A Comparative Analysis of Curitiba's Technology Industry and San Francisco's Silicon Valley and the Emission Patterns of Each City

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Table of Contents

Abstract

Over the past decade, the Brazilian city of Curitiba has attracted significant business interests in many fields, including automobile manufacturing and hospitality and tourism. However, one field in particular has the potential to completely revolutionize the city: the high-technology industry. Over the past twenty years, the number of national and multinational corporations present in the city has increased dramatically. Furthermore, cooperation between the public, local universities, and municipal government has fostered the development of specialized business districts designed specifically for high-technology industries. Most of this growth is concentrated in the *Ciudade Industrial de Curitiba* (CIC), which has specific areas designated for the technology industry. The most prominent of these high-tech hubs are *Tecnoparque de Curitiba*, (Curitiba Technopark) and *Parque de Software de Curitiba* (Curitiba Software Park). With development and growth of both parks expected to increase, the CIC is expected to have a significant impact on Curitiba's transportation needs and emissions stabilization. The evolution of the CIC has many similarities to the evolution of Silicon Valley in the San Francisco Bay Area of central California. Because of this, the CIC and Silicon Valley will be compared and contrasted in terms of their technology industries, transportation systems, and emission levels. In so doing, insight might be shed on potential solutions to issues facing similar cities in the future, specifically the rise of greenhouse gas emissions.

Keywords: Curitiba, Technopark, Software Park, Silicon Valley, San Francisco, transportation, greenhouse gas, emissions, geography, efficiency

A Comparative Analysis of Curitiba's Technology Industry and San Francisco's Silicon Valley and the Emission Patterns of Each City

Located in the east of the state, Curitiba is the state capital of Paraná. Throughout the city's history, Curitiba has been associated with a long tradition of innovation. This quality has come in handy in the 20th and 21st centuries, as the city has undergone significant innovations in sustainability, particularly in both business management and transportation efficiency. The city's BRT (bus rapid transit) system is world-renowned not just for its sustainability in reducing emissions, but also in its affordability, compatibility with the needs of the community, and efficiency (Session, 2006). Just as important in the city's success has been the growth of high-technology industries in the city, which will be the primary focus of this study. In many ways, Curitiba is often considered to be the South American counterpart of Silicon Valley, located in the San Francisco Bay Area (SFBA), in that both embodied the culmination of decades of cooperation between local university researchers/alumni and the private sector. This long-term cooperative strategy led to massive economic growth and technological innovations, making Silicon Valley the world technology hub. Just like Curitiba, San Francisco and its neighboring communities have a long history of progressive innovation. This feature gives hope to the idea that Curitiba can solve its current population strains and the associated problems, specifically emissions and air quality, through sustainable development, technological and social innovations, and increasing technological efficiency.

Comparison of Technology Industries

San Francisco is known for its ability to innovate in many areas, from social change to science and medicine. Over the span of four decades, Silicon Valley become an established world center

for technological innovation. Figure 1 is a map indicating the area of the San Francisco Bay Area where Silicon Valley is located.

