



# Urban Sustainability Solutions

---

**A FRAMEWORK FOR CITIES TO REDUCE GREENHOUSE GAS  
EMISSIONS THROUGH UTILIZATION OF ECONOMIC INCENTIVES  
AND PERSUASION**



**COLUMBIA UNIVERSITY**  
IN THE CITY OF NEW YORK

Columbia University  
SIPA | School of International and Public Affairs  
The Earth Institute  
Master of Public Administration in  
Environmental Science and Policy

Report prepared for:  
Natural Resources Defense Council – Urban Solutions Program

Spring 2016  
WORKSHOP IN APPLIED EARTH SYSTEMS  
MANAGEMENT AND POLICY ANALYSIS  
The views expressed in this report are those of the authors.

FACULTY ADVISOR:

Dr. Steven Alan Cohen

MANAGERS:

Ilinca Kung Parslow (Project Manager)

Frederic Klein (Deputy Manager)

TEAM:

Judah Aber

Tess Arzu

Paulo Bergamo Dos Santos

Matthew King

Scott Kjørtien

Siyao Liu

Brian Pellicore

Norman Shafiq

 COLUMBIA | SIPA  
School of International and Public Affairs

THE EARTH INSTITUTE  
COLUMBIA UNIVERSITY

## Preface

The Workshops in Applied Earth Systems Management and in Applied Earth Systems Policy Analysis are among the key components and the core curriculum of the Master of Public Administration in Environmental Science and Policy program at Columbia University. Students in each workshop group work together under the supervision of a faculty member to integrate knowledge and organize an effort to solve an environmental policy problem. In the spring semester, each workshop group completes a project and a report analyzing an actual environmental policy or managerial problem faced by its governmental or nonprofit client.

## Acknowledgements

This report was prepared for the Urban Solutions Program at the Natural Resources Defense Council to provide options and analysis for the design and implementation of city-level policies and programs based on worldwide best practices in the key areas of transportation, building energy and urban infrastructure finance. We would like to extend our deepest gratitude to Dr. Steven Alan Cohen, our faculty advisor and the Executive Director of Earth Institute; without whom we would not have been able to successfully complete this project. His advice and guidance were invaluable. We would also like to thank our client, Natural Resources Defense Council, especially Shelley Poticha, Director, Urban Solutions and Kimi Narita, Director of Strategic Engagement, City Energy Project for their guidance, expertise and feedback throughout the course of this project. Further, we would also like to thank Amanda Eaken, Director, Transportation and Climate, Prof. Nathanael Greene, Director, Renewable Energy Policy, Energy and Transportation Program, and Sarah Dougherty, Welch Environmental Innovation Fellow, Center for Market Innovation for their counsel at the outset of our project.

# Contents

Executive Summary	5
Background	7
Project Methodology	8
Analysis of Case Results	10
1. Summary	10
2. Transportation of the Public in Metropolitan Regions	12
3. Energy of the Built Environment	16
4. Financing Green Urban Infrastructure	20
Conclusion and Recommendations	24
Case Studies	28
Appendix A:	
Transportation of the Public in Metropolitan Regions	28
Appendix B:	
Energy of the Built Environment	47
Appendix C:	
Financing Green Urban Infrastructure	58
Appendix D:	
Evaluation Criteria	71
Appendix E:	
Case Study Framework	73
References	74

# Executive Summary

**S**ince the advent of the industrial revolution, anthropogenic greenhouse gas emissions have been drastically increasing due to the activities of a modern world including transportation, power generation and heat to support civil infrastructure. Homo sapiens are a resilient species, and over the past 50 years, we have increased our understanding of the broad impacts and climate change risks associated with this development. In tandem with this trend towards greenhouse gas emissions from industrial processes, global population has shifted dramatically towards highly concentrated activity centers: cities. Many cities are especially subject to projected impacts of climate change such as sea level rise and increased storm intensity, because of their roles in intercontinental trade as ports.

**GIVEN THE RISK** associated with coastal location, high populations, and sizeable infrastructure investment, cities have taken on a unique role in the face of slow national-level action, to lead on sustainable policy choices. A number of city groups and initiatives have sprung up as part of this approach, and the Natural Resources Defense Council (NRDC) has taken a principal role in helping to drive this change. One element of the NRDC approach is to look at emerging urban sustainable solutions and to facilitate the exchange of experiences between cities. The NRDC aims to create a roadmap for interested cities on how to implement effective solutions based on effective strategies already put into place from around the world. Our team from Columbia University has developed thirteen cases describing emerging

and sustainable solutions that have been used in various cities around the globe, and analyzed them for common goals, implementation processes, cost, greenhouse gas emissions, and applicability to other global cities.

**THREE PRIMARY CATEGORIES** of solutions have been investigated in this report. These categories are energy of the built environment, sustainable transportation, and finance of large urban sustainability infrastructure projects. The conclusion from this report is that there are two primary strategies that cities might consider in order to promote policy change and drive program implementation to reduce greenhouse gas emissions. First, cities can take a traditional approach such as setting standards or facilitating private development. This approach works well with cultures that have access to capital or have private markets that are already inclined to invest in green infrastructure. Second, cities can take a more proactive approach by cultivating financial incentives to motivate carbon-reducing investments that are cost-effective for both the investors and the operators.

**THERE ARE TWO APPROACHES** necessary for national or global impact. Without demonstrating that sustainable investment is also economically viable, regulations can be onerous and unwelcome, eroding public confidence and the demand for carbon emission reduction. However, by moving in both directions - showing that investment stands to be cost-effective and also setting standards for achievement - the ideal

framework for urban governments is established. This approach appeals to both idealistic and fiscal arguments in favor of carbon emission reduction without relying on esoteric climate science to garner public support.

Our report is based on a set of 13 detailed case analyses presented in Appendices A, B, and C. Table 1, below, lists the cases location and activity function along with available estimates of greenhouse gas reductions.

**TABLE 1:** This is a summary table of cases analyzed by key activity function showing approximate GHG savings per program/policy.

Key Activity	City	Program or Policy	GHG Savings *	Page
TRANSPORTATION	London	Congestion Pricing	N/A	28
TRANSPORTATION	San Francisco	Ride Share	N/A	30
TRANSPORTATION	Vienna	Electric Bus	~ 23 tons/per bus/per year	33
TRANSPORTATION	Paris	Bike Share	~0.1 tons/per bike-share user/per year	36
TRANSPORTATION	Bremen, Germany	Car Share	~1.4 tons/per car-share member/per year	39
TRANSPORTATION	Amsterdam	Electric Vehicles Fleet	N/A	43
ENERGY	New York City	NYU Co-Generation Plant	~26,500 tons/per year	47
ENERGY	Barcelona	Solar Thermal	~1,973 tons/per year	51
ENERGY	Rizhao, China	Solar City	~175,000 tons/per year	55
INFRASTRUCTURE FINANCE	Stockholm	Sustainable City	~1 ton/per capita/per year	58
INFRASTRUCTURE FINANCE	Singapore	Water Desalination Plant	N/A	62
INFRASTRUCTURE FINANCE	Portland	Light Rail Extension	~13,500 tons/per year	65
INFRASTRUCTURE FINANCE	Mexico City	Biogas Generation Plant	N/A	68

\* NOTE: Greenhouse Gas (GHG) Savings are in Carbon Dioxide Equivalent (CO<sub>2</sub>e)

# Background

**A**lthough a global phenomenon, climate change particularly affects urban centers. Cities are key contributors to climate change because urban activities are a major source of greenhouse gas emissions. Some observers estimate that cities are responsible for 75 percent of global carbon dioxide emissions with transport and buildings being among the largest contributors.<sup>1</sup> Global temperature increase and resulting sea level rise pose significant risk to coastal cities due to legacy infrastructure systems which were not designed for today's changing climate. Further, increasing sea surface temperatures and melting polar ice caps cause changes in oceanic and atmospheric circulations that affect storm intensity and weather patterns. These extremes, such as severe storms and droughts, result in costly impacts on basic services of cities, their infrastructure, housing, health, and welfare.

Current global population trends toward both increase and urbanization, placing additional pressure on the rate at which resources are consumed by cities. This further raises greenhouse gas emissions, simultaneously increasing the infrastructure investment at risk and the number of people vulnerable to perturbations in welfare.

**CITIES CAN ACT** as strategic partners and policy implementers taking independent action to enhance effectiveness of policies at multiple levels of government. They contribute to both global and national climate policy goals as they test new approaches, demonstrate best practices, and help build capacity and political support for action in achieving these reductions.<sup>2</sup> National governments and international communities need to foster local-level action and pilot projects aimed at advancing climate policy and establishing effective frameworks that will maximize greenhouse gas emissions savings.

---

<sup>1</sup> UNEP (2016). "Cities and climate change." United Nations Environment Programme.  
<http://www.unep.org/resourceefficiency/Policy/ResourceEfficientCities/FocusAreas/CitiesandClimateChange/tabid/101665/Default.aspx>

<sup>2</sup> Bloomberg and SEI (2015). "What cities do best."  
Bloomberg Philanthropies and Stockholm Environmental Institute.  
<http://www.bloomberg.org/content/uploads/sites/2/2015/12/What-Cities-Do-Best.pdf>

# Project Methodology

**W**e focused on city-level programs from around the world that represented best practices in greenhouse gas emission reduction strategies. Our aim was to generate a diverse database from which to draw conclusions. The cases selected reflect a broad swath of effective policy choices that could be applied in cities across the United States, but would also apply in global cities that have similar political and cultural structures.

**A BASIS OF EIGHT CRITERIA** was used to evaluate whether a program or policy was appropriate for this study (see evaluation criteria in detail in Appendix D on page 71). Relevance, replicability, and feasibility were considered in order to exclude cases that were products of particular circumstances or geographic location. As an example, the Stockholm case study was kept despite its history as part of a past Olympic bid. Funds allocated for that event were not used in achieving implementation of the program. Geothermal energy generation was excluded from our research because of its dependence on specific geologic factors. Efficiency and effectiveness were also included in the criteria because benchmark studies require evidence of results and results are based on data. Some cases were great examples of models that should be followed, but lacked publicly available data such as many in China (Tianjin Eco-City, Shenzhen Airport are two examples).

Our team was divided into **THREE GROUPS** based on research areas:

transportation, energy in buildings and green infrastructure finance. The overall analysis was conducted identically for each group through qualitative assessment of each areas searching for common themes and effective mechanisms; however, the selection method for case inclusion varied between groups.

In looking at programs for **FINANCING GREEN URBAN INFRASTRUCTURE**, we focused on cases that provided clear information about finance processes and data availability. We included examples of effective mechanisms even when each overall program could not be fully replicated, e.g. the Singapore desalination facility. In that case, renewable fuels were not used to generate required energy. Overall, if a case was able to contribute to a significant reduction in greenhouse gas emissions (whether through increased efficiency or replacement of carbon-intensive processes) we chose to include it.

In **TRANSPORTATION OF THE PUBLIC IN METROPOLITAN REGIONS**, we highlighted areas with the most similarities. We explored impediments to favorable outcomes of well-intentioned programs aimed at GHG reduction and some successful strategies used to overcome them. We did not examine mass transit systems in this analysis because it is a well-researched subject. This does not mean that the policies and programs we did examine are unaffected by a well-functioning mass transit. Most selected cases were made more effective when accompanied by robust mass transit options. Further, we researched programs and policies that

enhanced mass transit through increased ridership or through alternate funding mechanisms.

What we believe to be of greatest value coming from our analysis of **ENERGY OF THE BUILT ENVIRONMENT** is its emphasis on reduction of emissions from energy generated for use in buildings. We did not examine specific programs. Instead we focused on the processes by which they came into being. We believe the process is more

important than the examples, and chose our cases to best illustrate the spectrum of available policy tools to cities. The highlighted approaches show several methods of financing a project and different periods of monetizing the returns and provide examples of various ways a program can be conceived and implemented. Cases are similar in outcomes but differ in their development processes.

**TABLE 2:** This is a summary table of evaluation criteria used in case selection.

SUMMARY OF EVALUATION CRITERIA			
REPLICABILITY	RELEVANCE	EFFECIENCY	EFFECTIVENESS
FEASIBILITY	GHG REDUCTION	APPEAL	COHERENCE

# Analysis of Case Results

## 1. Summary

This report focuses on changing modes of transportation, identifying cleaner sources of energy to satisfy the built environment, and finding effective ways to invest in large-scale green infrastructure to reduce city greenhouse gas emissions. Successful projects can be scaled and replicated in other cities, adapting to their specific geographic, political, and cultural qualities.

Within the three areas of focus, there are key recurring themes despite the differences between cases and cities. There is a common theme of *push and pull* from policymakers. *Push* takes the form of public policy that establishes **REGULATIONS AND STANDARDS** to drive sustainable solutions, *e.g.* the solar energy requirement set in Barcelona. The *pull* theme is exemplified by policies which create **ECONOMIC INCENTIVES** and provide **SUBSIDIES AND LAND ACCESS**, *e.g.* Stockholm's effort to convert a former industrial site into a model neighborhood in sustainability. Successful city programs tend to use a mix of both, creating standards and regulations which motivate investors to act with urgency, providing financial support or facilitating investment to create an economically advantageous environment for carbon-reducing opportunities. Our cases combined these two components to some extent.

However, we discovered that the amount of private investment was inversely related to the availability of public money and high private investment was often complemented by economic benefits for the financiers. They experienced these benefits in the form of tax relief, government subsidies, or cost-savings from energy efficiency.

With regard to transportation, cities focused their policies in two ways. First, these policies promoted the reduction of the number of **PERSONAL VEHICLE TRIPS**, and second, they replaced combustion with **ELECTRIC POWER**. This was accomplished by creating a short-term policy structured to provide alternative transportation methods and discourage personal vehicle trips. Long-term policy aimed at encouraging conversion from combustion engines to electric power through broad implementation of charging networks and more efficient batteries.

With regard to energy of the built environment, our focus was on cities' efforts to **INCREASE USE OF SUSTAINABLE FUELS** in order to reduce carbon emissions. New York University's impetus to install a new cogeneration plant was spurred on by two things: nationwide college campus efforts to increase use of sustainable fuels and PlaNYC Climate Challenge that called for significant voluntary reductions in greenhouse gas

emissions. On the other hand, in Rhizao, China and Barcelona, Spain, the transition to solar-to-thermal and solar-to-electricity systems resulted from municipal-level political mandates diverging mainly in the economic incentives provided. Our cases were all focused on short-term policy choices, and we consistently found that cities struggle with long-term policies to improve carbon emission reductions.

In urban infrastructure finance, the main role city governments played was to **FACILITATE PRIVATE (OR NATIONAL/REGIONAL GOVERNMENT) INVESTMENT**. This

was accomplished by providing access to land for development, such as seen in Stockholm with the renovation of a brownfield site, or by working with other levels of government to secure financial investment such as in Mexico City, Singapore, and Portland. Effective city policy in this sector focused on long-term projects, and laid the foundation for significant systemic change aimed at reducing emissions. It took strong leadership and commitment to sustainability in order to plan well beyond a political term or administration, and required assembling support from the business community in order to maintain economic growth.



## 2. Transportation of the Public In Metropolitan Regions

**T**ransportation policy is a crucial method of greenhouse gas emission reductions for several reasons. First, transportation accounts for 14% of global greenhouse gas emissions<sup>3</sup> and intra-city transportation is a large portion of those emissions. Transportation is projected to continue growing along with the expected acceleration of the trend towards urbanization in the coming decades. Urban transportation has another characteristic that makes it well suited for programs focused on greenhouse gas reduction. Despite the vast heterogeneity of cities around the world, they have similar patterns of transportation and mobility. Those similarities facilitate a path to replicating programs from city to city. Replication allows for improvements in each successive iteration and just as importantly, through reviewing lessons learned, we can avoid mistakes and constantly improve performance. The largest portion of greenhouse gas emissions by the transportation sector come from combustion of gasoline and diesel fuel. The policies and programs discussed in this section and detailed in the attached case studies focus on reducing the number of passenger car trips and improving the emissions profile of vehicles within cities.

The first broad category we looked at are programs aimed at reducing the total number



**VEHICLE MILES TRAVELED (VMT)** of within a city by limiting the number of cars. The most direct method for a city to control vehicle population is to raise the cost of driving within its boundaries through the use of tolls. This type of program has long been used by tolling bridges and tunnels to enter cities. These tolls are set higher than they would need to be if their only goal was to recover the cost of construction, bridge operation, and maintenance. However, this practice does not capture all of the vehicles that occupy city streets. To alleviate those concerns and just as importantly to allow for the targeting of the districts for tolls and traffic reductions, a city can implement a toll for specific regions within a city and for specific hours such as was done in London. In

---

<sup>3</sup> US EPA

London, a congestion charge is used to reduce vehicle traffic and raise funds for mass transit.

One problem with using only bridges and tunnels as a means to control vehicle population and generate revenue is that often the entity controlling them is not the city itself. Thus, while there is some help in reducing VMT through tolls, cities do not always have the use of the funds collected, potentially depriving the city of a source of support for mass transit operations. One of the reasons London's system has been successful is that an act of Parliament created an executive agency, Transport for London, that had the authority to implement the toll system and was also responsible for running the city's mass transportation system. They received the initial capital to implement the system as a grant from the city of London and, subsequently, the congestion pricing scheme has generated surplus revenues each year allowing Transport for London to invest those proceeds into a better bus system. That type of complementary policy is what we believe should be the objective in projects aimed at GHG reduction in transportation. The costs were raised on the "bad" option, and lowered for the "good" option. The lowering of costs for bus option in this case was not direct cash savings, but instead a reduction in the opportunity cost of taking public transportation, because the system ran more smoothly and reliably with more buses on the streets.

**CAR SHARING** is another emerging technology that has the potential to help cities reduce the number of VMT and the associated GHG emissions. While a car share subscriber (such as for ZipCar in the United States) still has access to a personal vehicle when it is needed, most of the time they are car-free. Recent research has found that given

this dynamic, the active choice to take a car is made less frequently and there is thus a net reduction in car trips. ZipCar has said it found similar results dating back a decade. Car sharing is active in more than 1000 cities around the globe. However, few of those cities have built it into a program that is integrated with the rest of the city transportation infrastructure.

Bremen, Germany is an example of a city that has made this connection between shared vehicles and mass transit, through integration of bicycle, bus, and car shares. The city does not own the car sharing programs itself, but rather partners with one. That partnership includes allowing for car sharing vehicles to be available at train stations and bus stations scattered throughout the city. All of the car sharing stations also feature bike racks. This is yet another complementary opportunity that can be leveraged in other cities. The presence of bike racks at car sharing sites makes the idea of giving up a personal car easier, knowing that the trip to the shared car location will be less of a hassle. This was helped along by the fact that Bremen has a history of encouraging bicycle use and reports that 20% of trips within the city are completed by bike. The use of car sharing stations and user-friendly reservation system has increased the adoption rate of their car system. The combination of all of these efforts is a net reduction in VMT that continues to grow annually. Their system explicitly integrates bikes, car sharing, and mass transit.

**BIKE SHARING** offers another possible program for cities to invest in that can lead to a reduction in VMT and thus GHG emissions. City wide bike sharing programs are becoming more prevalent and as more systems are deployed, each new implementation effort can draw on more data

to consider when it is designed. The Paris system, known as Vélib', is one of the oldest and has grown to be the one of the largest as well. The city aimed to put bike stations as close as 300 meters apart in the densest parts and heaviest use portions of the city. The City of Paris contributed \$100 million to the installation of its bike share system and while the high initial cost may make it seem prohibitive to many cities, today there are alternative ways to finance the construction of a bike share system. The costs are now often offset by selling sponsorship rights, or by allowing private companies to install and collect the revenue from the system. Paris has found that many users prefer to have access when they come out of the subway and has worked to leverage that preference. The city believes that access will make it easier for people to make the decision not to travel by personal vehicle on trips within Paris.

**RIDE SHARING** is a further class of trip that cities can focus on, when the use of a car is called for by the traveler, but the need for a personal car or even a shared car can be avoided. This is the space that had typically been filled by taxis, and increasingly is being served by services such as Lyft and Uber. Even in a market as seeming mature as taxi service, there is opportunity for a reduction in GHG reduction. San Francisco has been on the vanguard of this effort. Technology also has a role to play here. Both Lyft and Uber debuted their shared ride systems in San Francisco. The services, Uber Pool and Lyft Line are quite different from a standard taxi or Uber/Lyft trip. For the shared rides the user selects to share at the time that they request the ride and inputs their destination. The technology then searches for nearby riders who are also planning to travel to a destination either nearby the original, or where one of the stops is along the route

towards the other. The process of matching takes less than a minute and is driven by volume in cities. The resulting trip is thus shared by at least two and up to four people, eliminating multiple trips and thus reducing VMT and GHG emissions. The user saves money, usually around 20%, and cost is a certainty for their trip.

In pushing those pooled trips, city policy can come into play most heavily and if done right, can align city policy with citizen/riders and the companies providing the service. San Francisco had some hiccups along the way in working with companies such as Uber and Lyft as they have grown. San Francisco has begun to investigate how it can encourage pooled trips, which is in the interest of all parties so that the system can continue to flourish. Uber believes that it has saved 3,800 metric tons of CO<sub>2</sub> emissions in just the first quarter of the year by riders choosing Uber Pool. These numbers are being studied by University of California at Berkeley among others to investigate the durability of the greenhouse gas reductions. If the numbers produced by Uber are accurate, and policies such as licensing and tax breaks for trips pooled trips can be implemented, then cities will have an additional tool to reduce VMT and GHG.

A final area we believe is available to cities in their efforts at GHG reduction from transportation within the city is in the **MAKEUP OF MUNICIPAL VEHICLE FLEETS**. From the city government perspective, a single program or regulation that changes many vehicles at once can have a far greater impact than programs aimed at changing behavior of citizens, even when those programs are successful. Reducing the number of VMT is very important because as we have shown it leads to measurable

reduction in GHG emissions. However, given all of the policies and programs to reduce VMT, trips will remain both in private cars, buses and from taxi/shared ride fleets. Here too, new technologies offer an important opportunity for cities to reduce their GHG emissions. Many cities have already looked to hybrid buses to help reduce the GHG emission of their transit fleet. Some are going farther and converting fleets to purely electric vehicles. The technology for the batteries has improved to the point where there is little risk from a reliability perspective for this switch. There does remain a cost burden, particularly at the outset when purchasing new buses or taxis. **ELECTRIC VEHICLES** also appear to have lower maintenance costs than internal combustion vehicles. While the importance of this initial capital outlay should not be diminished, there is payback over the useful life of new electric vehicles which can make up for the added expense of purchasing. Vienna has replaced their buses operating in the city center with all electric buses and has not seen any significant operational problems. Amsterdam has done something similar with the fleet of taxis that serve its airport. Again, there are significant upfront costs, but the GHG reductions are also significant. There are other benefits to electrification of vehicles besides GHG reduction, such as NO<sub>x</sub> and particulate matter reduction which increases the air quality and improves health conditions along the streets.

## RECOMMENDATIONS

Broadly, cities should focus transportation policy in two ways- first, reduce the overall number of personal vehicle trips and second, replace combustion with electric power. Effective short-term policy should be structured to provide alternative transportation methods (car share, ride share etc.) and discourage personal vehicle trips, while long-term policy should seek to incentivize conversion from combustion engines to electric power through broad implementation of a charging infrastructure and by taking advantage of more efficient batteries as the technology continues to evolve. The additional revenue from policies that help to encourage citizens away from personal vehicle trips can aid in strengthening a city's public transportation, leading to a complementary system that facilitates individual choice not to drive within a city.

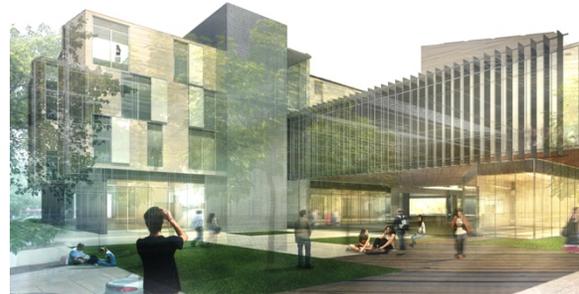
The other recommended avenue for GHG reduction in a city's transportation system is through electrification. This type of program, affects a large number of trips every day, and is generally within easier control of the city, requiring less political capital to implement. As sources of electricity become increasingly renewable, an electric vehicle fleet is positioned to take advantage of the changing sources of energy.

