becoming increasingly important and urban infrastructures and buildings require a more efficient and sustainable setup.

These changing environments set free a swarm of urban challenges. Developed cities for instance need to focus on cutting carbon emissions, improving efficiency in infrastructure and buildings, stimulating a market shift towards cleaner vehicles and more efficient and environmentally friendly public transportation. At the same time, infrastructure quality in many advanced economies is deteriorating. Looking forward to 2030, more than \$50 trillion will need to be invested in infrastructure globally to keep up with GDP and population growth [1].

Cities in emerging markets on the other hand face issues such as power outages and inadequate public transport and roads, which brake on growth and development. Infrastructures cannot be built fast enough to keep pace with economic and

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Fig. 1 Environmental reduction targets of different cities worldwide

urban development. In times of constrained budgets city leaders carefully need to identify their infrastructure investments ensuring that their investments address their environmental and economic priorities. Technologies need to be adapted to serve local needs to ensure that the right technologies are applied in the right environments, tailored to the specific characteristics of the individual city (Fig. 1).

To tackle these questions, Siemens has developed an interactive and comprehensive tool—the City Performance Tool (CyPT) [2]. It gives guidance to a city on how to achieve their environmental targets while providing an indication on how each infrastructure-related decision will influence job creation and the infrastructure sector growth. The results of the CyPT approach for a city is shown in Fig. 2. The main categories depicted are GhG emission reductions in MtCO₂ equivalents per year, air quality from kt NO_x and kt PM10 per year for time horizons from 2020 through 2050. The darker line represents the city target and the lighter line the reduction results calculated from the parameterized LCA model.

2 The City Performance Tool-Methodology and Process

The City Performance Tool is a dynamic simulation tool which studies a series of more than 70 technologies from Building, Transport and Energy Technologies—at different time periods and implementation rates. It covers greenhouse gas emissions from buildings and transport, as well as air pollutants such as particulate matter (PM) and nitrogen oxides (NO_x). It also looks at the creation of new local jobs to install, operate and maintain city solutions. In transport, for example, CyPT assesses how a technology would reduce demand (reduce parking search traffic), shift the mode (public transport instead of cars) or improve efficiency (automated trains). The model is based on Life Cycle Assessment (LCA) methodology and builds upon Siemens’ technology expertise and global databases of deep vertical

Fig. 2 Environmental reduction using CyPT methodology: results of applying a combination of different technology levers (light) are compared to City targets for the categories GhG-emissions and air quality

process knowledge. It can determine the implementation rate needed for your city to meet its future environmental targets. It can also measure the impacts of a city’s strategic plans, and compare traditional methods with state-of-the-art technologies for their benefits and value for money.

The methods and tools are a combination of conventional LCA, consequential LCA, greenhouse gas accounting for cities and futurology. Even though the software and modelling concept such as the functional units are common LCA-based, the model is aligned with the GPC-Protocol [3]. Forecasting elements are included from HBEFA [4] for market and technology development.

In total 70 technology levers from energy system, buildings and transport are included in the LCA parameter model. Thus are 20 electricity generation and 20 heat generation technologies, 10+ building types with its electricity, heat and cooling demand, 10 freight modes; 35 passenger transport modes; 15 road and rail infrastructure elements. To establish a baseline, the model requires data to determine the level of maturity of the infrastructure system and its individual

Table 1 Lever description of the 70 technology levers in buildings, transportation and energy

Buildings	Transportation	Energy
Wall insulation	Tram	Photovoltaic
Glazing	Metro	Wind power generation, combined cycle gas turbine
Building envelop	Regional train: new vehicles, new line, reduced headway	Combined heat and power
Efficient lighting	ATO Automated Train Operation	Network optimization, smart grid for monitoring and automation
Demand oriented lighting	Regenerative braking	Power system automation & optimized network
Demand controlled ventilation	Bus	Smart metering
Building efficiency monitoring	Car: CNG, hybrid, plug-in, electric, hydrogen	On shore power supply in harbors
Efficient motors & drives	LED street lighting	
Room automation	Smart street lighting, intelligent traffic light management	
HVAC & lighting + blinds	Intermodal traffic management	
Building automation, BACS A,B,C, remote monitoring	Low emission zone (truck)	
Heat recovery	Eco driving training, urban bike sharing, cycling highway, occupancy dependent T, tolling, city tolling	
Building performance optimization	E-Ticketing	
	E-Car sharing	
	E-Highway	
	e-BRT	
	Freight ram	
	Freight rail electrification	

components. This is necessary to later calculate the impact of levers. Levers are new technology or measures that are introduced to the system. The list of levers is depicted in Table 1.