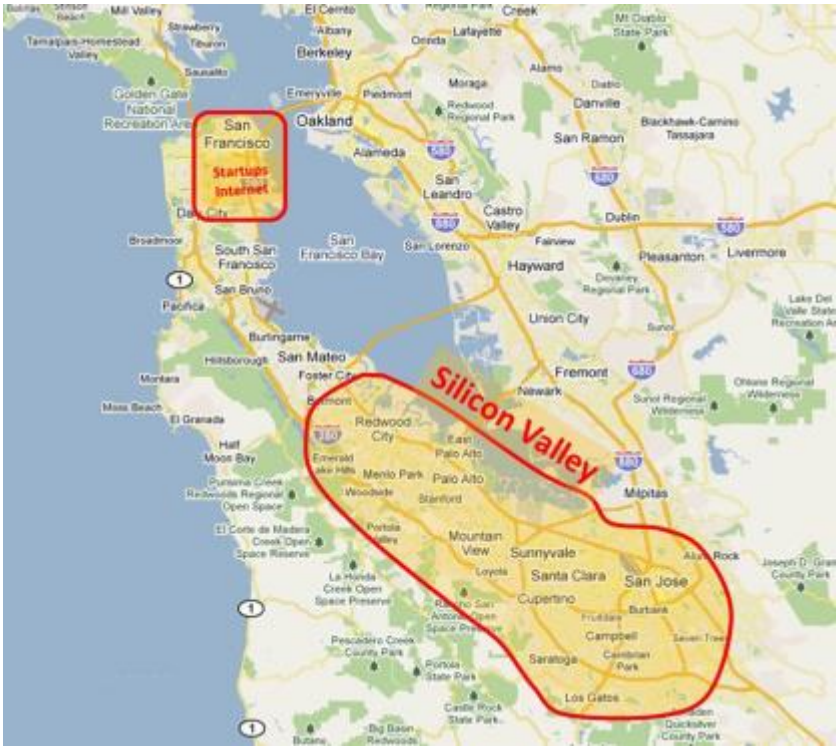


Figure 1. A layout of the San Francisco Bay Area with the main section of Silicon Valley and its auxiliary section in downtown San Francisco highlighted. Source: Flickr.

The Valley's rise to prominence started with joint entrepreneurialism between the local Stanford University and many of its alumni. Figure 2, shown below, is a timeline showing the technological progress of Silicon Valley.

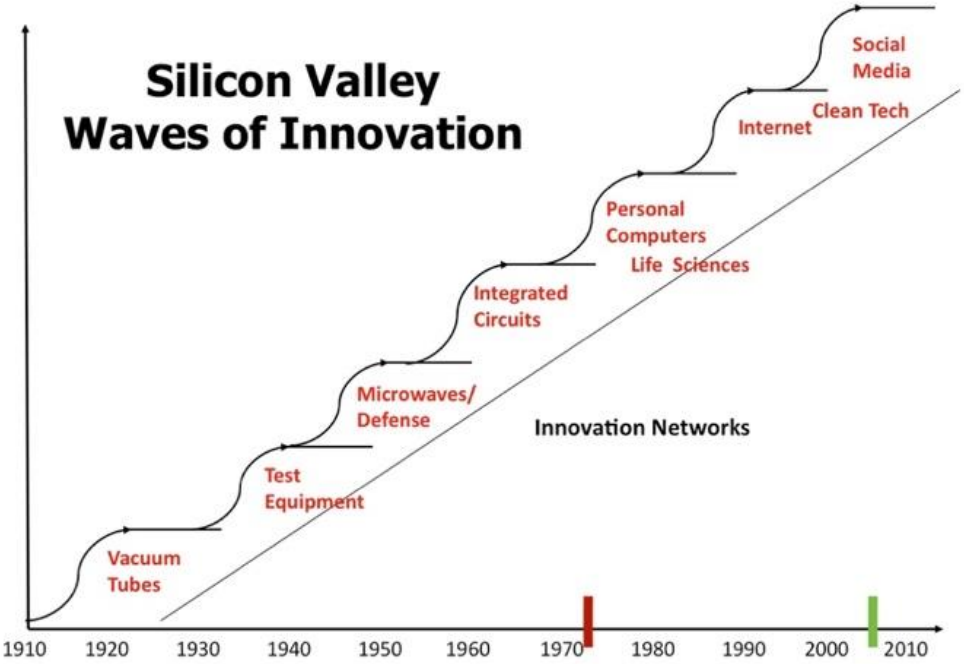


Figure 2. A timeline showing the technological innovations and technological foci of Silicon Valley. The maroon dash at 1971 represents the invention of integrated circuits (birthing Silicon Valley), while the green dash around 2009 represents the emergence of clean technology industries in the Valley. Source: SteveBlank.com

In 1953, the Stanford Research Park, a technological park, was formed in the community of Palo Alto (Carpian et al, 2012). Between then and 1971, significant technological bounds were taken in the field of computer technology and capitalism. During the 1970s, Silicon Valley continued to attract significant businesspeople and entrepreneurs. From the 1970s onward, Silicon Valley has served as the Mecca for the technology industry for not just North America, but also the world. The next great leaps came about in the 1980s, when companies such as Apple and Microsoft perfected the first personal computers (Carpian et al, 2012).