### 3. Energy of the Built Environment

Given the unique characteristics of each city, we believe that the processes behind urban policy addressing energy use in the built environment is paramount. Cities can take multiple approaches to reduce greenhouse gas emissions. These approaches depend on political will and infrastructure frameworks, ranging from traditional implementation of regulations and public goals to active encouragement, facilitating financial incentives and government subsidies. Budgetary considerations and government authority may make particular strategies more applicable. These depend on the many and varying resources available to each city. We examined three cases that covered this spectrum. The New York University cogeneration plant is an example of regulatory goal setting by the City of New York while Rizhao is an example of active government involvement through direct subsidies. Barcelona is somewhere between the two extremes where the municipality regulated minimum capacity and then facilitated private investment. What is important is that a city develops a strategy that reflects its unique circumstances.

The policies and programs examined in this analysis focused on the incorporation of renewable energy generation within cities, as well as the impact that city-wide **MANDATES OR INITIATIVES** can have on GHG emissions. These efforts work in a number of ways to produce effective results. Successful programs have been both voluntary and mandatory, some subsidized, some not.

New York City's approach to improving



building energy came in the form of mayor's PlaNYC initiative, which aims to reduce GHG emissions and increase the city's resilience in the face of climate change. Initiatives such as these **INFLUENCE THE PRIVATE SECTOR** by encouraging and incentivizing increased energy efficiency and expanding renewable energy sourcing. This initial voluntary approach is being replaced over time by new building standards and other energy efficiency methods.

New York University responded to the PlaNYC city-wide initiative by replacing an outdated and inefficient utility with a highly sophisticated cogeneration plant, reducing emissions and pollutants significantly. In the event of future blackouts, like the one that occurred during Hurricane Sandy in 2012, NYU has the capacity to provide power to many of its buildings and residents without relying on the municipal electric grid. The new plant provides twice the amount of energy as the former, with emissions reductions of 23% and other air pollutants decreased by 68%. This improved facility is responsible for an 81,000 metric tons of carbon equivalent emissions (MTCE) reductions per year. First year operating

savings were approximately \$778,000, with predictions that the project will pay for itself over its lifetime. The project cost \$125 million and future annual savings will be approximately \$5-8 million.

The NYU case was initiated by a state mandated shutdown of the utility for violations of air pollution standards. The institution responded by partnering with New York City's PlaNYC to build a new facility which met PlaNYC Climate Challenge goals of reducing building-based emissions by 30% by 2025. The city did its part by revising and reducing bureaucratic obstacles to building in heavy construction and by facilitating private investment through regulatory goal setting. The success of this program was highly contingent upon each of the entities involved carrying out their separate roles in a 'best practices' effort.

Cities around the world can look to implement this model by **PROVIDING A SET OF GOALS** for organizations to meet or exceed existing mandatory standards or, in some cases, creating new standards. Cities should make every effort to incentivize or subsidize these goals in order to facilitate rapid participation. Private organizations, such as NYU, can improve their buildings' energy source through these types of standards and initiatives. Once standards render older technology unusable, more efficient technologies, producing less GHG, are then incorporated largely through private investment. During this process, subsidies and tax breaks can be powerful tools to incentivize the most efficient or preferred methods of energy generation, while offsetting private capital investments. These new utilities, in most scenarios, see returns on investment over their lifetime, justifying the incorporation of the standards while making emissions reductions profitable.

Rizhao, China is an example of a successful active approach to promote greenhouse gas reductions through the provision of subsidies for solar panels manufacturers. Rizhao's solar city program, which began in 1992, uses solar installations in an effort to minimize emissions and other pollutants. The provincial government subsidized research and development for local solar manufacturers in order to obtain products at lower cost to the consumer. Solar water heaters were mandated to be used on all new buildings in the city, giving permanence to the project, while other efforts targeted existing buildings and their residents.

By 2010, 99% of residents in the city's central district had solar water heaters, with 30% of the suburban city populace following suit. Solar water heaters were priced at \$190 per unit, with yearly savings of \$120, leading to consumer savings over the product's life. The result of this program led to an approximate 175,000 MTCE reduction per year, based on 2010 information. This number has likely grown since then and has also been attributed toward increasing external investment and growth of the city.

Success of the Rizhao program was a result of a combination of strategies. First, the government appealed to the city's residents and stakeholders by subsidizing a comparable-cost alternative to non-renewable technology in order to create a financial incentive for adoption. This was done by strategically subsidizing research and development from the production side. Doing so produced a cheaper and more efficient product, whereas subsidizing purchasers would have had less environmental impact (less efficient technology) and perpetuate the need for subsidy until technology improved at the unsubsidized private rate of advancement.

Further, private innovation may be less incentivized with a consumer subsidy, as product price and demand can both remain high while government bears some of the consumer's burden. The city also mandated the technology's use in new buildings, while initiating an awareness campaign for users in existing buildings.

Information about solar water heater use and how it can save the consumer money while improving environmental health, was broadcast on television and radio. In addition, city-sponsored seminars regarding the technology were widely held in the city, providing consumers with a chance to ask questions about the solar water heaters before deciding to make a purchase.

Political will from within the city kept momentum for the program alive, and led the city to receive a number of honors and awards from organizations such as UN-Habitat. This process worked well in Rizhao for a number of reasons. The city's mandated use of solar technology on new buildings ensured that the city would continue to expand its solar portfolio as it grows, a simple and effective tool for other cities to consider. Further, the subsidized solar thermal heaters show the potential for other cities to subsidize local renewable technology development, making products more financially appealing than fossil fuel equivalents. Rizhao's awareness campaign highlights the effectiveness of economic incentives, as these initiatives can be responsible for significant voluntary change.

Barcelona, Spain targeted improved building energy by introducing a solar thermal ordinance policy, similar to aspects of rizhao and new york city cases. This policy required 60% of water heating demand be accomplished by solar heaters for properties

that used upwards of 0.8 MW per day on water heating. All swimming pool heating was also required to be accomplished through solar energy. Buildings that were too small for compliance standards were subsidized to provide solar water heating. The municipality of Barcelona financed the project, with Barcelona Energy Agency providing the service. In 2006, the 0.8 MW per day minimum was eliminated, and all new buildings had a requirement to use solar water heating. Solar heating through the ordinance covered demand for approximately 171,000 users in 2010, while reducing over 12,000 MTCE per year.

Program success was a result of a combination of strategies used in Barcelona, through **STANDARD SETTING AND ECONOMIC INCENTIVES**. The program was phased in, requiring certain buildings to obtain solar thermal heaters under the defined consumption requirements at first, but then incorporated more buildings while removing the consumption minimums. The phase-in style used in Barcelona gave the city time to consider how the program could become more effective, while allowing the private sector to adjust to the shifting mandates. Further, Barcelona's financing structure for the project played a big role in its success, using fair and effective strategies to minimize resistance to the ordinance. Interest-free credit arrangements were available that would cover 70% of the investment, reducing upfront capital costs. A four-year housing tax credit was provided for residents in order to counteract the cost burden, while a subsidy was also offered to cover up to 37% of user cost of solar technology. This ordinance ensures continued use of renewable technology, and was able to effectively change water heating sourcing through mandates and financial incentives for users. Instead of

subsidizing product development, as was the case in Rizhao, Barcelona chose to subsidize the consumer. For cities with access to sufficiently effective renewable technology, this may be a cost-effective option.

## RECOMMENDATIONS

Our analysis of energy of the built Environment found that much of the work currently being done is focused on implementation of solar energy capacity, primarily as a result of the difficulty in working with existing infrastructure and within densely populated areas. Barcelona and Rizhao were both able to reduce greenhouse gas emissions by using public funds to finance installations and product development, and in this way they avoided confronting the challenge faced in New York City. New York University was successful in increasing efficiency within the confines of a highly productive neighborhood, primarily because of city support in acquiring permits and engaging community residents throughout the process. One complication faced by all three programs analyzed in this report is that the majority of buildings are privately owned, and city governments had to motivate private

actors to change behavior. The common strategy in all three programs was to change behavior (adding solar panels to buildings or increasing efficiency of supplementary power plants) by reducing costs for building owners. This economic incentive was complemented by regulations and standards that promoted urgency for building owners to invest in the desired technology.

Moving forward, research should target developing cities and areas with reduced financial means. The case of Rizhao's solar initiative provides insight into a less wealthy city, however China's explosive economic growth over the past decade makes the comparison to more typical developing cities less reliable. Further, it would be worth exploring additional regulations and city codes that promote private investment in carbon emission reducing technologies. While both Rizhao and Barcelona were highly effective at installing solar energy production, they relied on government resources to enact change. The NYU model may be more applicable for cities with available private capital, as policy was focused on setting goals and standards for carbon reduction, leading private investors to creatively apply solutions that both met these goals and made economic sense.

## 4. Financing Green Urban Infrastructure

Perhaps the most obvious trend among the cases reviewed is the role of population growth and economic need in the development of an infrastructure project. Urban populations are on the rise, and people around the world, in countries at varying stages of development, are moving into cities for economic opportunity. This growth poses both a challenge and an opportunity for public officials, as they must increasingly rely on economic and demographic forecasts to determine how to best generate and invest capital resources today to serve more people tomorrow.

For cities in developed nations, such as Portland and Stockholm, the transition away from heavy, 20<sup>th</sup> century manufacturing is providing an opportunity to rezone neighborhoods, clean up hazardous sites, and retool former industrial areas into residential and business zones for the future growth of the city. Portland's response to the predicted increased road congestion was to prioritize public transit and biking infrastructure. The Portland-Milwaukie light rail project, a 7.3-mile extension of the existing light rail infrastructure, allows for the expansion of residential neighborhoods into former industrial districts and provides public transit to those developing areas to make more and better jobs accessible. Stockholm's response to population growth was to develop a former brownfield site into a green infrastructure pilot program, showcasing the latest in energy efficiency, renewable energy production, and



urban planning that discourages the use of private vehicles. Both of these examples illustrate how developed cities can and likely will adapt as their economies change and they need to be responsible for an increasing number of people, provide accessibility to jobs, while responding to a growing concern about climate change and sustainability.

In Singapore, population increase means a growing demand for clean water, a scarce resource for that small nation who relies on rainfall for 50% of its water needs. As a coastal city, desalination provides the largest opportunity to meet the challenge of providing clean water for its residents and guests. In the case of a desalination plant, energy efficiency is essential, as it reduces the variable costs of production, and produces cheaper desalinated water. SingSpring uses an energy recovery system, which is designed to minimize operation costs. The plant is one of the most energy efficient desalination facilities in the world, producing at 4.1 kWh/m<sup>3</sup>. This resulted in one of the lowest prices for

desalinated water at \$0.48/m<sup>3</sup> in its first year.<sup>4</sup> This project gives Singapore the capacity to meet 10% of its national demand, and similar projects are in the planning stages to further secure Singapore's water resources.

Sometimes infrastructure investment is not a response to economic challenges or population growth but is a result of growing concern over greenhouse gas emissions. The Mexico City biogas plant was developed due to a concern about greenhouse gas emissions from the Bordo Poniente landfill. In this case, the lower cost energy produced from the biogas plant which will save Mexico City about \$17M over the next 25 years, is just a secondary benefit to a concern about emissions.

Each of the observed cases had a different mix of funding sources, all of which included some **MIX OF PUBLIC AND PRIVATE CAPITAL**. Analyzing the proportion of public funding to private funding, it was clear that public funds played a more important role in public goods, while private funds were more important to private goods. public goods are non-excludable and non-rivalrous. As access cannot be excluded through price, anyone can enjoy the benefits, which makes them unsuitable as a private capital investment. private goods, on the other hand, are rival in consumption and excludable, so prices play a role in determining who can consume the resource. Prices create the ability for returns on the investment, which attracts private capital.

The Portland-Milwaukie light rail project

(Portland, Oregon) is an excellent example of **PUBLIC FUNDS BEING RESPONSIBLE FOR A LARGELY PUBLIC GOOD**.

Essential to the success of the Portland-Milwaukie light rail was the U.S. Federal Government's New Starts grant program, which provided 50% of the capital funding, approximately \$745M. Lauded for its use of rainwater retention infrastructure, green track design, and Tilikum crossing, a bridge that doesn't allow cars, anyone can benefit from the services that this project provides. From the perspective of a financial institution, however, rainwater infrastructure and an ecotrack are added costs that are not proven to increase the revenues generated by the project, and Tilikum crossing could potentially be viewed as a wasted opportunity to earn revenue from tolls. Therefore, public capital was crucial to funding this project, and revenue from the anticipated 22,800 average weekday riders by 2030 can go directly to operating costs and the payment of GARVEE bonds that helped fund the project.

Among the private goods analyzed, those more successful at **ATTRACTING PRIVATE CAPITAL** were in sectors with proven results and a stable revenue model. The SingSpring desalination facility in Singapore benefits from years of success and development of the technology, and a predictable, unending market for the product. These favorable market forces attract private capital, allowing the financing of two desalination facilities so far, with more planned over the next few decades. Energy efficient technologies, while adding to the project's value as green

---

<sup>4</sup> Water-Technology (2016). "Tuas seawater desalination plant, Singapore." <http://www.water-technology.net/projects/tuas-seawater-desalination/>

infrastructure, enhances the economics of the facilities. With one of the few variable costs of the facility being energy consumption, any decrease in that cost can have very favorable impacts on the economics of the project, providing a natural incentive for green building.

Another example of **PRIVATE CAPITAL PLAYING A STRONG ROLE** in green infrastructure was in Stockholm's Hammarby Sjöstad development. Approximately 80% of funding for the Stockholm project came from the 25 construction companies involved in building the project. In fact, the city role in this project was kept to a minimum, and it was the private players that developed the water and waste systems and built the distributed renewable energy, and energy efficient residences. This model worked because the developers incurred all of the risk, and construction costs, but they were also able to lease or sell the units for profit in the end. The city of Stockholm developed the vision of and provided leadership for the green pilot neighborhood in a former brownfield site, but the finances were managed by private companies. sustainable real estate developments are a feasible way to attract private capital to build green infrastructure, but this is under the assumption that the city's population finds value in green infrastructure and is willing to pay enough for the properties to give the developers an attractive return on their investment.

There are exceptions in the ability of private goods to attract private capital. Generally, these failed cases involved developing countries, and relied on both development banks and governments to play a pivotal role in proposing, financing and implementing these projects. **POLITICAL WILL AND GOVERNMENT FUNDING** emerged as a

common theme in developing nations. Some cases that are not included in this document, due to lack of access to information, follow this trend of government force. The Ethiopian Renaissance Dam, for example, is a \$4.8 billion project in Ethiopia, the world's third largest recipient of foreign aid. Since the risks were too high for private foreign investors, the Ethiopian government is funding the project entirely through bonds and raised taxes, encouraging their citizens to forego multiple months of income to pay the debt service on the bonds. This case provides an interesting example of how a poor country can navigate geopolitical conflict and fund a large hydroelectric dam in order to situate itself as a net exporter of electricity in the region, without the support of private capital.

The Mexico City Biogas Plant relied on a \$27M grant and a \$96M loan from Mexico's development bank, and required 30% equity from its developer. The large role of government in this case could be due to a number of factors. Although the electricity produced from biogas is cheap, it requires Mexico City to rethink their trash separation processes, adding management and operational costs that could increase the risk of the project. These management concerns result in exposure to commodity risk, which is not a problem for projects like SingSpring.

This analysis is based on four cases of urban infrastructure development that aimed to reduce greenhouse gases. These cases highlight the role of **GOVERNMENT**, the role of **PRIVATE ENTITIES**, and the importance of **MARKET FORCES**, in developing green infrastructure.

The various **MIXES OF FUNDING** that a green infrastructure project can attract is determined largely by the type of good. Green

infrastructure such as stormwater retention and bicycle paths can impact GHG emissions, but they likely will not attract private capital, as access to the services they provide are not excludable by price and are not scarce resources. Private capital will play a large role in GHG-reducing private goods with established players and known risks. Either way, governments will continue to recognize the economic and environmental need of green infrastructure developments, and it will be their support that will promote green projects. The atmosphere is a public good, and while both private and public mechanisms can help to combat climate change, government support will continue to play a key role in the mitigation of a global public problem.

An important takeaway from this analysis is the **COMMON THREAD OF ENERGY EFFICIENCY**. The International Energy Agency concluded that approximately 40% of the emissions reductions required to limit an increase in global temperatures to 2 degrees centigrade by 2050 can come from increased energy efficiency, leading the agency to consider energy efficiency an “invisible fuel” and an “invisible powerhouse,” worth at least \$310 production, which makes an interesting

case for a private good solving a public problem.

## RECOMMENDATIONS

The primary finding of our analysis of green infrastructure finance is that there are a number of strategies to reduce greenhouse gas emissions regardless of availability of private funding. GHG-mitigating infrastructure is interesting in that it includes private and public goods, which means it relies on a variety of funding sources depending on where the project lies on the public-private spectrum. Cities will continue to grow, and as their economies change, re-tooling old economic zones to meet the needs of future development will be an important opportunity to incorporating green infrastructure. The primary barrier to city action to reduce GHG emissions seems to be political will. Cities have the ability to initiate a conversation and create a culture around GHG reduction. They can make the choice to support green residential developments in a brownfield site, to build a biogas plant and implement management changes to their waste streams, and to continue to support and prioritize energy efficiency in their development.

# Conclusion and Recommendations

Cities are growing around the world. Roughly 54% of the world's population lives in cities as of 2014, and the percentage is projected to reach 66% by 2050.<sup>5</sup> People move to cities for economic opportunities, and since the advent of the industrial revolution those opportunities have been supported by power generation to drive machines, and climate control technology to keep people comfortable in various weather conditions. Power generation and climate control have historically been accompanied by greenhouse gas emissions, which are now known to cause climate change.

Cities have taken the lead around the globe to try and effect change that will reverse the trend of greenhouse gas rise and reduce the effects of climate change. To support the efforts of the cities, this analysis assessed various grassroots efforts and programs initiated by differing cities around the world to reduce emissions. Thirteen cases of emerging urban sustainable solutions have been analyzed in three broad groupings, energy of the built environment, transportation, and finance of large urban infrastructure projects. These provide insights into the commonalities of the approaches



taken by cities to facilitate their programs to ensure success.

There are two primary strategies that cities have taken to promote their policies to reduce greenhouse gases and to ensure successful implementation. One of the strategies is to set standards through regulation. By creating a regulatory requirement, capital is drawn in to provide a combination of solution development and implementation. This strategy is most effective where capital structures are available. The other strategy is a

---

<sup>5</sup> United Nations (UN (2014). "World's population increasingly urban with more than half living in urban areas."

more aggressive strategy where the government creates the financial motivation for the promotion of greenhouse gas reduction through access to financing, subsidy provision, or user fees.

Any city in the world can follow the models laid out in these cases by setting standards and creating economic incentives to promote greenhouse gas emission reduction. Ideally, city governments need to strike a balance between both approaches. Standards and regulations can seem onerous from a workload and financial perspective, unless they fit within the context of a larger financial framework. The framework provides the reason for the standards and regulations. Conversely, the standards and regulations provide a mechanism for achievement of the financial carbon reduction goal. Details vary somewhat in each of the three groupings,

which should be considered carefully before implementation.

Armed with these strategies, there are a whole range of approaches that cities can take to reducing greenhouse gases. The thirteen cases analyzed in this report provide a number of replicable and feasible approaches that cities can adopt as part of their arsenal in the fight against greenhouse gases.

Our study evaluated each of the thirteen cases on their implementation feasibility. Table 3, below, describes the feasibility criteria we used in our evaluation. Table 4 on the following pages is a summary evaluation of the thirteen programs and policies analyzed alongside our ranking of their potential for implementation from High to Low and a description of our reasoning for the ranking.

**TABLE 3:** This table describes the feasibility criteria we used.

	HIGH	MEDIUM	LOW
<b>FEASIBILITY</b> (how well the program adapts to different political settings and financial situations)	<b>Potential for implementation in any political structure. Manageable adoption efforts. Not expensive to implement.</b>  <b>AND</b>  <b>Does not require large management capacity.</b>	<b>It requires large amount of capital but has potential for implementation.</b>  <b>OR</b>  <b>It requires sophisticated management structure but can be adapted to lower management capacities.</b>	<b>It requires a particular political structure, is expensive to adopt and manage.</b>  <b>OR</b>  <b>It cannot be adopted unless certain management capacity exists.</b>

**TABLE 4:** This is a summary evaluation of the implementation feasibility of each program/policy based on political structure, management capacity, existing infrastructure and cost.

CITIES	PROGRAM/POLICY	IMPLEMENTATION FEASIBILITY EVALUATION	RANK
AMSTERDAM	Schiphol Airport Electric Cars and Buses Fleet	Requires government –private collaboration. No large management capacity needed. Capital investment offset by low maintenance costs. ) source of energy needs to be considered.	HIGH
BARCELONA	City Ordinance for Solar Thermal Heating in New and Old Buildings	Implementation may be challenging because of management capacity and complex political procedures. Tighter local regulations and financial incentives can be used to make adoption easier.	MEDIUM
BREMEN, GERMANY	Integration between Various Transportation Modes that Includes Car Sharing	Program seamlessly integrates car share with alternative forms of transportation from a payment and location perspective. Requires a more sophisticated urban region management capacity, but can be simplified. Further government should ease car share insurance requirements, provide free parking location and raise taxation.	MEDIUM
LONDON	Central District weekday Congestion Pricing used for Transport of London Revenue	Straightforward to implement, given new technologically advanced systems. Expensive, but has a positive net benefit when all costs and benefits are taken into account. Can provide revenues for city public transportation.	MEDIUM
MEXICO CITY	Biogas Recovery Energy Generation Program Developed to Reduce Emissions from Waste Decomposition	Requires heavy reliance on government financial support. Political will and ability to direct infrastructure development at city-level is needed.	LOW
NEW YORK	Private University Cogeneration Plant Using Heat-Recovery Steam Generators	Required adherence to updated regulatory standards can provide impetus for implementation. Initial capital cost is high but is offset by subsequent lower energy-related costs.	MEDIUM

CITIES	PROGRAM/POLICY	IMPLEMENTATION FEASIBILITY EVALUATION	RANK
PARIS	Extensive Bike Sharing Program	High cost for system startup and maintenance of bikes, but has high rates of success and potential for expansion, improvement and adaptation. Easier to implement in less-dense locations.	MEDIUM
PORTLAND	Eco-designed extension of Light Rail Connecting to Former Industrial Area	Expensive, requires federal capital investment. Requires a progressive political structure and public involvement.	LOW
RIZHAO, CHINA	Solar Technology Used for Heating and Lighting Made Affordable through Subsidies	Needs strategic collaboration between local government and solar panels manufacturers. Requires subsidies and funds for research and development for a lower costing end-product.	LOW
SAN FRANCISCO	Ride Sharing Programs Including Multi-passenger Trips and Employer-Owned Shuttle Buses	Requires a more progressive political structure and public-private partnership and change in city rules. System is not fully developed, may require a more complex management capacity.	MEDIUM
SINGAPORE	Desalination Plant Built with Private Equity Funds and Permit Incentives	Expensive to build. City government needs to provide capital access or facilitate finance.	LOW
STOCKHOLM	Sustainable City Built on a Former Brownfield Location through Public-Private Partnership	Requires a progressive political structure and proper municipal support. Requires access to federal funding, but private investment can be brought in.	LOW
VIENNA	Electric Bus Program Using Existing Electric Infrastructure and Bus Roof Chargers and Inverters for Connection	High infrastructure costs, but may be reduced by purchasing newer, improved (and more expensive) buses. Implementation in colder regions is dependent on the charging capacity and recharging time for batteries.	MEDIUM

# Appendix A: *Case Studies – Transportation of the Public in the Metropolitan Regions*

## BACKGROUND

The city of London had a population of just over 7 million at the time the congestion pricing program began in 2003. The central region of London is a zone with very high average property values and a high density of both people and business. At the time the congestion pricing scheme was enacted, London had only recently gained the authority to govern itself. The new mayor worked with large business leaders and small business owners and residents in crafting his plan. The act of parliament that allowed for the election of a mayor, also created a London Assembly that has some oversight of the mayor. Another key element was the creation of Transport for London; an executive agency headed by the mayor or mayor's appointee. The agency was responsible for major roads, buses, and traffic control. It was that authority that allowed the congestion pricing scheme to be put in place.