The common CYPT model determines the variety of process blocks to build any city in a common LCA tool (SimaPro) [5]: in Fig. 3 the underlying LCA model is depicted for the building sector.

The baseline model is using city data publicly available mostly from statistics, studies, and transport or household surveys. Around 300 city-specific data points are used for three main sectors: electricity, heating, and cooling demand for

Fig. 3 Subset of lever model: each technology is parameterized by input emissions factors from the SimaPro model

buildings; passenger and freight transport demand; and the transport network. The model baseline of the of a City’s lever network includes more than 2000 single processes, and more than 1000 customized parameters. This baseline has three KPIs —PM10 and NO_x (air quality) and CO₂ eq. emissions—which are also projected into the future based on a business-as-usual scenario and your own city’s demand projection (if available). This calculation delivers a basic understanding of the root causes of emissions in your city’s buildings and transport. A range of impacts can be studied based on a single lever and its implementation rates, comparing options, or combining several levers in one or more sectors [6].

Then mitigation strategies are applied in terms of what-if scenarios, by answering the following questions: Which and how much energy is required to serve the city’s demand in transport and buildings? Which infrastructure technologies are available, what is the efficiency of, how can the demand shifted or reduced?

The calculation of the KPI’s starts with the determination of demand which is than split into the contributing technologies. This is displayed in Fig. 3. Emissions related to buildings are a sum of heating, electricity etc. and its contributing technologies i.e. heat from gas. The CyPT model is multi-process LCA model, the change of one parameter defines a scenario, describing the transformation of the given infrastructure over time (Fig. 4).

Due to the scenario-based approach of the CyPT a process was developed to ensure the full stakeholder involvement of city representatives. At the beginning of

Fig. 4 Process of CyPT application in cities: collaboration starts in data collection using the LCA-model and the impacts of technologies for KPI's like CO₂ emission or air quality reduction

the process, data is collected on your city's energy, buildings and transport infrastructure to customize the CyPT model. Once all the data is collected, the CyPT Manager calculates the environmental baseline for your city based on activities in the three sectors. Comparing the results with your own targets it identifies future needs and improvement areas. The CyPT Manager also calculates the city-specific impacts of individual technologies. Levers can be pre-selected based on results, and city specific plans and policy can also be considered valuable mix of solutions.

A specially developed CyPT app visualizes the effects of individual levers on a city, its buildings and its transport system [7].

3 Inside-Out View—Results from Vienna, Copenhagen and Minneapolis

To understand the outside-in view we will present and discuss results of the CyPT projects and the resulting infrastructure reports from three different cities: Vienna [8], Copenhagen [9] and Minneapolis [10].

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 prioritizing in the run up to 2025, see Fig. 5. This study tested some of the technologies in Vienna's climate action programs named KLiP I and II. It was

Fig. 5 Lever mix used in the Vienna CyPT project from already implemented to experimental technologies

found that solutions are cost effective in reducing CO₂ eq. levels and improving air quality, the city will need to implement more of these intensive carbon reduction technologies if it is to meet its 2030 targets.

An investment of €8 bn over the next decade is needed to implement a set of technologies that can reduce CO₂ eq. emissions in Vienna by 9 Mt and add 85,000 full time equivalent jobs to the local economy. 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. Vienna has some untapped cost-effective technology opportunities to meet its CO₂ mitigation targets. In the energy sector, the city should continue its implementation of combined heat and power (Fig. 6).

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 CO₂ emissions, improve air quality and increase local jobs.

Minneapolis and its development organization Xcel has set a “80 by 50” target, meaning 80% reduction of GhG emissions by 2050 [8]. The outcome of CyPT study shows that its utilities need to use 65% clean energy sources as a base of their energy mix (Fig. 7).

But even with this step, Xcel will have to continue greening its electricity by implementing 40 buildings and transportation technologies and adopted at their highest implementation rates by 2050 to ensure that targets are met. Our results show that, if the electricity mix gets significantly cleaner, the top performing technologies for reducing carbon emissions include (1) electrifying both passenger and freight road transport and (2) improving energy efficiency in buildings, particularly in commercial and government buildings. The technology mix and its resulting improvements in air quality are depicted in Fig. 8. Additional benefits could be realized from public transit, if more people could be attracted to use it.