Development conducted along a similar path for the next two decades, when Silicon Valley's clean technology industry was invigorated. One of the prominent "clean tech" companies headquartered in the Silicon Valley town of Palo Alto is Tesla Motors, the brainchild

of Stanford University alumnus Elon Musk (Edelstein. 2016). While Musk and his Tesla have had a global impact on the automobile market, the presence of the company in Silicon Valley and the state of California has been revolutionary. As a Californian company, Tesla has had significant impacts on the encouragement of electric vehicles in California, and has worked with the state government in enacting legislation encouraging electric and hybrid vehicles. Some of these encouragements have come in the form of rewards and incentives for drivers. For example, four-figure rebates have been used to incentivize fully-electric and hybrid cars, and a white sticker program for drivers of cars with electric cars, allowing them complete access to carpool lanes (Edelstein, 2016). The clean tech boom in Silicon Valley also brought about the rise of green energy companies. The most prominent of these is Silicon Valley Power, a municipal utilities firm which, as will be discussed in Energy Infrastructure, Automobiles, and Emissions, has played a key role in bringing about clean energy growth not just in Silicon Valley, but the Bay Area as a whole.

The development of Curitiba's high technology industry started originally with the creation of the Industrial City of Curitiba in 1973, *Agência Curitiba*, but the later initiation of two programs establishing industrial parks in designated areas of the city had a much larger effect (Fischer, 2017). The first was *Parque de Software de Curitiba* (Software Park of Curitiba), which was informally started by the Municipality of Curitiba and private initiatives in 1996. The vision was to establish Curitiba as a South American center for the technology industry to create a vibrant example of sustainable technological development (Parque de Software de Curitiba 2017). The second park was *Tecnoparque de Curitiba* (Curitiba Technopark) started in 2008, when the then-mayor Carlos Alberto Richa issued Complementary Degree 64/2007, which established the *Technoparque da Cidade de Curitiba*, under the guidance of the *Agencia PUC de*

Ciência, Tecnologia e Inovaçao (PUC Agency for Science, Technology and Innovation (Lei Complementara No. 64, 2007). The PUC acronym in the name of the governing agency is a reference to *Ponificia Universidade Catolica do Paraná*, a local private university which will be discussed later on. Figure 3 below shows the locations of the Technopark and Software Park, respectively.

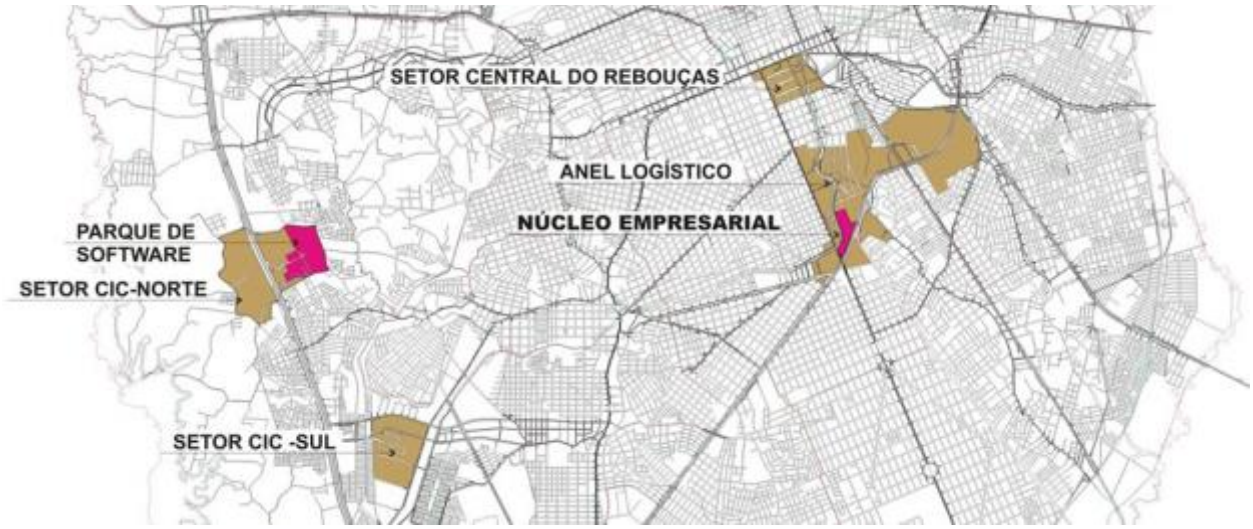
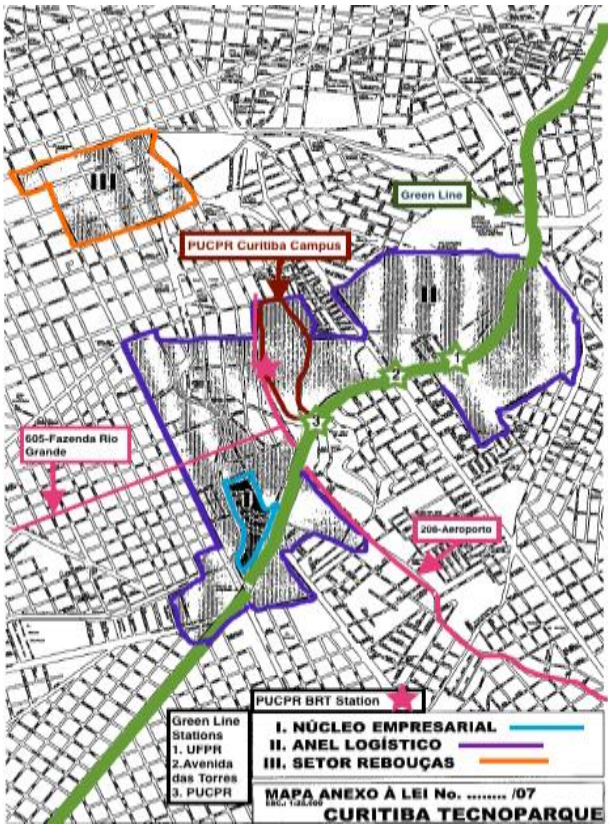