## LONDON (U.K.)

### Program: Congestion Pricing

Population: 8,539,000 (2014)



## PROGRAM DESCRIPTION

Central London had too many cars for the amount of traffic lanes available. This caused traffic jams which led to lost time and increased GHG emissions and particulate matter pollution from exhaust. The lost time was a measureable drag on the city's economy, and the pollution had negative health and environmental consequences. Additionally, there was a funding gap for the needed improvements to the London bus network. The program implemented a fee to enter the central district of London on weekdays between 7am and 6pm. There was a single fee of 5GBP with discounts available to residents of the district

and those with disabilities. The area of this district was approximately 8 square miles at its inception. The law also requires all fees to be allocated towards transportation infrastructure within the city, with a focus on buses, but not limited to them.

The main goals of the program are to: (1) reduce congestion in the city center, (2) improve bus service, (3) reduce emissions of CO<sub>2</sub>, NO<sub>x</sub> and particulate in the city center, and (4) ease the distribution of goods.

The program has been in continuous effect since

2003. The initial zone was later augmented with an additional zone called “the western edition” in 2007. At the end of 2010, the western edition was removed from the plan. It was removed by a new mayor from a different political party, after consulting with business owners and residents in that zone. The original zone has remained and fees were doubled over time.

### **PROGRAM COST**

The initial capital outlay for the plan was about 160 million GBP (-\$230,293,600). This was funded by the City of London and Transport for London was not required to pay it back. This allowed the new system to operate cash flow positive from its inception. This funding structure may not be available to all potential systems. However, various published cost benefit analysis, including those by the UK Parliament and Transport for London show that the system has a positive net benefit to the city when all costs and benefits are taken into account. The program returns net revenue to Transport for London each year. In 2014, the program generated 170 million GBP (-\$244,686,950) in net revenue which is more than the net revenue of 130 million GBP (-\$187,113,550) in 2007. The net revenues in this case are the funds that remain after the expense of running the program have been taken from the year’s tolls.

### **PROGRAM IMPLEMENTATION**

There have been a few significant stumbles. The western edition being added and removed went smoothly, and it is possible a new zone will be

added again at a later time. However, with better planning of the new zone from the outset, the reversal could have been avoided.

The technology used for toll collection was upgraded in 2009. If a new system were to be built today, it would begin with that system, or perhaps an even newer one. The system in London uses cameras to read the license plates numbers of cars entering and operating in the zone. This system was not the most technologically advanced system at the time, and is far from it today. There was some wrangling about what system to choose, but while this can be expensive, has been accurate. More recently some controversy has stemmed from the mayor giving database access to law enforcement authorities thereby raising privacy concerns.

### **PROGRAM EFFECTIVENESS**

The programs are largely viewed as a success. In the year following implementation and despite having fallen the previous year, bus ridership and tube ridership have increased. Traffic flow increased as measured by speed along predetermined streets. Transport for London has kept detailed data on speeds of traffic through the zone, and separately collects data on bus and taxi speeds. The reduction in GHG is determined by the reduction of single passenger car trips. The increase in overall traffic speed is determined by the city center. An additional benefit of the program has been a reduction in fatalities within the city center and also in the surrounding areas as discussed in a study by Colin Green from Lancaster University Management School.

## **RESULTS AND LESSONS LEARNED**

London expanded the program too quickly without accounting for the differences in the business and residential makeup of the expansion area and original area. Doing a thorough analysis of the area instead of relying on traffic patterns might have made the expansion a success. The core of the program encompassed reduced congestion as measured by traffic speeds along key streets. According to Transport for London, the speed of traffic is dropping again but remains above the speeds prior to the program’s inception. It is the decrease in speeds that is driving the idea of a new expansion and not the increased revenue it would bring.

## BACKGROUND

When thinking about ride sharing what comes to most people's mind first is the traditional carpool. Those are planned trips scheduled for time destination. These have long been staples in San Francisco and elsewhere for families to share the transportation burden for children to and from school. There is also a modernized version of rider sharing, commonly referred to as "real time ridesharing." This is done through a GPS enabled mobile phone app. In many cases this real time sharing is done with only a single rider and thus is not true sharing. That began to change in Summer of 2014 when the two biggest players in real time sharing, Uber and Lyft, began offering what are essentially a real time carpools: Uberpool and Lyft Line.

## SAN FRANCISCO (U.S.)

Program: Ride Share

Population: 837,442 (2013)



## POLICY DESCRIPTION

Both Uber and Lyft were founded in and are based in San Francisco. The reason for that is not as simple as saying that San Francisco is an extension of Silicon Valley and thus they were founded where the talent was located. Instead it is more valuable to consider several demographic and historical facts of the city's transportation system and population trends. According to the San Francisco City Council, the city had the fewest number of licensed taxis per capita of any city of comparable size in the country. The number was kept low by a politically powerful taxi commission. That low number kept the taxi fleet nearly 100% utilized, lowering incentive for good service and increasing the time spent waiting for a free cab. Another key reason the companies were born in and had such rapid growth in San Francisco is the large number of households

without a car. According to an analysis of US Census data done by Nelson Nygaard Consulting, 88% of new households in San Francisco between 2000 and 2014 were car-less. Thus there was room for services that could provide one-way automobile transit service.

This case is not a program in the classic sense, but it does offer an opportunity to examine factors that have been considered by the City of San Francisco as they attempt to encourage multi-passenger trips as a replacement for single passenger trips. Members of the SFMTA board wish to set aggressive goals for reducing the number of single passenger trips within the city. Their stated reason for needing such goals is that with the projected growth in the city, there will simply not be enough room on the city's streets if new residents drive with the same patterns are

current residents. The city already believes that approximately 27% of trips in the city were single passenger in 2014. An additional 21% were believed to be shared rides. That survey data showed the city met its 2012 goals to reduce private cars to 50% of trips. What is not clear to the city is what specific policies, if any contributed to their meeting that initial goal.

Both Uber and Lyft claim that more than 30% of their trips in the city are now shared. Both also say they are committed to increasing that percentage. They are each constantly tweaking their algorithms to generate better matches for shared rides and believe the increased efficiency and lower pooled fares will help drive this growth. The city does not yet have data to separate out pooled vs single rider trips from these services. It is now surveying with this in mind and future data will incorporate pooled rides from instant sharing services.

The city is looking at a number of ideas to further reduce the number of both private vehicle trips in general and all single passenger trips but none have been both implemented and measured. The longest standing policy of this nature in San Francisco has been to allow development of new housing units without associated parking spaces. Eliminating that requirement allowed for reduced cost of new construction while at the same time making it more difficult for new residents to own a car in the city. The city implemented a rule in 2012 that did not allow private cars on much of Market Street, the major road that bisects the city. Private cars could enter Market Street, but must turn right off of it within one block or risk ticketing. This made it more complicated to drive private cars in the city and thus less convenient. However, the purpose of the policy was to speed

buses and taxis along the main road, both reducing congestion and GHG emissions. The policy allows taxis and buses, but not Uber/Lyft which are private cars. It was implemented before the rise of the two companies and with their growth and especially the growth of the pooled rides, there is some pressure to allow these shared car services. The powerful taxi commission is on the other side of that battle and it is currently at a stalemate, preserving the status quo. The GHG effects of this policy have not been measured even though their reduction was part of its reason for implementation.

Another form of ride-sharing popular in the city is privately-owned buses, such as those provided by, large employers outside of the city to shuttle employees from San Francisco to offices south along the peninsula. Some of these buses only pick up people from the transit hub South of Market, adjacent to the freeway. For those bus lines, there are no direct or indirect costs to the city and the city accrues economic benefit. However, some of the buses go into other neighborhoods and uses city infrastructure including both roads and SF-MUNI bus stops. It possible that those trips add to GHG as they siphon riders from existing transit that could get them to the same transit hub. To the extent that they do take transit riders, they also reduce city revenue from bus and train fares. Several companies now pay the city more than \$100,000 a year each for the right to have their buses in the city and use of the MUNI stops, thus mitigating the impact on revenue from these private services. Again, while this does potentially decrease single rider trips, the actual affect on those trips and on GHG emissions is not yet known.

## RESULTS AND LESSONS LEARNED

The City of San Francisco has high hope that the steps they have taken and plan to put in place will lead to a reduction in trips with only a single passenger in a car. They have had some options from entrenched powers within the city, such as the taxi commission. In other areas, businesses or residents have objected to proposed change of city rules. The City Council and the MTA board are now working together so that any new policies are not in opposition with each other and will instead complement each other. By taking revenue from some new sources, the city has been able to allow for new forms or multi-passenger transportation without angering residents and voters. While San Francisco is efficient at measuring traffic patterns, they have struggled to come up with a system that satisfactorily measures GHG emissions by city traffic. Though they use a generalized and national standard, the city government does not believe it is accurate to San Francisco and are working to develop their own. They also plan earlier outreach to business within the city as they develop new policies for traffic management. While many of these steps seem obvious, they nonetheless posed challenges even in a progressive and well-governed city, and thus should be carefully considered by other cities when developing such policies in the future.

## BACKGROUND

On a global scale, transportation accounts for roughly 14% of greenhouse gases, according to the EPA. 95% of that comes from the use of gasoline or diesel fuel.<sup>6</sup> As cities look to reduce emissions and move emissions outside of the city, converting to electric buses is just beginning. China has the highest sales of electric buses with 27,000 sold in 2014, up 160% from 2013.<sup>7</sup> In the United States, electric bus sales are only in the hundreds so far, but there is interest in dozens of cities that are testing the technology. According to Idtechex, the combined market for hybrid and full electric buses will reach \$75B in 2025.<sup>8</sup>

## VIENNA (Austria)

### Program: Electric Bus

Population: 1,741,000 (2013)



## PROGRAM DESCRIPTION

Without major construction and disruption required by subways, and without installing track and overhead wires as required by trolleys, transportation can be electrified using buses that can go anywhere unimpeded by the restrictions of other forms of mass transportation. Of course, scarce surface land must be devoted to this use in crowded cities, but electric buses pollute less than conventional buses and cost less than subways, which also use electricity.<sup>9</sup>

## PROGRAM COSTS

less than what would be required to install a subway or a trolley, but it is more than what is

The costs associated with electric bus adoption are still evolving. At a high level, the initial cost of the physical bus is more expensive than the cost of a diesel, hybrid or CNG bus. However, the inner workings of an electric bus are much simpler than that of a diesel engine. Consequently, maintenance is less expensive. In addition, the cost of running an electric bus is lower than that of a diesel, hybrid or CNG bus. The resulting issue becomes the length of the payback period of the electric bus. One other important factor is the cost of the recharging infrastructure that is required. That infrastructure investment is significantly required when purchasing an additional diesel bus with existing infrastructure. So the payback will be

<sup>6</sup> EPA (2016). "Global greenhouse gas emissions data." United States Environmental Protection Agency. <https://www3.epa.gov/climatechange/ghgemissions/global.html>

<sup>7</sup> Smith, S. (2015). "China electric bus industry report, 2015-2020." PR Newswire. <http://www.prnewswire.com/news-releases/china-electric-bus-industry-report-2015-2020-300178202.html>

<sup>8</sup> Harrop, P. and Gonzalez, F. (2016). "Electric buses 2016-2026: forecasts, technology roadmap, company assessment." IDTechEx. <http://www.idtechex.com/research/reports/electric-buses-2016-2026-000467.asp>

<sup>9</sup> MacKechnie, C. (2014). "Electric buses - an introduction." About Money. [http://publictransport.about.com/od/Transit\\_Vehicles/a/Electric-Buses-An-Introduction.htm](http://publictransport.about.com/od/Transit_Vehicles/a/Electric-Buses-An-Introduction.htm)

longer for the initial installation.<sup>10</sup>

On average, electric buses cost roughly \$300K more than diesel buses today, and there is savings of roughly \$40K per year from fuel and maintenance.<sup>11 12</sup> On the surface, this would equate to a 7.5 year payback, which would not fly in the private sector. However, the lifetime of a bus is generally 12 years,<sup>13</sup> so the overall cost of the electric bus is less. Second, battery costs are coming down steadily, so electric bus costs are dropping commensurately.<sup>14</sup> Lastly, this does not take into account the health benefits associated with the reduced particulates and air pollution. This cost savings varies based on the density and cost of living in a city, but is estimated at over \$50K per bus per year in Chicago, and at over \$100K per bus per year in New York City.<sup>15</sup>

Important to note, however, is that these buses are still only being manufactured in relatively small numbers. Once manufacturing reaches economies of scale, prices will drop. In addition, the price of batteries has been declining significantly in recent years. So the payback period will improve, especially after the initial infrastructure has been set up.<sup>16</sup>

## PROGRAM IMPLEMENTATION

Vienna, Austria wants to be a leader in the green movement and has decided to eliminate greenhouse gases in its central historic district as a step forward. As part of the transition, they have converted to all electric buses for those inner city bus routes, not only reducing greenhouse gases, but reducing bus noise as well.<sup>17 18</sup>

The requirements for the city were very specific because there is an existing electric infrastructure associated with the extensive trolley system used in the city, and Vienna wanted to make use of that infrastructure rather than creating a duplicate electric charging infrastructure. Siemens designed and built buses specifically for the Vienna requirement by putting a pantograph on the roof that allows the charger and inverter installed in the roof of the bus to connect to the existing infrastructure.<sup>19</sup>

Another unique requirement by Vienna was that they wanted to limit the amount of recharging time required along the route. The buses that were designed for them recharge at the end of the route in less than 15 minutes while passengers board the bus. This allows the bus to recharge sufficiently to get through the daily routes, and the buses fully

---

<sup>10</sup> Eudy, L. et al. (2016). "Foothill transit battery electric bus demonstration results." National Renewable Energy Laboratory. <http://www.nrel.gov/docs/fy16osti/65274.pdf>

<sup>11</sup> Koch, W. (2015). "Tesla for the masses: electric, fuel cell buses take off." National Geographic. <http://news.nationalgeographic.com/energy/2015/03/150312-tesla-for-the-masses-electric-buses-take-off/>

<sup>12</sup> CTA (2016). "Electric bus." Chicago Transit Authority. <http://www.transitchicago.com/electricbus/>

<sup>13</sup> MacKechnie, C. (2016). "How long do buses (and other transit vehicles) last?" About Money. ([http://publictransport.about.com/od/Transit\\_Vehicles/a/How-Long-Do-Buses-And-Ohter-Transit-Vehicles-Last.htm](http://publictransport.about.com/od/Transit_Vehicles/a/How-Long-Do-Buses-And-Ohter-Transit-Vehicles-Last.htm))

<sup>14</sup> Nykvist, B. and Nilsson, M. (2015). "Rapidly falling costs of battery pack for electric vehicles." Nature Climate Change. [http://www.nature.com/nclimate/journal/v5/n4/full/nclimate2564.html?WT.ec\\_id=NCLIMATE-201504](http://www.nature.com/nclimate/journal/v5/n4/full/nclimate2564.html?WT.ec_id=NCLIMATE-201504)

<sup>15</sup> CTA (2016). "Electric bus." Chicago Transit Authority. <http://www.transitchicago.com/electricbus/>

<sup>16</sup> Eudy, L. et al. (2016). "Foothill transit battery electric bus demonstration results." National Renewable Energy Laboratory. <http://www.nrel.gov/docs/fy16osti/65274.pdf>

<sup>17</sup> Gies, E. (2013). "In Europe, greener transit on existing infrastructure." The New York Times. [http://www.nytimes.com/2013/07/08/business/energy-environment/greener-transit-in-europe-built-on-top-of-older-infrastructure.html?\\_r=2](http://www.nytimes.com/2013/07/08/business/energy-environment/greener-transit-in-europe-built-on-top-of-older-infrastructure.html?_r=2)

<sup>18</sup> Wiesinger, P. (2014). "Innovative electric buses in Vienna." Clean Fleets. [http://www.clean-fleets.eu/fileadmin/files/Clean\\_Fleets\\_case\\_study\\_\\_Vienna\\_-\\_Final.pdf](http://www.clean-fleets.eu/fileadmin/files/Clean_Fleets_case_study__Vienna_-_Final.pdf)

<sup>19</sup> Siemens (2014). "Electric buses: rapid charging in Vienna." Siemens. <http://www.siemens.com/innovation/en/home/pictures-of-the-future/mobility-and-motors/electric-mobility-electric-buses.html>

charge overnight.<sup>20</sup>

The unique bus implementation costs the city nearly twice what it would pay for diesel buses, but they have avoided the initial infrastructure cost, their operating and maintenance costs are 25% to 35% cheaper and bus prices will come down for them over time.<sup>21</sup>

The electricity used to power the buses comes from a mix of sources with 50% coming from

hydropower, 15% coming from wind, 8% from solar, and the remaining 27% coming from fossil fuel generated electricity. Using this mix of power generation results in an estimated reduction of approximately 23 metric tons of CO<sub>2</sub>e per bus per year, or 276 metric tons of CO<sub>2</sub>e per year for the 12 buses operating in Vienna.<sup>22</sup> These savings will vary depending on the type of bus previously used (fuel type, mpg or equivalent), the distance that the bus typically travels, and the sources of power generation for the electricity to charge the buses.

## RESULTS AND LESSONS LEARNED

Converting to electric buses raises a variety of challenges that can vary from city to city. Bus routes can be short or long, weather can be hot or cold, and bus speeds can vary dramatically. As a result, the size and range of the battery will vary as will the amount of time required to charge the battery. The size and range of the battery drives the recharging time as well as the cost of the bus. In addition, when first implementing an electric bus strategy, charging infrastructure must be purchased and installed.<sup>23</sup>

In the case of Vienna, infrastructure costs were reduced by purchasing more expensive and unique buses. In addition, because the technology was new and unique, there were certain challenges such as outer batteries getting colder and discharging more quickly than inner batteries. This will be fixed with small heaters. However, overall the implementation has achieved the city's goals of minimal recharging along the route, no greenhouse gas emissions in the historic district, and a quieter center of town for the both the Viennese and for the tourists.

---

<sup>20</sup> Siemens (2014). "Electric buses: rapid charging in Vienna." Siemens.  
<http://www.siemens.com/innovation/en/home/pictures-of-the-future/mobility-and-motors/electric-mobility-electric-buses.html>

<sup>21</sup> Van Der Pas, J. W. (2015). "A cleaner city: electric buses in Vienna (Austria)." Eltis.  
<http://www.eltis.org/discover/case-studies/cleaner-city-electric-buses-vienna-austria>

<sup>22</sup> Van Der Pas, J. W. (2015). "A cleaner city: electric buses in Vienna (Austria)." Eltis.  
<http://www.eltis.org/discover/case-studies/cleaner-city-electric-buses-vienna-austria>

<sup>23</sup> Wiesinger, P. (2014). "Innovative electric buses in Vienna." Clean Fleets. [http://www.clean-fleets.eu/fileadmin/files/Clean\\_Fleets\\_case\\_study\\_\\_Vienna\\_-\\_Final.pdf](http://www.clean-fleets.eu/fileadmin/files/Clean_Fleets_case_study__Vienna_-_Final.pdf)

## BACKGROUND

Paris has approximately 2.3 million residents and is known for its frequent high levels of pollution. In 2015 the mayor won a long-running battle to introduce emergency traffic bans when pollution from vehicles reaches dangerous levels.<sup>24</sup> The city has taken steps to permanently reduce the number of vehicles on city streets. One such policy that has been implemented is the Vélib' bike-sharing program, which is now one of the world's largest.

## PARIS (France)

**Program: Vélib' Bike Share**  
Population: 2,244,000 (2010)



## PROGRAM DESCRIPTION

The Vélib' was launched in 2007 by mayor Bertrand Delanoë, with an initial introduction of 7,000 bikes distributed among 750 rental stations. Since then, the number of bikes, stations, and rides have increased dramatically. With over 20,000 bikes available around the city and 1,800 bike stations located every 300 meters, Paris has encouraged its citizens to seek cleaner and healthier modes of transportation. Over 200 million journeys have been made since the program's creation, and the system has now expanded to include bikes for children.<sup>25</sup> Most recently, the program operator began experimenting with pedal electric systems and with bikes that have automatic gear changing.<sup>26</sup>

The real impact of the Vélib' program on vehicles and on emissions reduction is difficult to estimate, although sources estimate the reduction in average vehicle trips to be between 10-25%. Adam Stein, of TerraPass, a carbon offsetting company, estimated emissions at around 40,000 metric tons of CO<sub>2</sub> per year, which would be the equivalent of removing 5,700 cars from the road.

Measuring the real impacts of bike-share programs on urban greenhouse gas emissions is a common difficulty for programs around the world. Washington, DC's Capital Bikeshare did a survey of its users in 2011 which showed:

- 41% of users reported reducing their number of car trips

---

<sup>24</sup> Willsher, K. (2015). "Paris to stop traffic when air pollution spikes." The Guardian.

<http://www.theguardian.com/environment/2015/nov/03/paris-to-stop-traffic-when-air-pollution-spikes>

<sup>25</sup> Larsen, J. (2013). "Bike-sharing programs hit the streets in over 500 cities worldwide." Earth Policy Institute.

<https://earthpolicyinstitute.wordpress.com/2013/04/25/bike-sharing-programs-hit-the-streets-in-over-500-cities-worldwide/>

<sup>26</sup> DeMaio, P. (2016). "The need for innovation." The Bike-Sharing Blog. <http://bike-sharing.blogspot.com/>

- Users indicated that they drove an average of 523 miles per year less, which translates into avoiding releasing 487.7 pounds of carbon dioxide (CO<sub>2</sub>) into the atmosphere per bike share user
- Annually that translates into 1,632 tons of atmospheric CO<sub>2</sub> avoided<sup>27</sup>

In New York City, a 2013 field count found that there were approximately 113,000 daily trips within the bike share service area with 33,000 using Citi Bikes, the city's bike-share system, and the remainder using private bikes. Additionally, rider data was collected through surveys, finding that without Citi Bike, users would generally have taken the subway or walked, while one-quarter would have used a taxi/livery service or would have used their own car: (multiple responses allowed)

- 65% would have used the subway for current trip if bike share did not exist
- 63% would have walked
- 18% would have taken the bus
- 21% would have used a taxi, livery or their own car
- 9% would have used their own bike<sup>28</sup>

In the case of Nice Ride Minnesota, the bike-sharing program in Minneapolis and St. Paul, 2011 data shows that 53 percent of the program's riders used a car less often as a result of the program, while in Denver, 41 percent of Denver B-Cycle bike trips replaced car trips, and the programs is estimated to have avoided more than 1 million pounds of CO<sub>2</sub> emissions between 2010 and 2014. Clearly in every city the impacts of bike-share programs on ridership and greenhouse

gas emissions varies substantially, and often appear to be more successful in less-dense locations.

### PROGRAM COSTS

The Vélib' program initially suffered from high levels of theft and vandalism, but such incidents have diminished significantly over the years. The 10-year contract under which the system currently operates was won by JCDecaux, a French public relations and advertising company. Nearly \$142 million was initially invested to set up the system, and the company is also responsible for maintaining and repairing the bikes. The city of Paris gets the proceeds from the usage of the bikes plus royalties.<sup>29</sup> The bikes are not cheap, costing up to \$3,500 each when considering the system startup and maintenance.

### PROGRAM EFFECTIVENESS

Despite the difficulties of measuring real impacts on vehicle and emissions reductions, the program has shown to be effective. The system's popularity has allowed it to expand and improve throughout its existence, and has shown to be a viable option when vehicles are not available for use. In other programs, the success of bike-share systems varies substantially, often easier to implement and gain ridership in less-dense locations than in extremely dense and heavily congested regions such as New York City.