Fig. 6 Cost effectiveness comparison: the larger the bubble the more jobs the technology will induce. Bubbles on the top right of the chart, reduce the larger amount of greenhouse gases and PM10 levels per unit of investment Technologies such as plug-in hybrid electric cars that improve air quality and reduce CO₂ most effectively

Fig. 7 Resulting emission reduction (CO₂ eq.) applying a 65% clean energy mix

Copenhagen has been and continues to lead cities on climate policy globally. It ranked top of Siemens' European Green City Index in 2009 [11], and it is making great strides meeting its 2025 target for carbon neutrality. Siemens has used the CyPT and found that the City of Copenhagen is reducing emissions from nearly all of the sources where it has significant control in energy and transport.

Copenhagen is decoupling its CO₂ eq. emissions so that despite a growing population and increasing building floor-space, carbon emissions are expected to decrease over the next 10 years. This is predominantly derived from greener national electricity and local heating mixes. Using our accounting standard that captures direct and indirect emissions, our model quantifies these savings as high as

Fig. 8 The CyPT for Minneapolis shows which technology has the greatest air quality improvement potential and its reduction values

12% of current annual emissions. These are savings achieved from the expansion of wind power and biomass for combined heat and power in the 2025 Climate Plan. Maintaining its global leadership position will require delivering further building upgrades within its own public stock and incentivizing private building owners to take action to improve the efficiency of their buildings. The city will also have to stimulate a market shift towards cleaner vehicles and a modal shift towards low carbon public transportation. The report indicates that intelligent administrative inner-city infrastructure investments in energy or mass transit must be accompanied by effective incentives for the private sector, as well as a good national framework to promote alternative mobility and cost-effective renewable energy (Fig. 9).

Fig. 9 Major CyPT results for Copenhagen

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

Fig. 10 Shortlisted smart technologies providing the largest savings

For example, buildings are responsible for around 80% of Copenhagen's greenhouse emissions—and almost a third of the commercial building stock is managed by just 40 owners. If these owners have an incentive to invest in six cutting-edge building technologies selected by the CyPT, the city could save 10% of its emissions and create more 18,000 jobs over the next 10 years.

As buildings become more sustainable, transportation begins to have a bigger contribution to emissions. The report shows that, by 2050, transportation will account for 27% of Copenhagen's emissions, as opposed to 20% today. The big surprise in the Siemens "Copenhagen's Big Incentive" report is that the most effective technology investments are outside of the city's budgeting program.

It is about "national investments in wind, private investments in building retrofitting, and household and business investment in alternative cars." In figures: 95% of the estimated three billion euros needed to save an additional 26% of city-wide emissions over the next 10 years are outside of the city budget. This indicates the investment strategy of Copenhagen must be aligned to the state or governmental plans (Fig. 10).

4 Conclusions

Modern cities constantly need to balance long-term targets such as reducing greenhouse gas emissions with shorter term aims such as improving air quality and creating jobs. All too often, lack of public support means long-term objectives are sacrificed for more immediate needs. The cities in the world have different focuses on environmental, economic or social aspects/KPIs. These differ by region, in scope (Carbon Accounting Scope 1–3), in time (in terms of target setting, short term for air pollutants, long term for GHG-emissions) and at last by infrastructure vertical. The LCA based decision support approach CyPT is presented in this paper. A parameterized LCA model is used to calculate the GhG and air quality emissions from 70 technologies applied in cities. CyPT takes on the challenges of this balancing act by helping decision makers to recognise and select technologies that offer win-win solutions. This is shown in the example of Minneapolis and the air

quality improvement potentials and the underlying technology mix. CyPT highlights the benefits from key performance indicators to enable city leaders to deliver long-term advantages strongly linked to short-term gains. Cities can maximise CyPT results by identifying the most cost-effective solutions for improving air quality and reducing greenhouse gas emissions. By studying capital and operational investments across the lifespan of each technology, CyPT can report on kilograms of CO₂ eq. as well as PM₁₀ and NO_x levels for every euro spent. This was shown in the example of Vienna, where untapped cost-effective technology opportunities show how to meet its CO₂ mitigation targets. The CyPT helps to optimize investment strategies for your city's long-term needs. This was shown at the example of Copenhagen, where almost all of the technology investments must come from sources outside of the city budget.

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