Figure 3. A layout of the Technopark and the Software Park. The primary sectors of the Technopark are all located in Curitiba's east half (near the city center, with two additional sectors in *Ciudade Industrial de Curitiba (CIC)* (Industrial City of Curitiba) Source: Agência Curitiba.

Detailed images of the eastern and western campuses (shown in Figures 4 and 5 below) show the transportation system, which meets the needs of those in the communities and allows people to commute to their needed location.



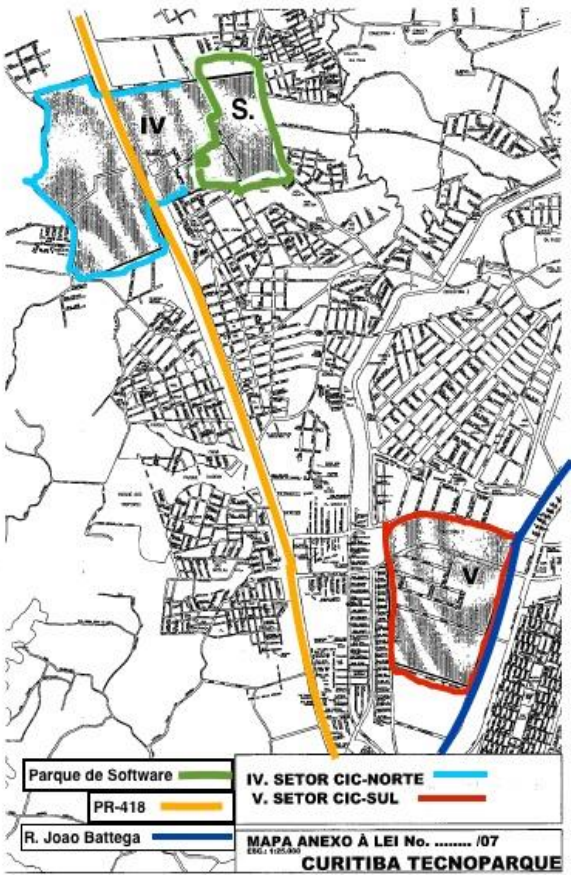


Figure 4. A layout of the eastern campus of Technopark and its respective components. (I. *Núcleo Empresarial*, Central Business District, II. *Anel Logístico*, Logistical Ring, III. *Setor Rebouças*, *Rebouças* Sector. The Green Line (and its bus stations), RIT Lines 605 and 208 (and their PUCPR station), and PUCPR's campus are also labeled. Source: Complentary Degree No.64