The effectiveness of the program may be influenced by other factors, such as the availability or accessibility of other forms of transportation. For example, on a day in 2014 when Paris placed a temporary ban on nearly half of the city's vehicles, the city's bike system saw a 130 percent

<sup>27</sup> Blaustein, L. (2013). "Citi bike...how green is it?" GreenSportsBlog. <http://greensportsblog.com/2013/08/05/citi-bike-how-green-is-it/>

<sup>28</sup> Solomonow, S. and Mosquera, N. (2013). "After First 200 Days of Citi Bike, NYC DOT Releases New Data Showing that Significant Numbers of New Yorkers are Biking, Complementing Transit System." New York City

Department of Transportation. <http://a841-tfpweb.nyc.gov/dotpress/2013/12/new-biking-data/>

<sup>29</sup> Erlanger, S. (2008). "A New Fashion Catches On in Paris: Cheap Bicycle Rentals." The New York Times. [http://www.nytimes.com/2008/07/13/world/europe/13paris.html?\\_r=2&ei=5087&em=&en=607f90e234d58472&ex=1216094400&pagewanted=all&oref=slogin&oref=slogin](http://www.nytimes.com/2008/07/13/world/europe/13paris.html?_r=2&ei=5087&em=&en=607f90e234d58472&ex=1216094400&pagewanted=all&oref=slogin&oref=slogin)

spike in ridership.<sup>30</sup> This shows that if private vehicles are simply no longer an option, residents

will increase the use of bikes and other transportation methods.

## RESULTS AND LESSONS LEARNED

Bike share programs have been implemented in over 150 cities around the world, and have proven to be successful to varying degrees. In some cities, such as New York City, bike share has not been as popular as hoped. The program originally faced significant opposition from business owners and residents who had lost parking spots to bike stations and lanes, as well as from taxi drivers who fear the increased number of bikes on the streets. In other implementations such as Paris and smaller cities in the US, programs have been very successful in attracting ridership. In either event, the number of riders who switch from private vehicles is often difficult to assess, as is their impact on greenhouse gas emissions. Cities where residents are open to new forms of transportation appear to have the best reception.

---

<sup>30</sup> Reed, C. (2014). "Pollution spikes send Europe scrambling for emission controls." ClimateWire. <http://www.eenews.net/stories/1059996347>

## BACKGROUND

Car Sharing is an alternative to car ownership that has been growing in recent years primarily in North America and in Europe, but in other locations like Australia as well. Car sharing is a variation of car renting where cars may be rented by the day, hour or even minute and the car is both picked up and returned in a self-service fashion. Essentially, car sharing separates car usage from actual car ownership.<sup>31</sup> According to Navigant Research, car sharing is projected to grow from a \$1 billion business with over 2 million members in 2015 to a \$6 billion business with over 10 million members by 2024.<sup>32</sup> One web site lists 1,000 cities that have car share programs today.<sup>33</sup> In the United States, Zipcar is the largest car share company followed by Car2Go.

## BREMEN (Germany)

**Program: Car Share**

Population: 546,451 (2013)



## POLICY DESCRIPTION

There are a number of variations in the implementation of car sharing. Zipcar, for example, has specific convenient locations throughout a city where cars may be picked up and dropped off. Other providers allow cars to be parked in regular parking spots, randomly located in the city. Most car share companies require

membership, and the whole process of rental, drop off, pricing, car selection and location is managed by software applications. Technological advances with the internet, GPSs, and applications have made the accelerated growth of car sharing possible. Other program features that vary by provider include the inclusion of fuel, insurance, roadside assistance, tolls, one-way capability, overnight capability and different car styles and

---

<sup>31</sup> Jung, A. (2015). "Carsharing services in emerging economies." Giz.

[http://www.sutp.org/files/contents/documents/resources/B\\_Technical-Documents/GIZ\\_SUTP\\_TD12\\_Carsharing-Services-in-Emerging-Economies\\_EN.pdf](http://www.sutp.org/files/contents/documents/resources/B_Technical-Documents/GIZ_SUTP_TD12_Carsharing-Services-in-Emerging-Economies_EN.pdf)

<sup>32</sup> Berman, B. et al. (2013). "Carsharing programs." Navigant Research. <http://www.navigantresearch.com/research/carsharing-programs>

<sup>33</sup> Ecoplan (2008). "One thousand world carshare cities in 2009." Ecoplan.

<http://ecoplan.org/carshare/general/cities.htm#latest>

types available.<sup>34 35 36</sup>

## PROGRAM COSTS

From a user perspective, there is an initial fee paid to the car sharing company, generally on the order of \$35 to \$100. The financial savings for the user comes primarily from reduced car ownership cost or from lower car maintenance cost. The average savings per year is estimated at between \$150 and \$500.<sup>37</sup>

From an investor perspective, as an example, Avis purchased Zipcar in 2013 for \$500M. At the time, Zipcar had 760,000 members, and the sale price of \$12.25 was well above current trading prices (under \$10), but below the initial public offering price of \$18.<sup>38</sup>

Most car share companies are for-profit and bear the costs of setting up the programs. From the perspective of cities, their requirements for the program will depend on the implementation of the car share company. In the case of Bremen, Germany, where the city actually set up the parking spaces to rent out to car sharing companies, the initial investment was about \$350,000.<sup>39 40</sup>

In the case of a company like Zipcar that provides cars at specific locations, cities may need to legislate the company's ability to make use of the

space for that purpose. In some cases, car share companies may lease space from landlords. In other cases, cities may provide parking areas to the car share companies, foregoing any revenue that they might otherwise have received for alternative use of that space.

Some cities may want to provide a level of integration between various transportation modes including car sharing. There could be a cost to the city depending on the type of integration intended.

## PROGRAM IMPLEMENTATION

Most cities have several for-profit car sharing companies that compete. However, there have been several other variations over time (not-for-profit, cooperatives etc.) which include car share programs that are managed by the city's transit department. One such example is in Bremen, Germany. Over time, the city has strongly promoted alternative forms of transportation and the city boasts that 25% of the trips in the city by their citizens are on bicycle, 14% use mass transit, and 20% of the trips are on foot. here is still a problem with too many cars causing congestion and excessive competition for parking. hey have developed an award winning car sharing program to reduce the number of cars used for local transportation. The car sharing program is integrated with other forms of transportation to make them appear seamless from both a payment

---

<sup>34</sup> Steinberg, S. and Vlastic, B. (2013). "Car-sharing services grow, and expand options." The New York Times. [http://www.nytimes.com/2013/01/26/business/car-sharing-services-grow-and-expand-options.html?ref=technology&\\_r=3](http://www.nytimes.com/2013/01/26/business/car-sharing-services-grow-and-expand-options.html?ref=technology&_r=3)

<sup>35</sup> Martin, R. (2013). "Carsharing services will surpass 12 million members worldwide by 2020." Navigant Research. <http://www.navigantresearch.com/newsroom/carsharing-services-will-surpass-12-million-members-worldwide-by-2020>

<sup>36</sup> Cervero, R. et al. (2002). "City carshare: assessment of short-term travel-behavior impacts." eScholarship - University of California. <http://escholarship.org/uc/item/7fn8966c?query=City%20CarShare#page-3>

<sup>37</sup> Cervero, R. et al. (2002). "City carshare: assessment of short-term travel-behavior impacts." eScholarship -

University of California.

<http://escholarship.org/uc/item/5k56406d?query=North%20American%20Carsharing#page-5>

<sup>38</sup> Kell, J. (2013). "Avis to buy car-sharing service Zipcar." The Wall Street Journal.

<http://www.wsj.com/articles/SB10001424127887324374004578217121433322386>

<sup>39</sup> Glotz-Richter, M. (2011). "Car-sharing in Bremen." Cities for Mobility. [http://www.cities-for-mobility.net/documents/wc11/michael\\_glotz\\_richter.pdf](http://www.cities-for-mobility.net/documents/wc11/michael_glotz_richter.pdf)

<sup>40</sup> Jung, A. (2015). "Carsharing services in emerging economies." Giz.

[http://www.sutp.org/files/contents/documents/resources/B\\_Technical-Documents/GIZ\\_SUTP\\_TD12\\_Carsharing-Services-in-Emerging-Economies\\_EN.pdf](http://www.sutp.org/files/contents/documents/resources/B_Technical-Documents/GIZ_SUTP_TD12_Carsharing-Services-in-Emerging-Economies_EN.pdf)

and location perspective. Although the city runs and manages the overall program, day-to-day operations are actually managed by several companies.<sup>41 42 43</sup>

Initial set up for Bremen brought a number of challenges. First, German law did not provide for car sharing, therefore specific legislation needed to be enacted. Germany still doesn't have a legal framework that supports the construct. Bremen also encountered complexities with initial operational implementation. Those problems were addressed working with the contractors that own operations.<sup>44</sup>

### PROGRAM EFFECTIVENESS

There are a number of key objectives to car sharing programs. According to the Car Sharing Association, the program objectives include reducing the number of vehicles on the road, providing affordable access to vehicles, improving urban land use, reducing automobile emissions through fewer miles driven, and promoting bicycling and walking.<sup>45</sup> That appears to be a tall order. The results to date, however, have been exceptional.

A study entitled "North America Carsharing: A Ten Year Retrospective," by Shaheen, Cohen and Chung, published in the Transportation Research Record in 2010 provides detailed results of car sharing implementations. Participants in car sharing programs walk more, cycle more, use mass

transit more, and drive fewer miles than before they entered these programs. A significant percentage of them, double digit, end up selling one of the vehicles that they owned previously, and a double digit percentage indicates that they avoided purchasing an additional car by joining the program.<sup>46</sup> Bremen reports similar experiences with 1,500 cars from the city having been sold by owners by 2010, because they joined the car share program that only began in 2009.

From a user perspective, the advantages of car sharing include lower cost than car ownership, eliminating many tasks associated with car ownership such as car registration, insurance, parking, maintenance and inspection. In addition, the social benefits include lower emissions (car share cars are newer and have lower emissions, fewer miles driven by those in car share programs), fewer cars on the road resulting in lower congestion and less parking required, and less energy required to produce fewer cars. An interesting predicament that auto manufacturers were already facing was that the younger generations are less inclined to drive and less inclined to own cars. So car sharing is a solution that fits with generational attitudes.<sup>47 48</sup>

There are potential disadvantages to the programs, depending on the user. Car sharing does not make typically make financial sense for frequent use such as commuting to work daily. In addition, many users find it inconvenient to not have their

---

<sup>41</sup> Mobil Punkt (2016). "Car-sharing in Bremen." Mobil Punkt. <http://mobilpunkt-bremen.de/english/>

<sup>42</sup> Glotz-Richter, M. (2011). "Car-sharing in Bremen." Cities for Mobility. [http://www.cities-for-mobility.net/documents/wc11/michael\\_glotz\\_richter.pdf](http://www.cities-for-mobility.net/documents/wc11/michael_glotz_richter.pdf)

<sup>43</sup> Glotz-Richter, M. (2011). "Car-sharing in Bremen." Cities for Mobility. [http://www.cities-for-mobility.net/documents/wc11/michael\\_glotz\\_richter.pdf](http://www.cities-for-mobility.net/documents/wc11/michael_glotz_richter.pdf)

<sup>44</sup> Glotz-Richter, M. (2015). "Bremen car-sharing scheme takes cars off the road (Germany)." Eltis. <http://www.eltis.org/discover/case-studies/bremen-car-sharing-scheme-takes-cars-road-germany>

<sup>45</sup> CSA (2016). "What is carsharing?" Carsharing Association. <http://carsharing.org/what-is-car-sharing/>

<sup>46</sup> Shaheen, S A. et al. (2009). "North American carsharing: 10-year retrospective." University of California, Berkeley. <http://trsc.berkeley.edu/sites/default/files/North%20American%20Carsharing%20-%20Shaheen.pdf>

<sup>47</sup> Shaheen, S A. et al. (2009). "North American carsharing: 10-year retrospective." University of California, Berkeley. <http://trsc.berkeley.edu/sites/default/files/North%20American%20Carsharing%20-%20Shaheen.pdf>

<sup>48</sup> Profita, C. (2013). "The pros and cons of car-sharing." Oregon Public Broadcasting. <http://www.opb.org/news/blog/ecotrope/the-pros-and-cons-of-car-sharing/>

car parked at or near their residence. There is also a level of convenience to have personal things that are always in the car. In addition, manufacturing of fewer cars means fewer jobs. Although as indicated based on generational attitudes, that may have occurred anyway.<sup>49 50</sup>

Removing cars from the roads in itself does not reduce greenhouse gases. Reduction in greenhouse gases comes from a reduction in vehicle miles traveled (VMT). The shift from car ownership to car share generally comes with a reduction of VMT because owners are more judicious in their

use of cars, consolidating trips and using other modes of transportation in order to reduce their costs. Zipcar reported in 2006 that there was an average reduction of over 4,000 VMTs per year for each car share member.<sup>51</sup> This translates to a reduction of roughly 1.4 metric tons of CO<sub>2</sub>e per year for each car share member. Martin and Shaheen report .84 metric tons of CO<sub>2</sub>e saved per year per household.<sup>52</sup> Bremen, Germany has over 10,000 members as of February, 2015.<sup>53</sup> Assuming the same averages apply, Bremen is saving 14,000 metric tons of CO<sub>2</sub>e per year

## RESULTS AND LESSONS LEARNED

From an implementation perspective, it is helpful for cities to partner in some fashion with car sharing companies as indicated by the Bremen experience. Car sharing locations should be convenient to other forms of mass transportation, and it may be convenient for users to have integrated payment systems. Other concerns that governments may get involved with include insurance requirements for car share programs, allowing parking and providing location for parking, and program taxation.

The city of Bremen has set goals for their car share program. They want to have at least 20,000 residents join the program by 2020 and they are hoping to eliminate 6,000 parking spaces. This is just one avenue to improving transportation and reducing emissions for the city of 550,000.<sup>54 55</sup>

Car share implementations exist in over 1,000 cities worldwide therefore car share has proven to be replicable. There are many different types of implementations, and Bremen, Germany's is just one. The city strongly believes in their program and speaks to cities all over the world about their experience.<sup>56</sup>

<sup>49</sup> Shaheen, S A. et al. (2009). "North American carsharing: 10-year retrospective." University of California, Berkeley. <http://tsrc.berkeley.edu/sites/default/files/North%20American%20Carsharing%20-%20Shaheen.pdf>

<sup>50</sup> <http://www.opb.org/news/blog/ecotrope/the-pros-and-cons-of-car-sharing/>

<sup>51</sup> CMAP (2014). "Impacts of car sharing." Chicago Metropolitan Agency for Planning. <http://www.cmap.illinois.gov/about/2040/supporting-materials/process-archive/strategy-papers/car-sharing/impacts>

<sup>52</sup> Martin, E. and Shaheen, S. (2011). "Greenhouse Gas Emission Impacts of Carsharing in North America." IEEE Transactions on Intelligent Transportation Systems.

<http://ieeexplore.ieee.org.ezproxy.cul.columbia.edu/stamp/stamp.jsp?tp=&arnumber=5951778>

<sup>53</sup> Mobil.Punkt (2016). "Car-Sharing station in Bremen." Mobil.Punkt. <http://mobilpunkt-bremen.de/english/>

<sup>54</sup> Kolson Hurley, A. (2014). "How Bremen, Germany, Became a Car-Sharing Paradise." City Lab. <http://www.citylab.com/commute/2014/12/how-bremen-germany-became-a-car-sharing-paradise/383538/>

<sup>55</sup> Glotz-Richter, M. (2011). "Car-sharing in Bremen." Cities for Mobility. [http://www.cities-for-mobility.net/documents/wc11/michael\\_glotz\\_richter.pdf](http://www.cities-for-mobility.net/documents/wc11/michael_glotz_richter.pdf)

<sup>56</sup> Kolson Hurley, A. (2014). "How Bremen, Germany, Became a Car-Sharing Paradise." City Lab. <http://www.citylab.com/commute/2014/12/how-bremen-germany-became-a-car-sharing-paradise/383538/>

## BACKGROUND

A large percentage of vehicles in cities tend to be fleet vehicles, such as delivery vehicles, government-owned vehicles, and taxis. These vehicles are responsible for significant quantities of greenhouse gas emissions, despite the fact that they are often not actually moving for very long periods of time. Changing the type of vehicles used, especially the adoption of electric vehicles, has the potential to significantly reduce greenhouse gas emissions produced by fleets.

A study in British Columbia, Canada, for example, found that fleet vehicle usage varied widely (as low as 900 km/year to up to nearly 70,000 km/year) and emitted an average of 469 grams of carbon dioxide equivalent (CO<sub>2e</sub>) per kilometer. The same study concluded that the average electric vehicle range of up to 300 kilometers would be long enough for 94% of the fleets studied.<sup>57</sup>

## AMSTERDAM (The Netherlands)

**Program: Schiphol Airport Electric Fleet**  
Population: 779,808 (2011)



## PROGRAM DESCRIPTION

Schiphol Airport, in Amsterdam, replaced part of its taxi and bus fleet with fully electric vehicles. In 2014 the airport acquired 167 Tesla Model S taxi cabs to replace some of its older vehicles. Although more expensive than some other electric vehicles, the benefits were determined to outweigh the costs of using the higher quality Teslas. Other places in the Netherlands are using the Nissan e-NV200 electric van, which can be purchased for less than

\$10,000 after incentives.<sup>58</sup>

Additionally, the city of Amsterdam purchased 35 electric buses from the Chinese electric vehicle and battery company BYD for use at the airport, which are expected to significantly reduce fleet maintenance costs as well as reduce greenhouse gas emissions and improve the airport's air quality.<sup>59</sup> The city is also encouraging a broad adoption of electric vehicles city-wide by installing 1,100

<sup>57</sup> Plug in BC (2014). "Electric Vehicle Fleet Modelling Project." 2013 Summary Report.

[http://www.e3fleet.com/\\_Library/docs/Plug\\_In\\_BC\\_EV\\_Suitability\\_Modelling\\_Project\\_-\\_White\\_Paper.pdf](http://www.e3fleet.com/_Library/docs/Plug_In_BC_EV_Suitability_Modelling_Project_-_White_Paper.pdf)

<sup>58</sup> DeMorro, C. (2014). "Amsterdam Airport Enlists 167 Tesla Taxis." Gas2. <http://gas2.org/2014/10/16/amsterdam-airport-enlists-167-tesla-taxis/>

<sup>59</sup> King, D. (2013). "BYD gets Europe's largest-ever e-bus contract, headed to Amsterdam airport." autoblog <http://www.autoblog.com/2013/07/18/byd-gets-europes-largest-e-bus-contract-for-amsterdam-airport/>

electric charging points in Amsterdam, with plans to increase the total to 4,000 charging stations by 2018.

### PROGRAM COSTS

The costs and savings of the electric taxis and buses are not available due to the recent implementation of this program. However, there are studies on the general benefits of electric fleet vehicles. Green Car Reports states that electric cars

can save fleet operators approximately \$16,000 per vehicle over a seven-year lifespan.<sup>60</sup> Exact figures will vary based on local incentives, but the lower maintenance needs and relatively simple charging systems are consistent independent of location. Table 5 shows the incentives provided by the governments of two cities in the Netherlands, which result in up to 76% in savings for consumers, and therefore make electric cars affordable options.

*Table 5: Costs of two electric vehicles in Rotterdam and Amsterdam after government incentives.<sup>61</sup>*

	LEAF	e-NV200
List Price (excl. VAT)	€19,926 (\$22,839)*	€20,490 (\$23,485)*
Cost after incentives – ROTTERDAM	€7,450 (\$8,539)*	€4,950 (\$5,673)*
Savings	63%	76%
Cost after incentives – AMSTERDAM	€8,350 (\$9,570)*	€5,650 (\$6,476)*
Savings	58%	72%

\* exchange rate used: mid-market rates 2016-05-01

In addition to the savings on vehicle purchase, average fuel savings per year are approximately €500 (\$573)

According to a 2014 report from the Rocky Mountain Institute, single-port charging stations for electric vehicles can be costly, anywhere between \$2,300 - \$6,000, and that public stations tend to have higher costs due to the need for mounting structures. The bulk of this cost in public stations (60-80%) are from installation due to the need to be in proximity to a breaker station

(\$100/ft. away), so installing dual and multi-port stations over single station significantly reduces cost.<sup>62</sup> Considering the number of stations the Netherlands are installing, the investment is well worth it in the long run.

### PROGRAM IMPLEMENTATION

Broadly, Amsterdam’s new agenda for “renewable energy, clean air, a circular economy, and a climate-resilient city” was adopted in March 2015. Historically, they have emphasized clean modes of transportation, shown by continuous bicycle infrastructure investment beginning in the

<sup>60</sup> Klippenstein, M. (2014). “Why an electric car saves fleet operators \$16000 in lifetime costs.” Green Car Reports [http://www.greencarreports.com/news/1092682\\_why-an-electric-car-saves-fleet-operators-16000-in-lifetime-cost](http://www.greencarreports.com/news/1092682_why-an-electric-car-saves-fleet-operators-16000-in-lifetime-cost)

<sup>61</sup> Electric Cars Report. (2014). “Rotterdam Introduces World’s Best EV Incentives.” Electric Cars Report.

<http://electriccarsreport.com/2014/08/rotterdam-introduces-worlds-best-ev-incentives/>

<sup>62</sup> Rocky Mountain institute. (2014). “Pulling back the veil on EV charging station costs.” Rocky Mountain Institute. [http://blog.rmi.org/blog\\_2014\\_04\\_29\\_pulling\\_back\\_the\\_veil\\_on\\_ev\\_charging\\_station\\_costs](http://blog.rmi.org/blog_2014_04_29_pulling_back_the_veil_on_ev_charging_station_costs)

1970's.<sup>63</sup> Based on the new agenda, the city aims to generate 20% more renewable energy and use 20% less energy per capita compared to 2013, which will contribute to an economy that will emit 40% less CO<sub>2</sub> by 2025 compared to 1990. The city expects to save money from avoided health care costs due to significantly reduced pollution.<sup>64</sup>

Steps will be taken to tighten environmental regulations on private vehicles and public and private fleet vehicles to ensure that the city becomes emission-free by 2025. Incentives such as preferential parking permits will be offered to owners of electric vehicles, as well as free charging in parking spots and garages and exemption from vehicle registration and annual circulation taxes.<sup>65</sup>

No issues have been encountered during the current expansion of electric vehicle fleets, such as the Tesla taxis and BYD buses at Schiphol Airport. While only implemented in the last couple of years, the vehicles and system as a whole are expected to continue functioning as designed, with savings on fuel and vehicle maintenance. While difficulties sometimes emerged due to range limitations, these are rapidly being addressed with

the installation of charging stations around the city. To ensure that the electric vehicles do really reduce pollution, the Netherlands has committed to install electric vehicle chargers at more than 200 stations across the nation, with at least one station every 31 miles.<sup>66</sup>

## PROGRAM EFFECTIVENESS

The program is too young to be deemed a success, but has effectively performed up to this point in terms of implementation and ongoing operation. One point to consider, however, is the source of the electricity powering the new electric vehicles. Many of the electric vehicles in the Netherlands are being charged with coal-generated electricity<sup>67</sup>. While the City of Amsterdam itself hopes to rapidly increase their renewable energy supply, electric vehicle fleets may not reduce as much pollution until an energy source conversion is implemented. Before implementing similar programs, cities should simultaneously consider their electricity source and attempt to use renewable energy to charge their fleets. Some cities may therefore benefit more from electric fleets than others in terms of greenhouse gas emissions reductions, depending on how far along a shift to sustainable energy they are.