Figure 5. A layout of the western campus of Technopark, its respective components (listed later), Software Park, the state highway of PR-418, and R. Joao Battega. The components of Technopark are as follows: IV. *Setor CIC-Norte* (CIC North Sector), V. *Setor CIC-Sul* (CIC South Sector). Source: Complentary Degree No.64

Upon their formations, both the Software Park and Technopark were accompanied with business incentives, which came predominantly in the form of property and service tax exemption, including a two percent rate on service taxes (*Programa Software de Curitiba* 2017). This strategy has been shown to be very successful in attracting businesses to the area and

generating economic growth. For example, between 1996 and 2000, economic growth in the city of Curitiba increased from 2.97 to 3.64, while the metropolitan area increased from 2.73 to 3.68, as indicated in Tables 1 (Fazzano & Weiss 2004).

Table 1
Changes in business growth in Curitiba and its metropolitan area, Parana, and the entirety of Brazil. Source: Global Urban Development.

Period/Rates in %					
Area	**1970-1980**	**1980-1990**	**1990-1996**	**1996-2000**	**Avg.**
Curitiba (city)	11.79	3.97	2.97	3.64	5.59
Curitiba (metro area)	12.16	4.16	2.73	3.68	5.68
Parana	9.29	2.16	2.25	2.19	3.97
Brazil	5.56	1.50	3.03	2.01	3.03

The last particular time period is of particular interest because 1996 marks the year in which the Software Park Program was initially started, though without formal planning. Additionally, two years later, then-Mayor Taniguch issued Complementary Degree No.22/98, officially designating the *Programa Software de Curitiba* (Lei Complementara No. 22,1998). This event is without a doubt one of the factors that contributed to the rise in economic growth seen from 1996 to 2000. When Complementary Degree No.64 was issued in late 2007, it also put into action a series of business incentives, such as exemption from the Real Estate Transfer Tax and a ten-year exemption from the Property and Urban Property Tax (Agência Curitiba). Technopark also sustained an incremental rise of economic growth. Specifically, from between 2007 and 2009, Curitiba's per capita GDP increased by an average of .5 points, from $R21 million in 2007 to $R21.8 million in 2009 (Investors' Guide 2010).

Additionally, collaboration between the central business district and local universities has played a significant role in establishing business presence in Curitiba. A notable university is

Pontifícia Universidade Católica do Paraná (Pontifical Catholic University of Parana) (PUCPR). PUCPR has its main campus located inside the logistical ring of Technopark's eastern campus and hosts diverse business and technology programs. Figure 6 indicates a layout of PUCPR's campus.

Figure 6. PUCPR's campus. The Technological Labs and Facilities Complex, Polytechnic School and School of Architecture and Design, Business School, and Technopark are all indicated by red circles. the RIT station for 605 and 208 is indicated by a pink star. Source:PUCPR Brochure

Business degrees offered include, among others, business administration and business management technology (*Pontifícia Universidade Católica do Paraná*, n.d.). PUCPR's Polytechnic School supports a variety of undergraduate and graduate science and engineering

degrees, including, but not limited to, computer science, computer engineering, industrial engineering, information systems, and industrial production management technology (PUCPR).

With their large Business and Polytechnic Schools, PUCPR has played a significant factor in the growth of Technopark by serving as a nexus for cooperation between universities and corporations. For example, in 2008, PUCPR inaugurated a resource and development (R & D) center with the American company Genband. Genband is a software company specializing in Internet communication software (*Planeta Universitario,* 2008). This R and D center became *PUCPR Tecnoparque*, where all companies with base of operations in Curitiba could collaborate with PUCPR faculty and students (Agência Curitiba). Apart from PUCPR, other institutions of higher education encompassed within Technopark districts include, among others, *Universidade Federal do Parana (UFPR)* (Federal University of Parana) and *Universidade Tecnológica Federal do Paraná (UTFPR)* (Federal Technology University of Parana), both of which offer similar degrees to PUCPR. These two universities are also located in Technopark's eastern campus, the former being located in the logistic ring and the latter located in the *Rebouças* industrial park section of Technopark. Currently, economic growth in Curitiba has risen significantly as a result of the presence of the aforementioned universities within the Technopark. In recent years, the Technopark has seen significant growth in clean energy and automobiles, while the Software Park has seen growth in the field of renewable energy. From 2004 to 2014, the Software Park has repeatedly partnered with the German electronics conglomerate Siemens to promote smart grids and energy efficiency. With this significant economic growth comes a need for increased energy production and subsequent consumption.