---

<sup>63</sup> Walljasper, J. (2010). "How to make biking mainstream: lessons from the Dutch." YES! Magazine. <http://www.yesmagazine.org/planet/how-to-make-biking-mainstream-lessons-from-the-dutch>

<sup>64</sup> City of Amsterdam. (2015). "Sustainable Amsterdam." City of Amsterdam [https://www.amsterdam.nl/publish/pages/675721/sustainable\\_amsterdam\\_27-3-2015.pdf](https://www.amsterdam.nl/publish/pages/675721/sustainable_amsterdam_27-3-2015.pdf)

<sup>65</sup> Amsterdam Round Tables and McKinsey&Company. (2014). "Electric vehicles in Europe: gearing up for a new phase?" Amsterdam Round Tables and McKinsey&Company. [https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKewjZxaeQr-](https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKewjZxaeQr-vLAhXG2R4KHUTeDdsQFggdMAA&url=http%3A%2F%2Fwww.mckinsey.com%2F~%2Fmedia%2FMckinsey%2520Offices%2FNetherlands%2FLatest%2520thinking%2FPDFs%2FElectric-Vehicle-Report-EN_AS%2520FINAL.ashx&usg=AFQjCNHD4p87eDheWXdnckdbp2Un1A7XiA)

[vLAhXG2R4KHUTeDdsQFggdMAA&url=http%3A%2F%2Fwww.mckinsey.com%2F~%2Fmedia%2FMckinsey%2520Offices%2FNetherlands%2FLatest%2520thinking%2FPDFs%2FElectric-Vehicle-Report-EN\\_AS%2520FINAL.ashx&usg=AFQjCNHD4p87eDheWXdnckdbp2Un1A7XiA](http://www.mckinsey.com%2F~%2Fmedia%2FMckinsey%2520Offices%2FNetherlands%2FLatest%2520thinking%2FPDFs%2FElectric-Vehicle-Report-EN_AS%2520FINAL.ashx&usg=AFQjCNHD4p87eDheWXdnckdbp2Un1A7XiA)

<sup>66</sup> Toor, A. (2013). "Every Dutch citizen will live within 31 miles of an electric vehicle charging station by 2015." The Verge. <http://www.theverge.com/2013/7/10/4509962/netherlands-nationwide-electric-vehicle-charging-network-abbreviated>

<sup>67</sup> Birnbaum Washington post source

## RESULTS AND LESSONS LEARNED

Amsterdam, and the Netherlands as a whole, are very committed to electric vehicle expansion, and have taken important steps to achieve this goal through investments in charging stations and consumer purchase incentives. The success of the program is therefore a result of the collaboration between the government and the people. Replicating the program elsewhere would require similar collaborative efforts, as without incentives electric vehicles are too expensive for the average consumer, although the price differential is reducing. Regional implementation may also be easier, rather than attempting to follow the Netherlands in changing the country as a whole. The surface area of the United States is more than 230 times larger than the Netherlands, for example, which would make nation-wide implementation difficult in the short term, and would require regional or state collaboration. One possibility is to provide incentives for companies with large fleets, such as delivery or passenger transport companies, as well as urban transportation fleets.

Other cities around the world, such as New York City, plan to convert their fleets to electric vehicles, which aims to replace around 2,000 city-owned sedans with Chevrolet Volt and Nissan Leaf vehicles by 2025, along with the installation of electric charging stations throughout the city. The program is expected to require a capital investment of \$50 million and \$80 million over 10 years, while it will help the city government to reduce their emissions by 50 percent by 2025.<sup>68</sup> Based on the city's prior investment in gas-electric hybrid vehicles, estimates show that the fleet would cost significantly less to maintain. Savings per vehicle are approximated as follows:

- Hybrid incremental purchase costs: (\$3,373)
- Lifetime (8 year) savings on fuel: (\$7,027)
- Lifetime (8 year) cost of maintenance: (\$5,032)
- Improved auction value: (\$2,126)
- Average lifetime reduction in cost per hybrid: (\$10,812)<sup>69</sup>

Importantly, electric vehicles are expected to require less maintenance than a traditional vehicle, therefore making them a viable option.

---

<sup>68</sup> Grynbaum, M. (2015). "New York City Aims for Vast Electric Car Fleet by 2025." New York Times.  
[http://www.nytimes.com/2015/12/02/nyregion/new-york-city-aims-for-a-vast-electric-car-fleet-by-2025.html?\\_r=0](http://www.nytimes.com/2015/12/02/nyregion/new-york-city-aims-for-a-vast-electric-car-fleet-by-2025.html?_r=0)

<sup>69</sup> NYC. (2014). "Benefits of hybrid gas-electric cars." New York City Government.  
[http://www.nyc.gov/html/dcas/downloads/pdf/fleet/nyc\\_fleet\\_hybrid\\_report\\_june\\_2014.pdf](http://www.nyc.gov/html/dcas/downloads/pdf/fleet/nyc_fleet_hybrid_report_june_2014.pdf)

# Appendix B: *Case Studies - Energy of the Built Environment*

## BACKGROUND

In January of 2011, New York University announced the completion of a new natural gas cogeneration plant. It is one of the largest private cogeneration plants in New York City which affects over 56,000 students, faculty, and staff that utilize the buildings powered by the plant. Implementation of the plant has decreased the university's greenhouse gas emissions by 23% and air pollutants by 68%, providing heat, electricity, and chilled water for cooling to 37 buildings, and produces twice the electrical power of the previous cogeneration plant.<sup>70</sup> NYU's greenhouse gas emissions in 2006 had been about 179,000 MTCe, with a goal to become carbon neutral by 2040.

**NEW YORK CITY (U.S.)**  
**Program: New York University**  
**Co-generation Plant**  
Population: 8,406,000 (2013)



## PROGRAM IMPLEMENTATION

The existing gas cogeneration plant was shut down in response to state air quality inspectors. Through New York City's PlaNYC Climate Challenge, an effort to reduce greenhouse gas emissions by 30%

by 2017, NYU pledged to develop a cleaner, more highly efficient system to replace the less efficient plant. Construction of the new cogeneration

---

<sup>70</sup> NYU. (2011). "NYU switches on green cogen plant and powers up for the sustainable future." NYU News. <https://www.nyu.edu/about/news-publications/news/2011/01/21/nyu-switches-on-green-cogen-plant-and-powers-up-for-the-sustainable-future.html>

started in September of 2008<sup>71</sup> and achieves almost 90% energy efficiency while doubling the output of the previous system to produce 13.4 megawatts of electricity. The Vanderweil Power Group provided design and engineering services for the \$125 million project and Skanska USA provided construction management.<sup>72</sup>

The cogeneration plant is located underground at the Courant Institute of Mathematical Sciences, near Washington Square Park.<sup>73</sup> Due to site limitations, the system as a whole had to fit within a 200-foot long vault only 60 feet deep and 40 feet wide. Rigging the gas turbines, heat-recovery steam generators, and other heavy equipment into the new plant was a challenge as most residential streets of the surrounding area tend to be narrow. The core of the system has two 5.6 MW Solar Taurus 60S dual-fuel gas turbines as each turbine drives the generator and feeds its own heat-recovery steam generator supplied by Nebraska Boilers.<sup>74</sup> Steam passes through the 2.4 MW steam turbine generator at 600 psi.<sup>75</sup> The exhaust from the turbine is fed to another pair of heat exchangers to then make high temperature hot water and if necessary to a 2400 ton steam-driven chiller to make cold water for air conditioning. This entire system runs from a fully digital control system that maintains peak performance and efficiency as it approaches 80% in normal operation. Overall, the plant is capable of producing 20,000 lb./hr. of steam and in the event an auxiliary boiler is fired up, can produce another 40,000 lb./hr.<sup>76</sup>

In 2006, The University produced about 18% of campus electricity at the Central Plant, and it

bought the remaining 82% from Consolidated Edison Solutions, one of many large electricity service companies (ESCOs) in New York State.<sup>77</sup> The development of this 13.4-MW co-generation power reduces demand in the city's strained electrical grid, which diminishes the chances of future brownouts, and allows NYU to weather potential city-wide blackouts.<sup>78</sup>

The NYU cogeneration plant is the largest capital investment ever made by NYU and provides heating and cooling to 40 buildings and electricity to 26 buildings, saving the university \$5–8 million per year and reducing greenhouse gas emissions by 20%. The plant also provides high-temperature hot water, avoiding the annual use of 500,000 gallons of carbon-intensive fuel oil and 280,000 therms of natural gas combustion in buildings.<sup>79</sup>

## PROGRAM EFFECTIVENESS

Hurricane Sandy left many in New York without power for several weeks when ConEd's 14<sup>th</sup> Street substation and transformers exploded and voltages dropped dramatically. The NYU microgrid had demanded a small amount of energy from the ConEd grid, which could have overly burdened the city system. However, the protective relays installed in this project allowed NYU to disconnect from the ConEd grid<sup>80</sup> to reserve supply for other users. Moreover, NYU did not lose their ability to generate energy during the storm and users connected to their system were able to maintain electricity access.

Before the cogeneration plant had been upgraded, NYU cut greenhouse gas emissions by 20-25% within 4 years from a peak of approximately 179,000 Metric Tons Carbon equivalent in 2006

---

<sup>71</sup> Overton, T. W. (2014). "New York University cogeneration plant, New York City." POWER Magazine

<sup>72</sup> Ibid

<sup>73</sup> Ibid

<sup>74</sup> Ibid

<sup>75</sup> Ibid

<sup>76</sup> Ibid

<sup>77</sup> NYU. (2006). "Greening the urban campus: a sustainability assessment of New York University." New York University.

<https://wildgreenyonder.files.wordpress.com/2007/01/greening-the-urban-campus.pdf>

<sup>78</sup> Microgrids. (2016). "New York University." Berkeley Lab. <https://building-microgrid.lbl.gov/new-york-university>

<sup>79</sup> NYU. (2016). "NYU Energy." New York University. <https://www.nyu.edu/life/sustainability/areas-of-focus/energy.html>

<sup>80</sup> Overton, T. W. (2014).

<http://www.powermag.com/new-york-university-cogeneration-plant-new-york-city/?pagenum=3>

to approximately 125,000 in 2010.<sup>81</sup> After the upgrade, NYU's total emissions are expected to decrease significantly by an additional 20% more for an estimated 98,500 MTCe which surpasses the Mayor's Challenge by 10% emission reductions, bringing the total reduction from NYU to almost 40%.<sup>82</sup> The main objective of the project included maintenance of energy security in the given region as well as establishing a type of price stability for energy used, and improvement of reliability and environmental performance to adhere to updated regulatory standards. Key performance indicators included increased electrical generation efficiency, the reduction of greenhouse gas emissions by decreasing total energy consumed and decreased dependence on utility power.<sup>83</sup>

### PROGRAM COST

This project was able to save \$5-8 million a year in energy-related costs. In addition, the new cogeneration system emits 23% less carbon

emissions. Nitrogen oxides and particulate emissions were projected to drop 68% compared to the previous oil-fired plant. The first year operating savings had been estimated at \$778,000.<sup>84</sup> According to total projected annual costs, it is long-term more financially efficient to rely on the newer cogeneration plant compared to purchasing all electricity from ConEd. Total annual utility cost in 2016 is around \$30,000 and projected to rise to \$55,000 by 2036. Debt service about \$28,000 per year as of the year 2016. Operations and maintenance of the plant cost around \$20,000 per year. The total project cost infrastructure avoidance, or cost reductions, causes future overall spending to decrease but is not below the level of current spending at \$27,635,193 with a debt service of \$1,797 per year for 30 years.<sup>85</sup> Overall, this project poses not only energy-savings and carbon equivalent reduction, but also is financially beneficial to NYU.

---

<sup>81</sup> NYU. (2011). "NYU switches on green cogen plant and powers up for the sustainable future." NYU News. <https://www.nyu.edu/about/news-publications/news/2011/01/21/nyu-switches-on-green-cogen-plant-and-powers-up-for-the-sustainable-future.html>

<sup>82</sup> NYU. (2011). "NYU switches on green cogen plant and powers up for the sustainable future." NYU News. [https://www.nyu.edu/about/news-](https://www.nyu.edu/about/news-publications/news/2011/01/21/nyu-switches-on-green-cogen-plant-and-powers-up-for-the-sustainable-future.html)

[publications/news/2011/01/21/nyu-switches-on-green-cogen-plant-and-powers-up-for-the-sustainable-future.html](https://www.nyu.edu/about/news-publications/news/2011/01/21/nyu-switches-on-green-cogen-plant-and-powers-up-for-the-sustainable-future.html)

<sup>83</sup> Bradley, J. (2011). "Greening a Village." New York University. <http://events.energetics.com/nyserdachp/pdfs/bradley.pdf>

<sup>84</sup> Bradley, J. (2011).

<sup>85</sup> Bradley, J. (2011).

## RESULTS AND LESSONS LEARNED

This project was awarded the U.S. Environmental Protection Agency Energy Star Combined Heat and Power Award in 2013.<sup>86</sup> It can be replicated in an urbanized region like that of Washington Square Park in New York for a smaller population within a much bigger city but given the limited space can be quite difficult to implement. MIT for example has plans to upgrade their cogeneration plant, similarly inspired by efforts to remain resilient as a campus as well as working towards a commitment of a 32% reduction in greenhouse gas emissions.<sup>87</sup>

The NYU cogeneration plant overall enables the campus to control their energy supply, reliability, and utility expenses. Projects such as these require executive sponsorship at highest levels of organization and also require defined objectives in the earlier stages of planning to successfully deploy. Proper strategy would have to be thought out by local government to ensure success of such implementation.

Project teams that encompass internal resources such as the NYU staff and external resources such as the engineers, with the defined roles and responsibilities to carry out tasks that align with their subject matter expertise.

---

<sup>86</sup> NYU. (2013). "NYU sets a 50% GHG reduction target by 2017." New York University. <https://www.nyu.edu/about/news-publications/news/2013/04/18/nyu-sets-a-50-ghg-reduction-target-by-2017.html>

<sup>87</sup> MIT. (2015). "Cogeneration: a bridge to the future." Massachusetts Institute of Technology. <https://powering.mit.edu/news/cogeneration-bridge-future>

## BACKGROUND

Barcelona, Spain has implemented the Solar Thermal Ordinance requiring the use of solar energy to heat water. With a population of 1.6 million people, Barcelona was the first European city to implement a solar ordinance that would efficiently utilize their 28,000 average hours of annual sunshine as promoted by the Sustainable City Council Program.<sup>88</sup> The Sustainable City Council Program was an initiative formulated by Ecoinstitut founded in 1999 that sought to incorporate sustainability principles in all sectors of society as an environmental management system.<sup>89</sup> The institute works for international, national, and local clients to offer specific support in sustainable public procurement. The initiative was implemented to foster awareness of municipal services available to assist in building environmental, social, and ethical criteria into decision-making processes.<sup>90</sup> The solar energy is used to supply 60% of hot water in public and private buildings (residential and commercial) that are new, renovated, or are changing their use.

## BARCELONA (Spain)

**Program: Solar Thermal Ordinance**  
Population: 1,602,000 (2014)



## PROGRAM IMPLEMENTATION

The municipality of Barcelona is the financing investor that developed the project concept. The service provider is the Barcelona Energy Agency and other parties involved are the IDAE (Spanish Energy Institute), Municipality of Barcelona (Urban Development and Environment Department), Catalonia Government, Catalonia Energy Institute, Solar Energy Companies Association, Catalonia Consumers Organization,

Catalonia architects Association, Catalonia Engineers Association and Catalonia Construction Engineers Association. The partner responsible for best practice description is the Barcelona Polytechnic University.<sup>91</sup>

At the initial stage, none of the sectors involved had enough information or experience, nor did they have a clear definition of the responsibilities of each party (architects, building promoters and

<sup>88</sup> ICLEI. (2014). "Barcelona, Spain: using solar energy - supporting community energy self sufficiency." Local Governments for Sustainability. [http://carbonn.org/uploads/tx\\_carbonndata/ICLEI\\_cs\\_173\\_Barcelona\\_UrbanLEDS\\_2014\(4\).pdf](http://carbonn.org/uploads/tx_carbonndata/ICLEI_cs_173_Barcelona_UrbanLEDS_2014(4).pdf)

<sup>89</sup> Procuraplus. (x). "Adjuntament de Barcelona." Procura+ - European Sustainable Procurement Network. <http://www.procuraplus.org/en/participants/spain-ajuntament-de-barcelona/>

<sup>90</sup> Procuraplus. (x). <http://www.procuraplus.org/en/participants/spain-ajuntament-de-barcelona/>

<sup>91</sup> Polis. (2010). "Barcelona solar thermal ordinance." Polis Solar. [http://www.polis-solar.eu/IMG/pdf/BARCELONA\\_SOLAR\\_THERMAL\\_ORDINANCE.pdf](http://www.polis-solar.eu/IMG/pdf/BARCELONA_SOLAR_THERMAL_ORDINANCE.pdf)

users). This situation demanded a period of discussion concerning stakeholder roles and a pilot project to be implemented.<sup>92</sup>

The installation contractors were not prepared for the level of demand for their services, leading Barcelona Energy Agency and the Federation of Builders to introduce and run specific training courses in solar energy to build specific capacity to builders. Also, initially the maintenance of the solar thermal installations was not guaranteed, and only after the Ordinance Reform of 2006 did quality certification for solar thermal installations and maintenance contract became mandatory.<sup>93</sup> The Barcelona Energy Agency is preparing a new text of the Ordinance with a lower threshold of application and the Barcelona Solar Energy Bureau has been formed with all the stakeholders involved in the application of the rules and the implementation of solar energy in general represented in the Bureau.

Its implementation was an important learning process for policymakers, as well as architects and building engineers, who gained practical experience with solar thermal technology.<sup>94</sup>

### PROGRAM DESCRIPTION

The ordinance required that new and old buildings on refurbishment using more than 0.8 MW per day for hot water production, change 60% of their demand to solar thermal collectors. The ordinance also subsidized those buildings too small to be subject to compliance, and required that 100% of energy to heat swimming pools be generated from SHW.<sup>95</sup>

In February 2006, the Ordinance reform

eliminated the 0.8 MW per day minimum requirement and incorporated all the standards established in the new National Building Code implemented in Spain, not only to simplify the legal process and incorporate mandatory maintenance regulations for the solar systems but also to integrate the solar systems in the architectural design.<sup>96</sup>

In the beginning, architects and building promoters feared that building prices would increase as a result of the new ordinance. However, it turned out that the extra cost for solar thermal installations was relatively modest, around 0.5 to 1 percent of total building costs.<sup>97</sup>

### PROGRAM EFFECTIVENESS

In 2005, Barcelona eliminated size requirement of households so that the ordinance would apply to all construction regardless of size or intended use. Over 70 municipalities and cities throughout Spain including 39 in Catalonia, Seville, Madrid, and Pamplona have since enacted similar ordinances.<sup>98</sup> Now, about 30 to 70% of hot water energy must meet Solar Hot Water Ordinance although it is dependent on consumption levels, how the building is situated, and how much energy is available based on the location, as well as the availability of backup fuel.

The overall energy efficiency of the program included over 25,000 MWh/year saved. The amount of energy produced is equivalent to domestic hot water demand of a population of 45,000 people and has increased over 20 times the surface of solar thermal square meters in Barcelona from 1.1 sqm per 1,000 inhabitants in 2000 to 19

---

<sup>92</sup> CCAP. (2013). "The solar thermal ordinance for efficient water heating in Barcelona, Spain." Center for Clean Air Policy. [http://ccap.org/assets/CCAP-Booklet\\_Spain.pdf](http://ccap.org/assets/CCAP-Booklet_Spain.pdf)

<sup>93</sup> CCAP. (2013). [http://ccap.org/assets/CCAP-Booklet\\_Spain.pdf](http://ccap.org/assets/CCAP-Booklet_Spain.pdf)

<sup>94</sup> CCAP. (2013). [http://ccap.org/assets/CCAP-Booklet\\_Spain.pdf](http://ccap.org/assets/CCAP-Booklet_Spain.pdf)

<sup>95</sup> C40. (2011). "Barcelona's solar hot water ordinance." C40 Cities. [http://www.c40.org/case\\_studies/barcelonas-solar-hot-water-ordinance](http://www.c40.org/case_studies/barcelonas-solar-hot-water-ordinance)

<sup>96</sup> C40. (2011). [http://www.c40.org/case\\_studies/barcelonas-solar-hot-water-ordinance](http://www.c40.org/case_studies/barcelonas-solar-hot-water-ordinance)

<sup>97</sup> CCAP. (2013). [http://ccap.org/assets/CCAP-Booklet\\_Spain.pdf](http://ccap.org/assets/CCAP-Booklet_Spain.pdf)

<sup>98</sup> C40. (2011). [http://www.c40.org/case\\_studies/barcelonas-solar-hot-water-ordinance](http://www.c40.org/case_studies/barcelonas-solar-hot-water-ordinance)

sqm per 1,000 inhabitants by March 2005.<sup>99</sup> Licenses requested for solar panel installations also increased from about 1,650 sqm in 2000 to 31,000 sqm in 2005. 20% of total solar thermal capacity area that has been approved for buildings has been installed and operates. In the period between 2002 and 2010, the solar thermal energy production reached 70,121-megawatt hours per year, enough to cover domestic hot water demand for 171,000 inhabitants.<sup>100</sup> Significantly, the solar thermal system allows for savings of 12,329 tons of carbon dioxide per year.

By surface area, the majority of the solar thermal installations were installed in residential buildings (69 percent), with much of the remainder in hotels, sports centers, and health care facilities.<sup>101</sup>

Solar thermal energy became the most widely used renewable energy, accounting for 52 percent of total renewable production in 2008 (compared to 6.9 percent in 1999) and 0.29 percent of total energy production. Between 1999 and 2008 because of the Solar Thermal Ordinance implementation, greenhouse gas emissions in Barcelona were reduced from 4,737,300 tons (3.15 tons per inhabitant per year) to 4,053,766 tons (2.51 tons per inhabitant per year).<sup>102</sup>

## PROGRAM COST

Installation of solar thermal in buildings was estimated at 0.5 to 1 percent of total construction

costs. The Institute for Energy Diversification which is a public business entity under the State Secretariat for Energy of the Spanish Ministry of Industry, Energy and Tourism as well as Instituto de Credito Oficial which is a state-owned corporate body attached to the Ministry of Economic Affairs and Competitiveness, provided interest-free credit arrangements for solar thermal installations, covering 70% of the total investment.<sup>103</sup> Costs of mandatory installation of solar thermal heaters under the ordinance are carried by the private sector. To limit the costs, Barcelona offers a housing tax incentive for voluntary solar installations, which is regulated by the Municipal Fiscal Ordinance. This incentive provides a 50 percent tax reduction for four years after installation. In 2006, nearly half of the overall budget of 50,000,000 € (\$57,343,114) subsidies for renewable energy systems was allocated to solar thermal projects. The maximum subsidy was fixed at 37% of the investment costs, equivalent to approximately 260 € to 300 € (\$298 to \$344) per m<sup>2</sup> collector area.<sup>104</sup> Financing of municipal solar thermal installations have been carried out by Barcelona City Council with a municipal budget of about 2,295,881,000 € (\$2,633,026,648).<sup>105</sup> The Barcelona model was replicable to other cities and several financial benefits have since been offered by regional governments and local authorities in Spain, such as tax waivers for property developments that incorporate renewable energy.<sup>106</sup>

---

<sup>99</sup> C40. (2011).

[http://www.c40.org/case\\_studies/barcelonas-solar-hot-water-ordinance](http://www.c40.org/case_studies/barcelonas-solar-hot-water-ordinance)

<sup>100</sup> C40. (2011).

[http://www.c40.org/case\\_studies/barcelonas-solar-hot-water-ordinance](http://www.c40.org/case_studies/barcelonas-solar-hot-water-ordinance)

<sup>101</sup> CCAP. (2013). [http://ccap.org/assets/CCAP-Booklet\\_Spain.pdf](http://ccap.org/assets/CCAP-Booklet_Spain.pdf)

<sup>102</sup> CCAP. (2013).

<sup>103</sup> CCAP. (2013).

<sup>104</sup> Peters, C. (2013). "Solar thermal legislation on municipal, regional and national level in Spain: success and remaining barriers." Institut Catala d'Energia.

<http://www.solarthermalworld.org/sites/gstec/files/legislation%20spain.pdf>

<sup>105</sup> ICLEI. (2014).

[http://carbonn.org/uploads/tx\\_carbonndata/ICLEI\\_cs\\_173\\_Barcelona\\_UrbanLEDS\\_2014\(4\).pdf](http://carbonn.org/uploads/tx_carbonndata/ICLEI_cs_173_Barcelona_UrbanLEDS_2014(4).pdf)

<sup>106</sup> C40. (2011).