Comparison of City Layout/Geography and Transportation Compatibility

Located on the San Francisco Peninsula, Silicon Valley is nestled within the Santa Clara Valley, which lies at a low elevation of about 285 m and is adjacent to the low-lying Santa Cruz Mountains to the west (National Park Service; USGS) Being part of the San Francisco Bay Area, Silicon Valley is reliant upon the Bay Area Rapid Transit (BART). BART, like most other urban rapid-transit systems, is a subway. Figure 7 shows the current layout of BART in the Bay Area.

Figure 7. A transit map showing the current infrastructure of the Bay Area's BART system. Source: *The Urbanist*

As the layout indicates, there are currently two main BART lines linking the downtown area of San Jose to the neighboring areas of the Bay Area. Additionally, future BART expansion line lines and future commuter rail lines are being proposed, several of which would travel through other Silicon Valley cities, such as Santa Clara. Figure 8 is a transit map showing the confirmed and proposed additions to the BART system as well as other commuter rail lines.

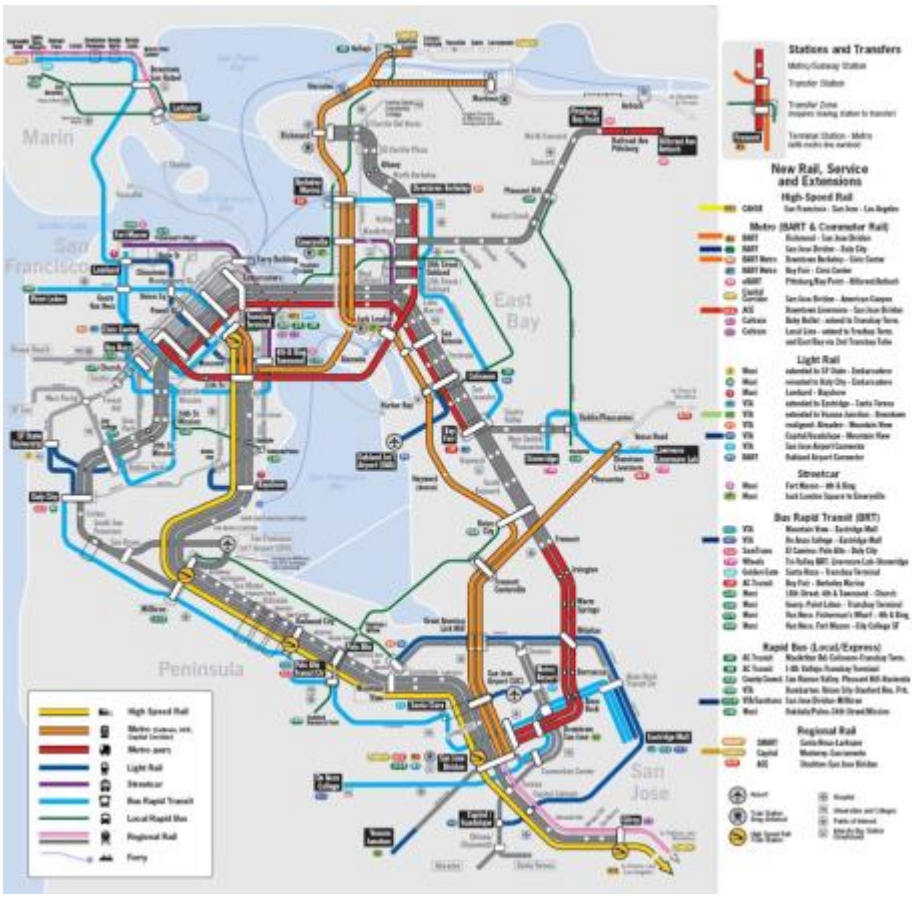


Figure 8. Transit map showing future additions to the Bay Area's BART system. These future additions consist of confirmed future lines as well as proposed, but unofficial, future transit lines. Source: *The Urbanist*

The combination of the existing lines and the envisioned future additions would increase efficiency by increasing transport capacity to the Silicon Valley area. The need for these additions come as a result of the severity of the traffic issues which have plagued the Valley for decades (Meachum 2016). The traffic issue and its relation to Silicon Valley emissions will be discussed in Part III.