## RESULTS AND LESSONS LEARNED

Barcelona Energy Agency states, “Since its first adoption, we experienced a qualitative conceptual change as the solar thermal installation is not anymore perceived as an obligation, but rather as a guaranteed right: a norm that guarantees the right to be supplied with solar energy”. To make sure that the program has been useful, people must be aware of how to use solar panels and maintain them. Barcelona Energy Agency has implemented an education campaign, Porta Porta, in coordination with Neighborhood Association and Building owners to make sure that residents and the public measure how much energy they are saving, while making sure the installation of solar panels has also been a success. Barcelona Energy Agency has also provided an information hub that is open 6 days a week to provide the public with solar use and maintenance information.<sup>107</sup>

In order to implement such a program there were some challenges along the way. These included lack of subsidies or financial incentives, the complex nature of bureaucratic procedures, and lack of experience and expertise for the involved parties. Initial implementation of the project was difficult as installers, architects, building engineers, and decision-makers were not fully trained or practiced yet in this construction and solar systems were planned later along stages which would result in increased costs since there was a lack of familiarity with the technology as well. With commitment of all parties, this enforced a decreased reliance on fossil fuels and reduction of CO<sub>2</sub> emissions while also creating jobs. There is room for improvement with respect to financial incentives and providing building owners with information with respect to bureaucratic procedures.

Moreover, Barcelona’s solar thermal model has contributed to popularizing the use of solar thermal energy within and outside of the city. As of December 2010, 87,600 square-meters of solar thermal panels were installed which had almost reached the Barcelona Energy Improvement Plan goal of an installed 88,015 square-meters of solar thermal panels.<sup>108</sup> Barcelona’s Solar Thermal Ordinance therefore is replicable as it has been a model for other municipalities especially in Catalonia, which has adopted similar and sometimes more stringent local regulations as well as several financial benefits offered by regional governments and local authorities in Spain, such as tax waivers for property developments that incorporate renewable energy. Countries such as Israel, which has had the oldest solar obligation, Germany, Italy, Ireland, and Portugal for instance have already implemented such solar thermal systems.<sup>109</sup>

---

<sup>107</sup> C40. (2011). [http://www.c40.org/case\\_studies/barcelonas-solar-hot-water-ordinance](http://www.c40.org/case_studies/barcelonas-solar-hot-water-ordinance)

<sup>108</sup> CCAP. (2013). [http://ccap.org/assets/CCAP-Booklet\\_Spain.pdf](http://ccap.org/assets/CCAP-Booklet_Spain.pdf)

<sup>109</sup> [www.estif.org/fileadmin/estif/content/.../ProSTO%20Blueprint%20EN.pdf](http://www.estif.org/fileadmin/estif/content/.../ProSTO%20Blueprint%20EN.pdf)

## BACKGROUND

The city of Rizhao, China has a population of approximately 3 million people. Rizhao is located along the coast of the Shandong province.<sup>110</sup> The city's residents have a below average (in terms of surrounding areas) mean income.<sup>3</sup> Many cities and areas in China have poor air quality due to the country's robust consumption of fossil fuels, especially coal. As a result of the poor air quality associated with many Chinese cities, cities such as Rizhao have looked for ways to improve their local environmental conditions and stand out as environmental leaders. China overall has aimed to meet 15% of its energy requirements through renewables by 2020.<sup>2</sup>

## RIZHAO (China)

**Program: SolarCity**

Population: 1,148,000 (2000)



## PROGRAM DESCRIPTION

The Rizhao “SolarCity” program makes use of solar for energy, heating, and lighting. This is accomplished through subsidies, political will and policy, and attracting investment and opportunity for innovation. 99% of Rizhao’s central district households use solar water heaters, with roughly 30% of suburban households following suit.<sup>111</sup> Local policy makers have been determined to ensure that the program succeeds to improve local quality of life and attract further investment toward the city. The provincial government worked closely with the local solar power manufacturers to ensure mutual benefits,

subsidizing the solar panels and providing funds for research and development.<sup>2</sup>

Poor air quality in many areas of China, as well as deteriorating environmental conditions, make the transfer from coal to renewables beneficial for the country’s population. Rizhao shows promising efforts to realistically decrease the amount of coal that needs to be burned.<sup>112</sup>

## PROGRAM IMPLEMENTATION

The most crucial elements in bringing about this program were incorporating solar technology into everyday life in Rizhao, and making the option

<sup>110</sup> DAC. (2014). “Rizhao: mainstreaming solar energy on city level.” Danish Architecture Center. <http://www.dac.dk/en/dac-cities/sustainable-cities/all-cases/energy/rizhao-mainstreaming-solar-energy-on-city-level/>

<sup>111</sup> DAC. (2014). “Rizhao: mainstreaming solar energy on city level.” Danish Architecture Center. <http://www.dac.dk/en/dac-cities/sustainable-cities/all-cases/energy/rizhao-mainstreaming-solar-energy-on-city-level/>

<sup>112</sup> DAC. (2014). “Rizhao: mainstreaming solar energy on city level.” Danish Architecture Center. <http://www.dac.dk/en/dac-cities/sustainable-cities/all-cases/energy/rizhao-mainstreaming-solar-energy-on-city-level/>

affordable for the public. This was accomplished by funding solar research and development, subsidizing solar technology so that it was priced similarly to its fossil fuel counterparts, and creating legislation that mandates new buildings to have solar arrays. Approximately 2.2 billion US dollars were invested through the private sector and the provincial government in order to subsidize the solar panels and fund the program.<sup>4</sup> Further, local governance encouraged the city's residents to attend seminars relating to solar technology and placed public advertising for solar tech on television networks, thus creating solar technology awareness and education initiatives.<sup>2</sup>

The program has been in place since 1992, continually gaining momentum over time. Changes in city legislation that mandated solar arrays as well as the increased educational awareness campaign have led the city to be among the best air quality cities in China.<sup>3</sup> In recent years, Rizhao has been listed as one of the ten best air quality cities in China, receiving international awards including the World Clean Energy Award in 2007 and the UN-Habitat Scroll of Honour Award in 2009. Every year recently, Rizhao has been listed among the ten best cities in China for air quality, and it has received numerous international awards including the World Clean Energy Award in 2007 and the UN-Habitat Scroll of Honour Award in 2009.<sup>4</sup>

The major strategy used to prevent implementation issues was in the policy makers ensuring familiarity with their population. Understanding that the area was relatively poor (in the context of surrounding areas) the policy makers subsidized the producers to ensure a more efficient and lower costing end product, rather than trying to subsidize end users for a less efficient and more expensive product.<sup>3</sup> The end result was a \$190 unit that reduced user cost by \$120 per year.<sup>5</sup>

### **PROGRAM EFFECTIVENESS**

The program has been widely successful, indicated by the 99% of homeowners who use solar water heaters. The project has also been linked to increases in tourism to the area, as well as increasing outside investment. Residents also benefit by saving money over the duration of their solar heater's life and reducing local emissions which can lead to negative health and environmental impacts.<sup>3</sup> In 2007, the half million square meters of solar panels within Rizhao reduced the equivalent of 100,000 tons of coal from being burned that year.<sup>5</sup> That number continues to grow alongside the program. Conservatively, the reduction in coal would lead to approximately 175,000 fewer tons of CO<sub>2</sub> entering the atmosphere per year (as well as other greenhouse gases), based off of the assumption that the coal is bituminous.<sup>6</sup>

## RESULTS AND LESSONS LEARNED

The promotion of solar technology, while not necessarily universally feasible, has been shown in this case to be extremely productive and likely replicable and scalable. Proper strategy and will from the local government ensured the success of this program, with aims at cutting costs as much as possible in order to lead to higher overall returns. By investing in developing the solar technology, the local government helped gain an affordable product that benefits the producer, consumers, and overall environmental health. Mandating the use of solar technology in new buildings also helped make this program successful and relevant as time progressed. The city's economy has grown with the resultant increase in foreign investment, leading to better living conditions for the people of the city.<sup>4</sup> Other cities or areas can seek to make similar impacts by assessing their capacity for solar technology or other renewables, promoting technologies that can lower user costs in the long run. Improving these technologies on the production end can also be highly impactful by resulting in lowering users' upfront costs, which can often be burdensome for renewable and efficient technologies. Educational initiatives, such as those used to detail the benefits of solar water heaters in Rizhao, should also be employed to inform the populace of the individual and collective benefits of renewable technologies and how greenhouse gas reductions can positively impact their lives.<sup>113 114 115 116 117 118 119</sup>

---

<sup>113</sup> DAC. (2014). "Rizhao: mainstreaming solar energy on city level." Danish Architecture Center. <http://www.dac.dk/en/dac-cities/sustainable-cities/all-cases/energy/rizhao-mainstreaming-solar-energy-on-city-level/>

<sup>114</sup> AREA. (2016). "Sustainable cities - case study Rizhao." African Renewable Energy Alliance. [http://area-net.org/wp-content/uploads/2016/01/WFC\\_Case-Study\\_China-Rizhao.pdf](http://area-net.org/wp-content/uploads/2016/01/WFC_Case-Study_China-Rizhao.pdf)

<sup>115</sup> Bai, X. (2007). "China's solar-powered city." Renewable Energy World. <http://www.renewableenergyworld.com/articles/2007/05/chinas-solar-powered-city-48605.html>

<sup>116</sup> WWF. (2012). "Rizhao solar water heating." World Wide Fund for Nature. [http://wwf.panda.org/wwf\\_news/?204452/Rizhao-solar-water-heating](http://wwf.panda.org/wwf_news/?204452/Rizhao-solar-water-heating)

<sup>117</sup> The Climate Group. (2010). "China clean revolution report III: low carbon development in cities." The Climate Group. [http://www.theclimategroup.org/\\_assets/files/China-Clean-Revolution-III.pdf](http://www.theclimategroup.org/_assets/files/China-Clean-Revolution-III.pdf)

<sup>118</sup> Martinot, E. and Junfeng, L. (2011). "Powering China's development - the role of renewable energy." Worldwatch Institute. [http://www.worldwatch.org/files/pdf/Powering\\_China%27s\\_Development.pdf](http://www.worldwatch.org/files/pdf/Powering_China%27s_Development.pdf)

<sup>119</sup> <https://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11>

# Appendix C: Case Studies - Financing Green Urban Infrastructure

## BACKGROUND

Stockholm, Sweden has a population of just under 900,000 residents with a density of 12,000 people per square mile, and 40% of the residents are between the ages of 20 and 44.<sup>120</sup> Over a quarter of the residents are either immigrants or non-Swedish with 15% being foreign-born, and the population is projected to grow to 3 million residents by 2045 due mainly to immigration from central Eurasia.<sup>121</sup> The city is governed by assembly, elected every four years, and has an executive council that implements policies in tandem with county councils. Politically, the Swedish government operates through coalition building with a multi-party system that ultimately has led to environmentally sympathetic policy decisions from both the liberal and conservative sides.

## STOCKHOLM (Sweden)

### Program: Hammarby Sjöstad Sustainable City

Population: 897,000 (2014)



## PROGRAM DESCRIPTION

Hammarby Sjöstad is a former industrial site that was redeveloped through a public-private partnership as an initiative to demonstrate the viability of an environmentally sustainable city. The city began construction in 1999 and is expected to finish in 2017.<sup>122</sup> Program funding

originated with a national subsidy to promote an ecologically sustainable society, called the Local Investment Program, from which Stockholm received \$82m including \$24m for Hammarby Sjöstad.<sup>123</sup> The site on which Hammarby Sjöstad stands is a former brownfield location, but had fewer abandoned properties compared to other

<sup>120</sup> <http://worldpopulationreview.com/world-cities/stockholm-population/>

<sup>121</sup> Ibid

<sup>122</sup> ITDP Europe (2014) "Hammarby Sjöstad" [https://www.itdp.org/wp-content/uploads/2014/07/20-092211\\_ITDP\\_NED\\_Hammarby.pdf](https://www.itdp.org/wp-content/uploads/2014/07/20-092211_ITDP_NED_Hammarby.pdf)

<sup>123</sup> CP 249 Urban Design Planning 2007 <http://www.aeg7.com/assets/publications/hammarby%20sjostad.pdf>

European brownfield locations.<sup>124</sup> However, given the heavily industrial use in such close proximity to city center, there was broad support for residential redevelopment and contaminant remediation. Originally the redesign of this area was intended as a site for the Olympic Village, supporting Sweden's bid to host the Olympic games in 2004. After that fell through, the area was still redeveloped.<sup>125</sup>

The program is an urban development project with funding from the City of Stockholm, Stockholm Transport, National Road Administration, as well as private investments.<sup>126</sup> This is a pilot program run by the city of Stockholm primarily to promote innovative technologies and test systems for commercial acceptance.<sup>127</sup> The entire neighborhood was designed to integrate disparate infrastructure systems in order to reduce waste and pollution

impacts, including greenhouse gases.<sup>128</sup> There are several key program elements that affect greenhouse gas impact, such as incorporation of renewable energy sources and integration of transportation networks to reduce carbon-based energy consumption.<sup>129</sup> Average building energy use is 113 kWh/m<sup>2</sup>/year compared to the national average of 200 kWh/m<sup>2</sup>/year, with 50% of energy produced from renewable sources.<sup>130</sup> Furthermore, there is only one parking space per two households and every residence is within 300m of a light tram station, vastly improving greenhouse gas emissions from the transportation sector.<sup>131</sup> As a result of this unique design, 80% of individual trips are made using either public transportation, walking, or biking.<sup>132</sup> Overall, Hammarby Sjöstad is projected to demonstrate a 30% reduction in carbon dioxide equivalents compared to typical city emissions.<sup>133</sup>

## PROGRAM COST

The city government was responsible for land ownership and master planning. Financing was sourced from construction companies, as well as from expansion of the area through land sales to both public and private



developers, with operational costs covered through taxation (municipal tax rates around Stockholm are near 18%).<sup>134</sup> The county government was responsible for developing the tram line, which was funded through taxation and ticket revenues (ticket prices

---

<sup>124</sup> Vestbro, Dick Urban (2011) "Conflicting Perspectives in the Development of Hammarby Sjöstad, Stockholm" [[https://www.researchgate.net/publication/265982250\\_Conflicting\\_perspectives\\_in\\_the\\_development\\_of\\_Hammarby\\_Sjostad\\_Stockholm](https://www.researchgate.net/publication/265982250_Conflicting_perspectives_in_the_development_of_Hammarby_Sjostad_Stockholm)]

<sup>125</sup> SWECO & Energy Innovation (2015) "An Urban Development Case Study of Hammarby Sjöstad in Sweden, Stockholm" <http://energyinnovation.org/wp-content/uploads/2015/12/Hammarby-Sjostad.pdf>

<sup>126</sup> CP 249 Urban Design Planning 2007 <http://www.aeg7.com/assets/publications/hammarby%20sjostad.pdf>

<sup>127</sup> Ibid

<sup>128</sup> Ibid

<sup>129</sup> Ibid

<sup>130</sup> SWECO & Energy Innovation (2015) "An Urban Development Case Study of Hammarby Sjöstad in Sweden, Stockholm" <http://energyinnovation.org/wp-content/uploads/2015/12/Hammarby-Sjostad.pdf>

<sup>131</sup> Ibid

<sup>132</sup> ITDP Europe (2014) "Hammarby Sjöstad" [https://www.itdp.org/wp-content/uploads/2014/07/20.-092211\\_ITDP\\_NED\\_Hammarby.pdf](https://www.itdp.org/wp-content/uploads/2014/07/20.-092211_ITDP_NED_Hammarby.pdf)

<sup>133</sup> SWECO & Energy Innovation (2015) "An Urban Development Case Study of Hammarby Sjöstad in Sweden, Stockholm" <http://energyinnovation.org/wp-content/uploads/2015/12/Hammarby-Sjostad.pdf>

<sup>134</sup> Ibid

for the train run between \$3-9).<sup>135</sup> Government infrastructure companies owned management and operation of utility services, which was expanded through facility fees paid by project developers, with operational costs covered by charging property owners. Developers were responsible for financing the building and development of residential and commercial properties, which were then leased or sold to individual residents.<sup>136</sup>

The total investment is estimated to be \$693m, with the Swedish government contributing \$24m through LIP,<sup>137</sup> but 80% of overall costs being shared among 25 construction companies.<sup>138</sup> The funding was primarily used for energy efficiency and renewable energy projects (9% and 26% respectively), with waste handling projects utilizing a combined 21% (11% on waste projects, 10% on waste and sewage projects) of funding. Traffic projects accounted for 10% of funding.<sup>139</sup>

## PROGRAM IMPLEMENTATION

The city role was minimized, with Stockholm determining purchase price and access for land area to the developers, as well as dictating approximate overall plans for the developers. The city also paid for the relocation of existing pipes that needed to be moved. Developers were then responsible for everything else, including construction costs, waste and water management systems, and quality of open spaces and overall design.<sup>140</sup> The project was met with public support due to the reallocation of central city land from contaminated and industrial to revenue generating

and residential.

There were some problems that arose. Efficiency did not always align with living preferences, for example living on a water body would increase heating costs in cold times.<sup>141</sup> Also, the parking space cap is controversial, and was raised from an initial goal of one space per four residences to three spaces per four residences. Lastly, there was not a solid data collection system put into place so it is difficult for the neighborhood to track overall environmental impact.<sup>142</sup>

## PROGRAM EFFECTIVENESS

Key performance indicators are total greenhouse gas emissions, which by all interpretations have been effectively reduced in this project. Through the utilization of renewable energy and increased efficiency, carbon dioxide equivalents were reduced by a significant amount (30%). Furthermore, the neighborhood is connected to the city at large in a sustainable way, with easy access to mass transit and innovative waste disposal systems that reduce heavy vehicle traffic within the area. Additionally, housing price and vacant units are important to consider when contemplating scalability because they are measures of whether promoting sustainable living situations adversely affects livability. In this sense, the program was also successful because a contaminated brownfield site is less valuable than a cleaned up residential area.

---

<sup>135</sup> <http://sl.se/en/fares--tickets/>

<sup>136</sup> SWECO & Energy Innovation (2015) "An Urban Development Case Study of Hammarby Sjostad in Sweden, Stockholm" <http://energyinnovation.org/wp-content/uploads/2015/12/Hammarby-Sjostad.pdf>

<sup>137</sup> CP 249 Urban Design Planning 2007 [http://www.aeg7.com/assets/publications/hammarby%](http://www.aeg7.com/assets/publications/hammarby%20CP%20249%20Urban%20Design%20Planning%202007.pdf)

<sup>138</sup> SymbioCity (2015) "Making an Entire Sustainable Urban District" <http://www.symbiocity.org/en/approach/Cases-undersidor/Hammarby-Sjostad-three-in-one/>

<sup>139</sup> SWECO & Energy Innovation (2015) "An Urban Development Case Study of Hammarby Sjostad in Sweden, Stockholm" <http://energyinnovation.org/wp-content/uploads/2015/12/Hammarby-Sjostad.pdf>

<sup>140</sup> Ibid

<sup>141</sup> Ibid

<sup>142</sup> Ibid

## RESULTS AND LESSONS LEARNED

This program is certainly replicable; however, it should be noted that Stockholm is a very progressive city in the sustainability field. Other progressive cities could learn from this project by identifying underutilized areas that are close to urban centers of economic activity. These areas could be brownfield sites that are not used for residential purposes due to contamination, or simply underdeveloped post-industrial warehouse areas or factory spaces. The lessons to be drawn from Hammarby Sjöstad is that when redeveloping these areas, it is feasible and productive to plan new neighborhoods in sustainable ways. Though not all cities will have access to federal funding, this program demonstrates that city policy can be used to encourage and foster private investment to compensate for missing funds. Furthermore, Stockholm's role was primarily to facilitate land acquisition and because the site was a former brownfield location this was a mutually beneficial arrangement.

Many cities have areas that have been contaminated by industrial activity, so through government encouragement and facilitation the city managed to not only create an economically active center where there was no longer any money being generated, but also cleaned up a highly contaminated site. In the United States and Europe, there are hundreds of sites just like this one that are often in close proximity to cities because of the relationship between manufacturing and distribution. Based on the model set by Hammarby Sjöstad, with proper municipal support and coaxing there is much opportunity for sustainable and environmentally beneficial redevelopment into profitable commercial and residential centers.

## BACKGROUND

Singapore is a rapidly growing city, with over 5.5 million residents and a growth rate of almost 2% per year. Furthermore, 80% of the country is under the age of 55 with 30% under the age of 25,<sup>143</sup> so the city can be expected to continue growing as young people have families of their own. The city has a population density of over 10,000 people per square kilometer,<sup>144</sup> ranking 218th globally. Politically, Singapore is unusual in that it is both a city and a state. This leads to more political autonomy for Singapore compared to other cities that are embedded within national political structures. Policy decisions are made by a cabinet, whose members are selected by the President at the recommendation of the Prime Minister (who is also appointed by the President). Singapore is a former British colony, and has modeled their political structure off the British Parliamentary system.<sup>145</sup>

## SINGAPORE

### Program: SingSpring Desalination Plant

Population: 5,399,000 (2013)



## PROGRAM DESCRIPTION

Given the growing population, Singapore has struggled to meet demand for freshwater especially as an island without local lakes or rivers.

Historically, Singapore has relied on water imports from Malaysia and a system of reservoirs to retain rainwater.<sup>146</sup> Over the last two decades, they have built and planned a series of seawater desalination

<sup>143</sup> Index Mundi (2014). "Singapore demographics profile 2014." Index Mundi.

[http://www.indexmundi.com/singapore/demographics\\_profile.html](http://www.indexmundi.com/singapore/demographics_profile.html)

<sup>144</sup> Demographia (2015). "Demographia world urban areas." Demographia. <http://www.demographia.com/db-worldua.pdf>

<sup>145</sup> <http://app.singapore.sg/about-singapore/government>

<sup>146</sup> LEGCO (2015). "Seawater desalination in Singapore." Legislative Council Secretariat. <http://www.legco.gov.hk/research-publications/english/1415fs09-seawater-desalination-in-singapore-20150930-e.pdf>

plants to reduce dependence on foreign water. However, desalination is a very energy intensive and, therefore, the filtration of saltwater can produce greenhouse gas emissions.

In order to meet growing demand for freshwater, the Singapore Public Utilities Board developed a strategy in 2002 called Four National Taps with the third and fourth taps referring to reclaimed and desalinated water. The SingSpring Desalination Plant was created in 2003 and completed in 2005 using space from the industrial district of Tuas, with a 20-year design-build-own-operate contract split between two private companies.<sup>147</sup> This one plant aims to provide 10% of national water demand (110,000 cubic meters/day) at a rate of USD\$0.57/m<sup>3</sup> to remain competitively priced with water imports. Furthermore, the plant aimed to maintain low water prices by utilizing energy efficient production methods to minimize fuel cost and includes submerged discharge to minimize environmental damage from waste brine.<sup>148</sup>

Upon opening, the plant produced freshwater at a rate of USD\$0.35/m<sup>3</sup> with the savings primarily coming from energy efficiency.<sup>149</sup> The plant was established through a government contract with a private agency (SingSpring Pte Ltd, subsidiary of HyFlux an international company), with the private group responsible for financial arrangements. Their contract with Singapore PUB runs from 2005-2025 with rates adjusted for inflation and fuel prices starting from the original price of USD\$0.57/m<sup>3</sup>. After the completion of the first plant, a second plant commenced operation in 2013 and there are plans for more plants to accommodate a water demand expected to double by 2060.<sup>150</sup>

---

<sup>147</sup> <http://www.water-technology.net/projects/tuas-seawater-desalination/>

<sup>148</sup> Ibid

<sup>149</sup> Ibid

<sup>150</sup> LEGCO (2015). "Seawater desalination in Singapore." Legislative Council Secretariat. <http://www.legco.gov.hk/research->

## PROGRAM COST

The SingSpring plant had an overall budget of USD\$147m, with USD\$26m coming from HyFlux equity and the remaining USD\$125m coming from private equity groups such as international banks. Of the borrowed money, USD\$116m came from a senior debt facility and USD\$5m came from an associated contingency facility who would cover up to 70% in cost overrun.<sup>151</sup> Loan syndication was facilitated by the Development Bank of Singapore, who arranged three other banks (Standard Chartered, KBC, and ING Bank) in a limited recourse arrangement, where repayment is provided by the buyers of water (Public Utilities Board).<sup>152</sup> The loan was structured for 18 years, the first time Singapore has taken part in a loan of this length. Hyflux contributed 70% equity, and are a leading domestic company with a dependable reputation in the water industry.

While it is unclear what the overall operational costs are, one of the main costs is energy use as shown by water rates that include adjustments for fuel prices and those will be covered by the operating company (SingSpring Ptd Lte.).

## PROGRAM IMPLEMENTATION

The Singapore government held a competitive bidding process that featured three other bidders in addition to the winning SingSpring group.<sup>153</sup> The selection process took 18 months, and included pre-qualification, tender, and tender evaluation in an attempt to be transparent. Singapore government assisted in timely issuance of permits and other consents, land access, and a minimum purchase of water, as well as agreed to make capacity payments in the event of a

publications/english/1415fs09-seawater-desalination-in-singapore-20150930-e.pdf

<sup>151</sup> <http://www.water-technology.net/projects/tuas-seawater-desalination/>

<sup>152</sup> CECI (2011) "Financing and Case Study of Singapore PPP Desalination Project"

<http://www.ceci.org.tw/book/90/web/114-125.pdf>

<sup>153</sup> Ibid

restructuring of monetary law or regulations. Additionally, SingSpring engaged in fuel swaps to mitigate fluctuating energy prices and maintain consistent costs.

There have not been issues with implementation that have been popularized, and in fact freshwater prices from this plant have been lower than expected. However, given the political reputation of Singapore and its approach to dissent the validity of these claims merit further research.

## **PROGRAM EFFECTIVENESS**

Key indicators of performance include two key components - water price and energy demand. A low price of water assures feasibility of this model of freshwater provision, and a low energy demand (in conjunction with renewable energy sources) provide an indication of greenhouse gas emission reductions. Tangentially, water quality (both intake and discharge) are also important, but they speak more to ecological status than greenhouse gas emissions and while important to consider are beyond the scope of this research.

## **RESULTS AND LESSONS LEARNED**

The program is certainly replicable given access to seawater and energy, in particular places such as California and Texas in the United States or areas in the Middle East, Australia, Coastal Africa, or the Mediterranean. A desalination plant powered by renewable and non-carbon emitting fuels (tidal, wind, and solar in particular) would address growing freshwater demand in growing urban areas. This water could then be used for agricultural and industrial use, reducing greenhouse gas emissions from transporting these goods from further distances. Furthermore, given that Singapore has opened a second plant with plans for two more, the support system appears to be effective. City governments can play a role that facilitates finance if they don't want to be the main providers of capital access, and can adjust policies and provide guaranteed consumer support to foster new projects.

## BACKGROUND

Portland, Oregon, a city of just over 609,000 people, is known as a biking town with 5.9% of its commuters traveling by bike, the largest percentage in the nation.<sup>154</sup> The City of Portland has had great success in creating popular mass transit and bike paths due to some key decisions beginning in the late 1960's.<sup>155</sup> These decisions included changed ownership of the transit company in 1969, a bicycle plan that was rolled out in 1973, and the Airport MAX line, completed in 2001. The city has a rich history of success in promoting mass transit and bicycling, and it has shown through the Portland-Milwaukie Light Rail Transit Project that it is committed to both sustainability and to promoting alternative modes of transportation.

Completed in September 2015, the Portland-Milwaukie Light Rail Transit Project (PMLR) was proposed as a 7.3 mile extension of the transit system, expanding upon the existing orange line to connect the South Waterfront district, an ex-shipyard turned modern condo development and university campus, and the Central Eastside, which is undergoing rezoning.<sup>156</sup> Projections show an increase of 22,000 homes and 85,000 employees to the region by 2030, which would add ridership to the existing bus system, and increase traffic congestion.<sup>157</sup> Development of these two districts presented an economic need to connect them with a bridge that could extend the light rail, expand bus routes, and provide a means for pedestrians and cyclists to cross.

## PORTLAND (U.S.)

### Program: Portland-Milwaukie Light Rail Transit

Population (city): 609,456 (2013)

(metropolitan region): 2,226,009 (2010)



<sup>154</sup> Sivak, M. (2015). "Commuting to work in the 30 largest U.S. cities." *University of Michigan - Transportation Research Institute*. [http://www.umich.edu/~umtriswt/PDF/UMTRI-2015-17\\_Abstract\\_English.pdf](http://www.umich.edu/~umtriswt/PDF/UMTRI-2015-17_Abstract_English.pdf)

<sup>155</sup> Emergy, J. (2012). "Turning away from the automobile 1969-2012." *PDXPlanning*. <http://pdxplanning.weebly.com/a-pedestrian-priority.html>

<sup>156</sup> Libby, B. (2015). The Bridge that Bans Cars. *The Atlantic*. Retrieved from <http://www.theatlantic.com/magazine/archive/2015/10/the-bridge-that-bans-cars/403234/>

<sup>157</sup> Tri-County Metropolitan Transportation District of Oregon. (2010). "Portland-Milwaukie Light Rail Project Final Environmental Impact Statement". Portland, OR.

## PROGRAM DESCRIPTION

The 7.3-mile extension of the orange line in Portland includes flowers and evergreen plants lining 4,204 square feet of track. Aside from being aesthetically pleasing, the eco-track also reduces train noise and vibration. Green roofs cover eight structures along the orange line, intended to absorb stormwater, lower urban temperatures, and filter pollutants out of the air. Additionally, a joint effort between TriMet, Department of Transportation, Urban Green, and Oregon Metro produced a sustainable, net-zero energy garage that collects and treats stormwater with its on-site solar panels. Along the line, platform shelters are roofed with solar panels, bioswales and rain gardens are prevalent, and the line makes use of regenerative energy storage, a system that captures braking energy and distributes it to other trains for acceleration or uphill climbs. Finally, this project produced Tilikum Crossing, a suspension bridge that will carry people, bikes, buses, transit cars, and emergency vehicles, but will prohibit private automobiles. As the bridge is dedicated partly to biking and walking, infrastructure improvements along the orange line reflect this commitment, with 446 new bike parking spaces, 10 miles of replaced sidewalk and 8 miles of bicycle facilities.<sup>158</sup>

## PROGRAM COST

The total cost of the Portland-Milwaukie Light Rail Transit Project was \$1.49 billion. As of one of the largest capital projects in the region in decades, and in a state without a sales tax, funding proved to be difficult. Approximately 50% of the project's funding came from a federally awarded New Starts fund, covering \$745M<sup>159</sup>. This money is granted under a competitive application process administered by the Federal Transit Authority.

The remaining \$745M was funded through a variety of state, city and regional mechanisms. \$250M came in the form of Oregon State Lottery Bonds, where the State of Oregon pledged lottery proceeds to repay the bonds. \$119.1M was raised in bonds called GARVEE (Grant Anticipation Revenue Vehicle).<sup>160</sup> Additionally, in-kind property donations were provided by various organizations who saw economic opportunity in the light rail expansion.<sup>161</sup> The remaining funds were provided by state and local funding.

## PROGRAM IMPLEMENTATION

The project began in the early 1990's through evaluating alternatives, all of which can be explored in a very thorough Environmental Impact Summary. The various options were largely a debate of how far the new train should go. The Environmental Impact Summary, submitted by TriMet and Oregon Metro won awards for its approach to public involvement, clear writing, and inclusion of climate change information.

The project faced opposition mainly from small community groups, concerned that the project would cause noise pollution, decrease safety and security in the neighborhood, and cause negative economic effects. Others were also concerned about the cost of the project, and felt that over \$1B for this expansion was a frivolous use of capital.<sup>162</sup> In the process of acquiring property, there were some particularly challenging relocations. Some condo developments disliked the project, and even one group of people refused to sign the acquisition agreement until eventually, a settlement was reached. The project displaced approximately 57 business, 11 residential structures, and 20 vacant lots.<sup>163</sup>

---

<sup>158</sup> <http://catchtheorange.com/#/sustainability>

<sup>159</sup> Tri-County Metropolitan Transportation District of Oregon. (2010). "Portland-Milwaukie Light Rail Project Final Environmental Impact Statement". Portland, OR.

<sup>160</sup> Ibid.

<sup>161</sup> Finnigan, L. (2013). The Portland-Milwaukie Light Rail Project, Connecting a Metropolitan Area Once Segment at a Time. IRWA. Retrieved from

[https://www.irwaonline.org/eweb/upload/web\\_novdec13\\_PortlandMilwaukie.pdf](https://www.irwaonline.org/eweb/upload/web_novdec13_PortlandMilwaukie.pdf)

<sup>162</sup> Tri-County Metropolitan Transportation District of Oregon. (2010). "Portland-Milwaukie Light Rail Project Final Environmental Impact Statement". Portland, OR.

<sup>163</sup> Finnigan, L. (2013). The Portland-Milwaukie Light Rail Project, Connecting a Metropolitan Area Once Segment at a Time. IRWA. Retrieved From

## PROGRAM EFFECTIVENESS

It is too soon to know the results of the transit upgrade, but it is expected to generate 22,800 average weekday riders by 2030.<sup>164</sup> According to the Final Environmental Impact Statement, under a No-Build scenario, regional CO2 emissions are 36,292 tons per day.<sup>165</sup> The light rail will reduce this figure to 36,255, which means a total reduction about 13,505 tons CO2 per year due to

the construction of this light rail. The stormwater mitigation infrastructure and the use of regenerative energy storage technology will only add to the GHG benefits of this project. Economic benefits will further reveal themselves as the newfound accessibility helps these regions continue to develop, bringing new residents, businesses, and infrastructure projects.

## RESULTS AND LESSONS LEARNED

The completion of this project was extremely reliant on the New Starts program. Without that source of 50% of the funding, TriMet would not have been able to expand their orange line. The other two main sources of funding, aside from various forms of government tax revenue, were the GARVEE bonds, and the Oregon State Lottery bonds.

---

[https://www.irwaonline.org/eweb/upload/web\\_novdec13\\_PortlandMilwaukie.pdf](https://www.irwaonline.org/eweb/upload/web_novdec13_PortlandMilwaukie.pdf)

<sup>164</sup> Tri-County Metropolitan Transportation District of Oregon. (2010). "Portland-Milwaukie Light Rail Project Final Environmental Impact Statement". Portland, OR.

<sup>165</sup> Ibid.

## BACKGROUND

Mexico City has a population of approximately 9 million residents, with a metropolitan population that exceeds 20 million,<sup>166</sup> and an urban population density of over 6,000 people per square kilometer.<sup>167</sup>

## MEXICO CITY (Mexico)

### Program: Bordo Poniente Biogas Generation Plant

Population: 8,851,000 (2010)



## PROGRAM DESCRIPTION

In 2010, Mexico City decided to close Bordo Poniente, one of their landfills, due to concerns of greenhouse gas emissions from garbage decomposition. In order to finance the closing of this plant and the required environmental measures needed to be taken, Mexico City commissioned a 25-year contract to develop a biogas energy generation plant to create electricity for city use. This plant is projected to reduce greenhouse gas emissions by 19.8m CO<sub>2</sub> equivalents (or 20% of total emissions by Mexico City Government) over the 25-year lifetime of this project.<sup>168</sup> Included in the project is a recycling and compost program, which in conjunction with compost and WTE programs, reduces landfilled waste from 12,500 tons per day of municipal solid waste (MSW) generated to only 5,500 tons per day.

This program was developed to reduce landfilling and the related greenhouse gas emissions produced by waste decomposition. In 2007, through the C40 group of cities, Bill Clinton and Michael Bloomberg identified Bordo Poniente as one of the main sources of greenhouse gas for all of Mexico City. Originally opened in 1985, the landfill was closed in 2010 through an agreement with the federal government. The closure of Bordo Poniente led to an increase in waste sorting in order to compensate for diminished landfill space. The development of this biogas energy plant mitigated some of the cost of closure. However, it has led to more truck miles being driven to deliver waste to further locations. Major tasks in delivering this program involve establishing infrastructure to separate inorganic and reclaimable waste products from compostable and combustible materials, and establishing transit

---

<sup>166</sup> UN Data (2016). "City population by sex, city and city type."

<http://data.un.org/Data.aspx?q=mexico+city&d=POP&f=tableCode%3a240%3bcountryCode%3a484>

<sup>167</sup> City Population (2016). "Mexico: Ciudad de Mexico (Distrito Federal)." <http://www.citypopulation.de/Mexico-DistritoFederal.html>

<sup>168</sup> <http://cities-today.com/how-mexico-city-has-turned-garbage-into-fuel/>

routes that maintain greenhouse gas reductions achieved from this program.

### PROGRAM COST

The program is valued at over USD\$121m, and was granted to a private consortium (BMLMX) for 25 years.<sup>169</sup> The city expects to save USD\$17m per year by purchasing cheaper biogas energy to provide electricity, saving USD\$0.05 per kilowatt-hour compared to existing utility companies. The final expenditure for closing Bordo Poniente is about US\$75mil and covers landfill closure, biogas recovery, and leachate evaporation. Construction of the power generation component is about US\$90mil. The Mexican government's development bank (BANOBRAS) provided a grant of US\$27mil<sup>170</sup> and also a loan of US\$96.6mil to cover the cost of the power plant. The loan required 30% equity and has a payback period of 4.33 years from project developers (Sistemas Eléctricos Metropolitanos – SEM) to BANOBRAS. SEM expects to pay maintenance costs of about USD \$0.02 per kilowatt-hour.

### PROGRAM IMPLEMENTATION

According to one project antagonist, the cost to replace Bordo Poniente is expected to rise to US\$1.2bil, including 17 new waste and recycling process centers.<sup>171</sup> To address this cost, the same opposition group has raised a suggestion to

develop the former landfill site as a new airport to alleviate strained passenger capacity at the main airport in Mexico City.<sup>172</sup> Furthermore, transportation costs are unclear and it is difficult to determine whether an accelerated rate of travel mitigates the cost of further distances to processing facilities. In 2012, a political transition took place from one mayoral administration to another, but that does not seem to have slowed the program.

Electricity generation in Mexico City is controlled by a state-owned entity (CFE) that owns over 75% of installed generation capacity, but allows private producers to operate within a small subcategory of energy sources - including cogeneration.<sup>173</sup> The Bordo Poniente plant used lessons learned from a previous biogas generation plant in Monterey in order to create the current strategy. The Monterey plant used fuel that contained siloxanes which reduced equipment lifetimes by 50%, therefore Bordo Poniente installed technology that removes these compounds in order to realize estimated lifetime projections.<sup>174</sup>

### PROGRAM EFFECTIVENESS

Key performance indicators for this project include electricity cost savings seen by the city as well as loan repayments to BANOBRAS. Loan

---

<sup>169</sup> Hristova, D. (2012). "Mexico City awards USD 163m biogas energy project." *See News Renewables*.

<http://renewables.seenews.com/news/mexico-city-awards-usd-163m-biogas-energy-project-313336#>

<sup>170</sup> Gutierrez Vera, J. A. (2014). "CHP project in the largest landfill in Mexico." *14th International Symposium on District Heating and Cooling*.

[http://www.svenskfjarrvarme.se/Global/Konferenser/DHC14/Proceedings/P\\_4%20Gutierrez%20Vera%20Jorge%20CHP%20PROJECT%20IN%20THE%20LARGEST%20LANDFILL%20IN%20MEXICO.pdf](http://www.svenskfjarrvarme.se/Global/Konferenser/DHC14/Proceedings/P_4%20Gutierrez%20Vera%20Jorge%20CHP%20PROJECT%20IN%20THE%20LARGEST%20LANDFILL%20IN%20MEXICO.pdf)

<sup>171</sup> Corrales, I. (2010). "Replacing Bordo Poniente to cost \$1.2bn." *BNamericas*.

[http://www.bnamericas.com/en/news/waterandwaste/Replacing\\_Bordo\\_Poniente\\_to\\_cost\\_US\\*1,2bn\\_-\\_expert](http://www.bnamericas.com/en/news/waterandwaste/Replacing_Bordo_Poniente_to_cost_US*1,2bn_-_expert)

<sup>172</sup> Conan, R. (2012). "A new airport on Bordo Poniente site would fund remediation." *BNamericas*.

<http://subscriber.bnamericas.com/Subscriber/en/news/w>

<aterandwaste/a-new-airport-on-bordo-poniente-site-would-fund-remediation-expert/>

<sup>173</sup> Gutierrez Vera, J. A. (2014). "CHP project in the largest landfill in Mexico." *14th International Symposium on District Heating and Cooling*.

[http://www.svenskfjarrvarme.se/Global/Konferenser/DHC14/Proceedings/P\\_4%20Gutierrez%20Vera%20Jorge%20CHP%20PROJECT%20IN%20THE%20LARGEST%20LANDFILL%20IN%20MEXICO.pdf](http://www.svenskfjarrvarme.se/Global/Konferenser/DHC14/Proceedings/P_4%20Gutierrez%20Vera%20Jorge%20CHP%20PROJECT%20IN%20THE%20LARGEST%20LANDFILL%20IN%20MEXICO.pdf)

<sup>174</sup> Gutierrez Vera, J. A. (2014). "CHP project in the largest landfill in Mexico." *14th International Symposium on District Heating and Cooling*.

[http://www.svenskfjarrvarme.se/Global/Konferenser/DHC14/Proceedings/P\\_4%20Gutierrez%20Vera%20Jorge%20CHP%20PROJECT%20IN%20THE%20LARGEST%20LANDFILL%20IN%20MEXICO.pdf](http://www.svenskfjarrvarme.se/Global/Konferenser/DHC14/Proceedings/P_4%20Gutierrez%20Vera%20Jorge%20CHP%20PROJECT%20IN%20THE%20LARGEST%20LANDFILL%20IN%20MEXICO.pdf)

repayment is a key indicator which reflects replicability in other urban areas through demonstrating that this financial model is effective to achieve both business and government interests.

Furthermore, overall greenhouse gas emissions of biogas generation and waste transportation should be compared to the previous emissions of landfill and waste transportation.

## **RESULTS AND LESSONS LEARNED**

This program depended heavily on government support in the form of loans and intrusion into the utility market. A city that wishes to replicate this program would need to have similar political will and ability to play an active financial role in infrastructure development. However, this case is a good example of how a government can play to role of financier without also adopting the role of electricity provider. The creative trade of electricity production contracts for loan access is a model that could very easily be used in many cities, provided there is a political climate that supports using public money as a shared capital bank for major projects.

# Appendix D: *Evaluation Criteria*

	HIGH	MEDIUM	LOW
<b>RELEVANCE</b> (relationship between needs/ problems addressed and the objectives of the policy)	The objectives of the policy intervention meet the problems/needs identified in the impact assessment of the policy.  Policy is easily adaptable to technological improvements and/or operational changes.	The objectives of the policy intervention partially meet the problems/needs identified in the impact assessment of the policy.  Technological improvements and/or operational changes are continually addressed.	Policy is only relevant for a short timeframe: needs/ problems are not the same as when the policy was designed.  There are issues with adaptability to technological improvements and/or operational changes.
<b>EFFECTIVENESS</b> (achieving progress towards objectives)	Very successful in achieving or progressing towards its intended objectives.  Actual quantitative measures are available (performance measurements, budget data) that show success.	Unexpected or unintended effects have slowed down progress towards objectives but were dealt with immediately.  Quantitative measures are available (performance measurements, budget data) but don't show clear success.	It has fallen short of its target objectives.  No quantitative measures are available.
<b>EFFICIENCY</b> (relationship between resources used and changes generated by the policy intervention; costs and benefits)	Costs are justified and/or proportionated to benefits achieved and changes produced.	There are some discrepancies between cost and benefits, but the factors that influence these are being addressed.	There are significant differences between costs and benefits.
<b>COHERENCE</b> (how well different actions of the policy work together)	Internal components of the intervention operate together to achieve its objectives.	There is evidence of inconsistencies between actions but are being addressed.	Policy actions are not well coordinated.

	HIGH	MEDIUM	LOW
<p><b>APPEAL/NOVELTY</b></p> <p>(how interesting and innovative it is)</p>	<p>It provides an interesting story.</p> <p>It has not been implemented broadly.</p>	<p>Idea is original, but does not bring about significant change</p> <p>Idea is adaptation of existing program, but the expansion in scope is new.</p>	<p>It is widely implemented.</p> <p>It is not an interesting idea.</p>
<p><b>REPLICABILITY</b></p> <p>(the extent to which its features can be 'exported'/tailored to other urban conditions)</p>	<p>It has potential for broad implementation</p> <p>any distinct local features can be 'exported' to other physical settings/geographical locations.</p> <p>It can be adapted to different city magnitudes.</p> <p>It is socially acceptable in a variety of settings.</p>	<p>It can only be implemented in particular regions/continents</p> <p>only some of its features can be adapted to other areas.</p> <p>It requires a specific city-size.</p>	<p>It can only be implemented when very specific factors exist.</p>
<p><b>FEASIBILITY</b></p> <p>(how well it adapts to different political settings and financial situations)</p>	<p>Potential for implementation in any political structure.</p> <p>Manageable adoption efforts.</p> <p>Not expensive to implement.</p> <p>Does not require large management capacity.</p>	<p>It requires large amount of capital but has potential for implementation.</p> <p>It requires sophisticated management structure but can be adapted to lower management capacities.</p>	<p>It requires a particular political structure</p> <p>expensive to adopt and manage.</p> <p>It cannot be adopted unless a certain management capacity exists.</p>
<p><b>POTENTIAL/ACTUAL GHG REDUCTION IMPACT ASSESSMENT</b></p> <p>(*depends data availability including baseline emissions)</p>	<p>Proven or potential significant impact reduction.</p> <p>Reductions can be sustained over long-term.</p>	<p>Some impact but not consistent with greenhouse gas policy objectives.</p>	<p>Impact is uncertain or can't be measured.</p>

# Appendix E: *Case Study Framework*

## **Background**

What are the salient features of the jurisdiction relevant to the program?

- Population size, age distribution, density, race and ethnicity, income distribution
- Political structure and autonomy (especially power to tax and allocate funds)
- Other social, economic and cultural factors
- History (only background relevant to the project)
- Stakeholders and their position on the program

## **Description of Policy/Program**

What problem does it address? Why is it needed?

What is the policy/program?

- Goals (timeline and measurable impact)
- The major tasks involved in delivering the program

How long has the program been in place and how has it changed over time?

## **Program Cost**

What is/was the program's capital budget? What are the operational costs?

What is the source of the capital funding (if any)? What is the source of the funding to operate the program?

## **Program implementation**

Have there been issues with implementation? Operational and/or technical issues?

- Management issues? Political issues

What steps were taken to address implementation issues?

## **Program effectiveness**

What are the key performance indicators and how has the program performed?

## **Regulatory Framework (PERTAINING TO INFRASTRUCTURE FINANCE ONLY)**

What public policies have successfully attracted capital to sustainability initiatives? What policies have been tried but have not met expectations?

## **Project Profitability (PERTAINING TO INFRASTRUCTURE FINANCE ONLY)**

What factors have generated profitable sustainability initiatives? What factors have contributed to a need for subsidies or incentives?

## **Results and Lessons Learned**

Is the program replicable, scalable?

# References

- Amsterdam Round Tables and McKinsey&Company. (2014). "Electric vehicles in Europe: gearing up for a new phase?" Amsterdam Round Tables and McKinsey&Company. <http://goo.gl/9V2lhH>
- AREA. (2016). "Sustainable cities - case study Rizhao." African Renewable Energy Alliance. [http://area-net.org/wp-content/uploads/2016/01/WFC\\_Case-Study\\_China-Rizhao.pdf](http://area-net.org/wp-content/uploads/2016/01/WFC_Case-Study_China-Rizhao.pdf)[http://area-net.org/wp-content/uploads/2016/01/WFC\\_Case-Study\\_China-Rizhao.pdf](http://area-net.org/wp-content/uploads/2016/01/WFC_Case-Study_China-Rizhao.pdf)
- Bai, X. (2007). "China's solar-powered city." Renewable Energy World. <http://www.renewableenergyworld.com/articles/2007/05/chinas-solar-powered-city-48605.html>
- Berman, B. et al. (2013). "Carsharing programs." Navigant Research. <http://www.navigantresearch.com/research/carsharing-programs>
- Blaustein, L. (2013). "Citi bike...how green is it?" GreenSportsBlog. <http://greensportsblog.com/2013/08/05/citi-bike-how-green-is-it/>
- Bloomberg and SEI (2015). "What cities do best." Bloomberg Philanthropies and Stockholm Environmental Institute. <http://www.bloomberg.org/content/uploads/sites/2/2015/12/What-Cities-Do-Best.pdf>
- Bradley, J. (2011). "Greening a Village." New York University. <http://events.energetics.com/nyserdachp/pdfs/bradley.pdf>
- C40. (2011). "Barcelona's solar hot water ordinance." C40 Cities. [http://www.c40.org/case\\_studies/barcelonas-solar-hot-water-ordinance](http://www.c40.org/case_studies/barcelonas-solar-hot-water-ordinance)
- CCAP. (2013). "The solar thermal ordinance for efficient water heating in Barcelona, Spain." Center for Clean Air Policy. [http://ccap.org/assets/CCAP-Booklet\\_Spain.pdf](http://ccap.org/assets/CCAP-Booklet_Spain.pdf)
- Cervero, R. et al. (2002). "City carshare: assessment of short-term travel-behavior impacts." eScholarship - University of California. <http://escholarship.org/uc/item/7fn8966c?query=City%20CarShare#page-3>
- City of Amsterdam. (2015). "Sustainable Amsterdam." City of Amsterdam [https://www.amsterdam.nl/publish/pages/675721/sustainable\\_amsterdam\\_27-3-2015.pdf](https://www.amsterdam.nl/publish/pages/675721/sustainable_amsterdam_27-3-2015.pdf)
- City Population (2016). "Mexico: Ciudad de Mexico (Distrito Federal)." <http://www.citypopulation.de/Mexico-DistritoFederal.html>
- CMAP (2014). "Impacts of car sharing." Chicago Metropolitan Agency for Planning. <http://www.cmap.illinois.gov/about/2040/supporting-materials/process-archive/strategy-papers/car-sharing/impacts>
- Conan, R. (2012). "A new airport on Bordo Poniente site would fund remediation." *BNamericas*. <http://subscriber.bnamericas.com/Subscriber/en/news/waterandwaste/a-new-airport-on-bordo-poniente-site-would-fund-remediation-expert/>
- Corrales, I. (2010). "Replacing Bordo Poniente to cost \$1.2bn." *BNamericas*. [http://www.bnamericas.com/en/news/waterandwaste/Replacing\\_Bordo\\_Poniente\\_to\\_cost\\_US\\*1,2bn\\_-\\_expert](http://www.bnamericas.com/en/news/waterandwaste/Replacing_Bordo_Poniente_to_cost_US*1,2bn_-_expert)
- CSA (2016). "What is carsharing?" Carsharing Association. <http://carsharing.org/what-is-car-sharing/>
- CTA (2016). "Electric bus." Chicago Transit Authority. <http://www.transitchicago.com/electricbus/>
- DAC. (2014). "Rizhao: mainstreaming solar energy on city level." Danish Architecture Center. <http://www.dac.dk/en/dac-cities/sustainable-cities/all-cases/energy/rizhao-mainstreaming-solar-energy-on-city-level/>
- DeMaio, P. (2016). "The need for innovation." The Bike-Sharing Blog. <http://bike-sharing.blogspot.com/>

- Demographia (2015). "Demographia world urban areas." Demographia. <http://www.demographia.com/db-worldua.pdf>
- DeMorro, C. (2014). "Amsterdam Airport Enlists 167 Tesla Taxis." Gas2. <http://gas2.org/2014/10/16/amsterdam-airport-enlists-167-tesla-taxis/>
- Ecoplan (2008). "One thousand world carshare cities in 2009." Ecoplan. <http://ecoplan.org/carshare/general/cities.htm#latest>
- EIA (2015). "How much carbon dioxide is produced when different fuels are burned?" U.S. Energy Information Administration. <https://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11>
- Electric Cars Report. (2014). "Rotterdam Introduces World's Best EV Incentives." Electric Cars Report. <http://electriccarsreport.com/2014/08/rotterdam-introduces-worlds-best-ev-incentives/>
- Emergy, J. (2012). "Turning away from the automobile 1969-2012." *PDXPlanning*. <http://pdxplanning.weebly.com/a-pedestrian-priority.html>
- EPA (2016). "Global greenhouse gas emissions data." United States Environmental Protection Agency. <https://www3.epa.gov/climatechange/ghgemissions/global.html>
- Erlanger, S. (2008). "A New Fashion Catches On in Paris: Cheap Bicycle Rentals." The New York Times. [http://www.nytimes.com/2008/07/13/world/europe/13paris.html?\\_r=2&ei=5087&em=&en=607f90e234d58472&ex=1216094400&pagewanted=all&oref=slogin&oref=slogin](http://www.nytimes.com/2008/07/13/world/europe/13paris.html?_r=2&ei=5087&em=&en=607f90e234d58472&ex=1216094400&pagewanted=all&oref=slogin&oref=slogin)
- Eudy, L. et al. (2016). "Foothill transit battery electric bus demonstration results." National Renewable Energy Laboratory. <http://www.nrel.gov/docs/fy16osti/65274.pdf>
- Finnigan, L. (2013). The Portland-Milwaukie Light Rail Project, Connecting a Metropolitan Area Once Segment at a Time. IRWA. Retrieved from [https://www.irwaonline.org/eweb/upload/web\\_novdec13\\_PortlandMilwaukie.pdf](https://www.irwaonline.org/eweb/upload/web_novdec13_PortlandMilwaukie.pdf)
- Gies, E. (2013). "In Europe, greener transit on existing infrastructure." The New York Times. [http://www.nytimes.com/2013/07/08/business/energy-environment/greener-transit-in-europe-built-on-top-of-older-infrastructure.html?\\_r=2](http://www.nytimes.com/2013/07/08/business/energy-environment/greener-transit-in-europe-built-on-top-of-older-infrastructure.html?_r=2)
- Glott-Richter, M. (2011). "Car-sharing in Bremen." Cities for Mobility. [http://www.cities-for-mobility.net/documents/wc11/michael\\_glott\\_richter.pdf](http://www.cities-for-mobility.net/documents/wc11/michael_glott_richter.pdf)
- Glott-Richter, M. (2015). "Bremen car-sharing scheme takes cars off the road (Germany)." Eltis. <http://www.eltis.org/discover/case-studies/bremen-car-sharing-scheme-takes-cars-road-germany>
- Grynbaum, M. (2015). "New York City Aims for Vast Electric Car Fleet by 2025." New York Times. [http://www.nytimes.com/2015/12/02/nyregion/new-york-city-aims-for-a-vast-electric-car-fleet-by-2025.html?\\_r=0](http://www.nytimes.com/2015/12/02/nyregion/new-york-city-aims-for-a-vast-electric-car-fleet-by-2025.html?_r=0)
- Gutierrez Vera, J. A. (2014). "CHP project in the largest landfill in Mexico." *14th International Symposium on District Heating and Cooling*. [http://www.svenskfjarrvarme.se/Global/Konferenser/DHC14/Proceedings/P.\\_4%20Gutierrez%20Vera%20Jorge%20CHP%20PROJECT%20IN%20THE%20LARGEST%20LANDFILL%20IN%20MEXICO.pdf](http://www.svenskfjarrvarme.se/Global/Konferenser/DHC14/Proceedings/P._4%20Gutierrez%20Vera%20Jorge%20CHP%20PROJECT%20IN%20THE%20LARGEST%20LANDFILL%20IN%20MEXICO.pdf)
- Harrop, P. and Gonzalez, F. (2016). "Electric buses 2016-2026: forecasts, technology roadmap, company assessment." IDTechEx. <http://www.idtechex.com/research/reports/electric-buses-2016-2026-000467.asp>
- Hristova, D. (2012). "Mexico City awards USD 163m biogas energy project." *See News Renewables*. <http://renewables.seenews.com/news/mexico-city-awards-usd-163m-biogas-energy-project-313336#>
- ICLEI. (2014). "Barcelona, Spain: using solar energy - supporting community energy self sufficiency." Local Governments for Sustainability. [http://carbonn.org/uploads/tx\\_carbonndata/ICLEI\\_cs\\_173\\_Barcelona\\_UrbanLEDS\\_2014\(4\).pdf](http://carbonn.org/uploads/tx_carbonndata/ICLEI_cs_173_Barcelona_UrbanLEDS_2014(4).pdf)
- Index Mundi (2014). "Singapore demographics profile 2014." Index Mundi. [http://www.indexmundi.com/singapore/demographics\\_profile.html](http://www.indexmundi.com/singapore/demographics_profile.html)

- International Energy Agency (IEA) (2015). "Energy efficiency market report 2015."  
<https://www.iea.org/publications/freepublications/publication/MediumTermEnergyefficiencyMarketReport2015.pdf>
- Jung, A. (2015). "Carsharing services in emerging economies." Giz.  
[http://www.sutp.org/files/contents/documents/resources/B\\_Technical-Documents/GIZ\\_SUTP\\_TD12\\_Carsharing-Services-in-Emerging-Economies\\_EN.pdf](http://www.sutp.org/files/contents/documents/resources/B_Technical-Documents/GIZ_SUTP_TD12_Carsharing-Services-in-Emerging-Economies_EN.pdf)
- Kell, J. (2013). "Avis to buy car-sharing service Zipcar." The Wall Street Journal.  
<http://www.wsj.com/articles/SB10001424127887324374004578217121433322386>
- King, D. (2013). "BYD gets Europe's largest-ever e-bus contract, headed to Amsterdam airport." autoblog  
<http://www.autoblog.com/2013/07/18/byd-gets-europes-largest-e-bus-contract-for-amsterdam-airport/>
- Klippenstein, M. (2014). "Why an electric car saves fleet operators \$16000 in lifetime costs." Green Car Reports  
[http://www.greencarreports.com/news/1092682\\_why-an-electric-car-saves-fleet-operators-16000-in-lifetime-cost](http://www.greencarreports.com/news/1092682_why-an-electric-car-saves-fleet-operators-16000-in-lifetime-cost)
- Koch, W. (2015). "Tesla for the masses: electric, fuel cell buses take off." National Geographic.  
<http://news.nationalgeographic.com/energy/2015/03/150312-tesla-for-the-masses-electric-buses-take-off/>
- Kolson Hurley, A. (2014). "How Bremen, Germany, Became a Car-Sharing Paradise." City Lab.  
<http://www.citylab.com/commute/2014/12/how-bremen-germany-became-a-car-sharing-paradise/383538/>
- Kolson Hurley, A. (2014). "How Bremen, Germany, Became a Car-Sharing Paradise." City Lab.  
<http://www.citylab.com/commute/2014/12/how-bremen-germany-became-a-car-sharing-paradise/383538/>
- Larsen, J. (2013). "Bike-sharing programs hit the streets in over 500 cities worldwide." Earth Policy Institute.  
<https://earthpolicyinstitute.wordpress.com/2013/04/25/bike-sharing-programs-hit-the-streets-in-over-500-cities-worldwide/>
- LEGCO (2015). "Seawater desalination in Singapore." Legislative Council Secretariat.  
<http://www.legco.gov.hk/research-publications/english/1415fs09-seawater-desalination-in-singapore-20150930-e.pdf>
- Libby, B. (2015). The Bridge that Bans Cars. The Atlantic. Retrieved from  
<http://www.theatlantic.com/magazine/archive/2015/10/the-bridge-that-bans-cars/403234/>
- MacKechnie, C. (2014). "Electric buses - an introduction." About Money.  
[http://publictransport.about.com/od/Transit\\_Vehicles/a/Electric-Buses-An-Introduction.htm](http://publictransport.about.com/od/Transit_Vehicles/a/Electric-Buses-An-Introduction.htm)
- MacKechnie, C. (2016). "How long do buses (and other transit vehicles) last?" About Money.  
[http://publictransport.about.com/od/Transit\\_Vehicles/a/How-Long-Do-Buses-And-Other-Transit-Vehicles-Last.htm](http://publictransport.about.com/od/Transit_Vehicles/a/How-Long-Do-Buses-And-Other-Transit-Vehicles-Last.htm)
- Martin, E. and Shaheen, S. (2011). "Greenhouse Gas Emission Impacts of Carsharing in North America." IEEE Transactions on Intelligent Transportation Systems.  
<http://ieeexplore.ieee.org.ezproxy.cul.columbia.edu/stamp/stamp.jsp?tp=&arnumber=5951778>
- Martin, R. (2013). "Carsharing services will surpass 12 million members worldwide by 2020." Navigant Research. <http://www.navigantresearch.com/newsroom/carsharing-services-will-surpass-12-million-members-worldwide-by-2020>
- Martinot, E. and Junfeng, L. (2011). "Powering China's development - the role of renewable energy." Worldwatch Institute.  
<http://www.worldwatch.org/files/pdf/Powering%20China%27s%20Development.pdf>  
[http://www.worldwatch.org/files/pdf/Powering China%27s Development.pdf](http://www.worldwatch.org/files/pdf/Powering%20China%27s%20Development.pdf)
- Microgrids. (2016). "New York University." Berkeley Lab. <https://building-microgrid.lbl.gov/new-york-university>

- MIT. (2015). "Cogeneration: a bridge to the future." Massachusetts Institute of Technology.  
<https://powering.mit.edu/news/cogeneration-bridge-future>
- Mobil.Punkt (2016). "Car-Sharing station in Bremen." Mobil.Punkt. <http://mobilpunkt-bremen.de/english/>
- NYC. (2014). "Benefits of hybrid gas-electric cars." New York City Government.  
[http://www.nyc.gov/html/dcas/downloads/pdf/fleet/nyc\\_fleet\\_hybrid\\_report\\_june\\_2014.pdf](http://www.nyc.gov/html/dcas/downloads/pdf/fleet/nyc_fleet_hybrid_report_june_2014.pdf)
- Nykvist, B. and Nilsson, M. (2015). "Rapidly falling costs of battery pack for electric vehicles." *Nature Climate Change*.  
[http://www.nature.com/nclimate/journal/v5/n4/full/nclimate2564.html?WT.ec\\_id=NCLIMATE-201504](http://www.nature.com/nclimate/journal/v5/n4/full/nclimate2564.html?WT.ec_id=NCLIMATE-201504)
- NYU. (2006). "Greening the urban campus: a sustainability assessment of New York University." New York University. <https://wildgreenyonder.files.wordpress.com/2007/01/greening-the-urban-campus.pdf>
- NYU. (2010). "Climate Action Plan." NYU 2031.  
<http://www.nyu.edu/nyu2031/nyuinnyu/sustainability/climate-commitments.php>
- NYU. (2011). "NYU switches on green cogen plant and powers up for the sustainable future." NYU News.  
<https://www.nyu.edu/about/news-publications/news/2011/01/21/nyu-switches-on-green-cogen-plant-and-powers-up-for-the-sustainable-future.html>
- NYU. (2013). "NYU sets a 50% ghg reduction target by 2017." New York University.  
<https://www.nyu.edu/about/news-publications/news/2013/04/18/nyu-sets-a-50-ghg-reduction-target-by-2017.html>
- NYU. (2016). "NYU Energy." New York University. <https://www.nyu.edu/life/sustainability/areas-of-focus/energy.html>
- Overton, T. W. (2014). "New York University cogeneration plant, New York City." *POWER Magazine*.  
<http://www.powermag.com/new-york-university-cogeneration-plant-new-york-city/>
- Peters, C. (2013). "Solar thermal legislation on municipal, regional and national level in Spain: success and remaining barriers." Institut Catala d'Energia.  
<http://www.solarthermalworld.org/sites/gstec/files/legislation%20spain.pdf>
- Plug in BC (2014). "Electric Vehicle Fleet Modelling Project." 2013 Summary Report.  
[http://www.e3fleet.com/\\_Library/docs/Plug\\_In\\_BC\\_EV\\_Suitability\\_Modelling\\_Project\\_-\\_White\\_Paper.pdf](http://www.e3fleet.com/_Library/docs/Plug_In_BC_EV_Suitability_Modelling_Project_-_White_Paper.pdf)
- Polis. (2010). "Barcelona solar thermal ordinance." Polis Solar. [http://www.polis-solar.eu/IMG/pdf/BARCELONA\\_SOLAR\\_THERMAL\\_ORDINANCE.pdf](http://www.polis-solar.eu/IMG/pdf/BARCELONA_SOLAR_THERMAL_ORDINANCE.pdf)
- Procuraplus. (2016). "Adjuntament de Barcelona." Procura+ - European Sustainable Procurement Network.  
<http://www.procuraplus.org/en/participants/spain-ajuntament-de-barcelona/>
- Profita, C. (2013). "The pros and cons of car-sharing." Oregon Public Broadcasting.  
<http://www.opb.org/news/blog/ecotrope/the-pros-and-cons-of-car-sharing/>
- Reed, C. (2014). "Pollution spikes send Europe scrambling for emission controls." *ClimateWire*.  
<http://www.eenews.net/stories/1059996347>
- Rocky Mountain institute. (2014). "Pulling back the veil on EV charging station costs." Rocky Mountain Institute.  
[http://blog.rmi.org/blog\\_2014\\_04\\_29\\_pulling\\_back\\_the\\_veil\\_on\\_ev\\_charging\\_station\\_costs](http://blog.rmi.org/blog_2014_04_29_pulling_back_the_veil_on_ev_charging_station_costs)
- Shaheen, S A. et al. (2009). "North American carsharing: 10-year retrospective." University of California, Berkeley. <http://tsrc.berkeley.edu/sites/default/files/North%20American%20Carsharing%20-%20Shaheen.pdf>
- Siemens (2014). "Electric buses: rapid charging in Vienna." Siemens.  
<http://www.siemens.com/innovation/en/home/pictures-of-the-future/mobility-and-motors/electric-mobility-electric-buses.html>
- Sivak, M. (2015). "Commuting to work in the 30 largest U.S. cities." *University of Michigan - Transportation Research Institute*. [http://www.umich.edu/~umtriswt/PDF/UMTRI-2015-17\\_Abstract\\_English.pdf](http://www.umich.edu/~umtriswt/PDF/UMTRI-2015-17_Abstract_English.pdf)

- Smith, S. (2015). "China electric bus industry report, 2015-2020." PR Newswire.  
<http://www.prnewswire.com/news-releases/china-electric-bus-industry-report-2015-2020-300178202.html>
- Solomonow, S. and Mosquera, N. (2013). "After First 200 Days of Citi Bike, NYC DOT Releases New Data Showing that Significant Numbers of New Yorkers are Biking, Complementing Transit System." New York City Department of Transportation. <http://a841-tfpweb.nyc.gov/dotpress/2013/12/new-biking-data/>
- Steinberg, S. and Vlastic, B. (2013). "Car-sharing services grow, and expand options." The New York Times. <http://www.nytimes.com/2013/01/26/business/car-sharing-services-grow-and-expand-options.html?ref=technology&r=3>
- The Climate Group. (2010). "China clean revolution report III: low carbon development in cities." The Climate Group. [http://www.theclimategroup.org/\\_assets/files/China-Clean-Revolution-III.pdf](http://www.theclimategroup.org/_assets/files/China-Clean-Revolution-III.pdf)
- Toor, A. (2013). "Every Dutch citizen will live within 31 miles of an electric vehicle charging station by 2015." The Verge. <http://www.theverge.com/2013/7/10/4509962/netherlands-nationwide-electric-vehicle-charging-network-abb-fastned>
- Tri-County Metropolitan Transportation District of Oregon. (2010). "Portland-Milwaukie Light Rail Project Final Environmental Impact Statement". Portland, OR.
- UN Data (2016). "City population by sex, city and city type." <http://data.un.org/Data.aspx?q=mexico+city&d=POP&f=tableCode%3a240%3bcountryCode%3a484>
- UNEP (2016). "Cities and climate change." United Nations Environment Programme. <http://www.unep.org/resourceefficiency/Policy/ResourceEfficientCities/FocusAreas/CitiesandClimateChange/tabid/101665/Default.aspx>
- United Nations (UN (2014). "World's population increasingly urban with more than half living in urban areas." <http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html>
- Van Der Pas, J. W. (2015). "A cleaner city: electric buses in Vienna (Austria)." Eltis. <http://www.eltis.org/discover/case-studies/cleaner-city-electric-buses-vienna-austria>
- Walljasper, J. (2010). "How to make biking mainstream: lessons from the Dutch." YES! Magazine. <http://www.yesmagazine.org/planet/how-to-make-biking-mainstream-lessons-from-the-dutch>
- Water-Technology (2016). "Tuas seawater desalination plant, Singapore." <http://www.water-technology.net/projects/tuas-seawater-desalination/>
- Wiesinger, P. (2014). "Innovative electric buses in Vienna." Clean Fleets. [http://www.clean-fleets.eu/fileadmin/files/Clean\\_Fleets\\_case\\_study\\_\\_Vienna\\_-\\_Final.pdf](http://www.clean-fleets.eu/fileadmin/files/Clean_Fleets_case_study__Vienna_-_Final.pdf)
- Willsher, K. (2015). "Paris to stop traffic when air pollution spikes." The Guardian. <http://www.theguardian.com/environment/2015/nov/03/paris-to-stop-traffic-when-air-pollution-spikes>
- WWF. (2012). "Rizhao solar water heating." World Wide Fund for Nature. [http://wwf.panda.org/wwf\\_news/?204452/Rizhao-solar-water-heating](http://wwf.panda.org/wwf_news/?204452/Rizhao-solar-water-heating)

## Photo Credits

Cover Page – Adapted from: [http://pexetothemes.com/demos/mineral\\_wp/quick-gallery-sidebar-layout/#lightbox\[group-402\]/3/](http://pexetothemes.com/demos/mineral_wp/quick-gallery-sidebar-layout/#lightbox[group-402]/3/)

pg. 12 -- <http://www.euratechnologies.com/en/location>

pg. 16 – <http://hammerandhand.com/perform/design-competition/perform-2014/>

pg. 20 -- Illustration by Samuel Castano, | <http://ensia.com/features/urban-infrastructure-what-would-nature-do/>

pg. 24 – Adapted from: <http://www.ecodallecitta.it/notizie/112669/smart-city-in-un-dossier-di-hera-le-buone%20pratiche-su-rifiuti-e-mobilita>

pg. 28 -- [http://news.bbc.co.uk/hi/spanish/science/newsid\\_6665000/6665459.stm](http://news.bbc.co.uk/hi/spanish/science/newsid_6665000/6665459.stm); Getty Images

pg. 30 (1) -- Image by Noah Burger | <http://mtc.ca.gov/our-work/plans-projects/major-regional-projects/bay-area-express-lanes>

pg. 30 (2) -- <http://www.dailytech.com/Cities+to+Carpoolers+Sharing+Your+Car+is+Illegal+We+Will+Seize+Your+Cars/article34659.htm>

pg. 33 -- <http://www.tu.no/artikler/her-har-de-12-batteribusser-i-kollektivnettet/235380>

pg. 36 -- <http://20littlecities.com/practical-info/velib-bicycling-in-paris/>

pg. 39 (1) -- <https://www.transportxtra.com/publications/local-transport-today/supplements/628/48066/cycle-cities-can-be-car-friendly>

pg. 39 (2) -- [http://www.civitas.eu/sites/default/files/documents/carsharing\\_bremen.pdf](http://www.civitas.eu/sites/default/files/documents/carsharing_bremen.pdf)

pg. 43 -- <https://teslamondo.com/2014/10/22/amsterdam-airport-places-bulk-order/>

pg. 47 (1) -- [http://www.capjeff.com/Edu\\_NYU\\_Plant.php](http://www.capjeff.com/Edu_NYU_Plant.php)

pg. 47 (2) -- <https://building-microgrid.lbl.gov/new-york-university>

pg. 51 -- <http://www.renewables-made-in-germany.com/en/renewables-made-in-germany/technologies/solar-thermal-energy/solar-thermal-energy/introduction.html>

pg. 55 -- <http://greens.org.au/magazine/national/10-inspiring-and-innovative-cities>

pg. 58 -- <http://www.symbiocity.org/en/approach/Cases-undersidor/Stockholm-Royal-Seaport-eco-living-on-the-waterfront/>

pg. 59 -- [http://www.wikiwand.com/sv/Hammarby\\_sjöstad](http://www.wikiwand.com/sv/Hammarby_sjöstad)

pg. 62 -- <http://www.waterworld.com/articles/wwi/print/volume-25/issue-4/editorial-focus/water-reuse/overcoming-the-global-barriers-to-water-reuse.html>

pg. 65 -- <http://trimet.org/history/orangeline/openhouse/lightrailbridge.htm>

pg. 68 -- <http://diarionoticiasweb.com/2016/04/bordo-poniente-contamina-diario-lo-que-1-millon-de-autos/>