Located on a wide plateau adjacent to the *Serra do Mar* mountain range, Curitiba is the largest city and state capital of the state of Paraná. With an average elevation of 934 m, the city is largely flat, which allows for ease in developing a transportation network (Figure 7 displays a topographic map of Curitiba and the surrounding areas). This feature allowed for the evolution of

one of the most sustainable and cost-efficient transportation system in the world: Curitiba's *Rede Integrada de Transporte* (RIT). Figure 9, shown below, provides a transit map of Curitiba's RIT.

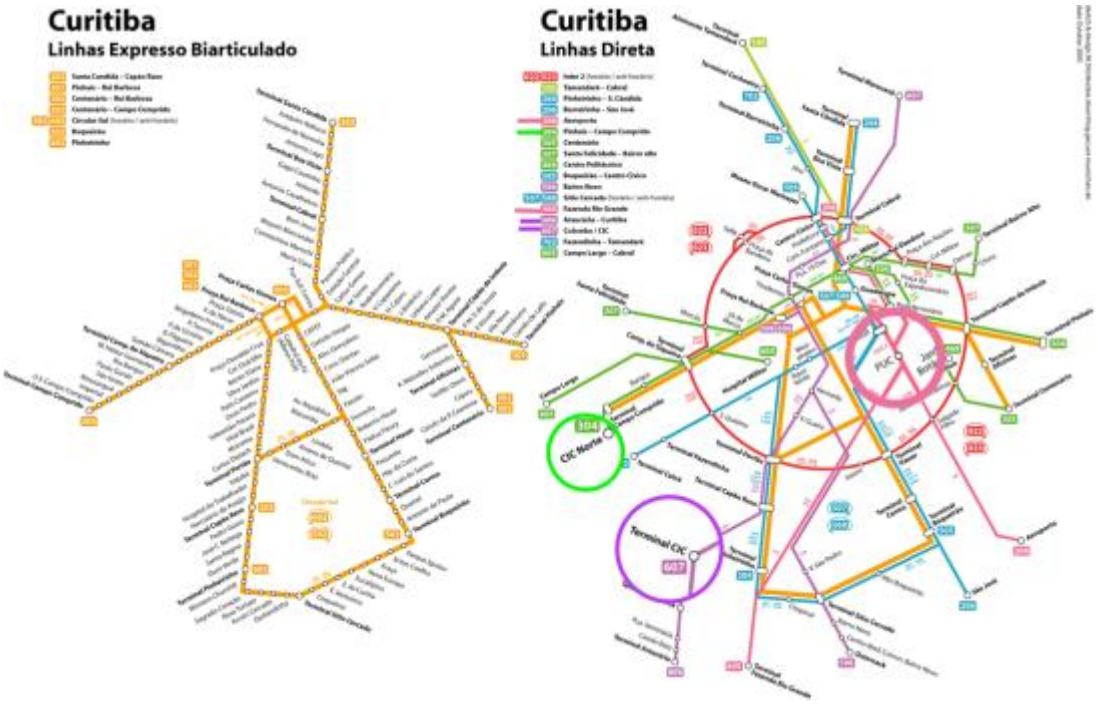


Figure 9. A transit map of the RIT system. Indicated are several terminals and their respective transit lines.

The brainchild of Jaime Lerner, RIT was initiated in 1971, when Curitiba was facing rapid population growth. In order to accommodate the influx of people. RIT was a component of a much larger Master Plan also initiated by Lerner in January 1973 to create a system of sustainable and efficient zoning Curitiban districts (Parasram, 2000). As mentioned, this is when the Industrial City of Curitiba was initiated in the western portion of the city. It also created the core business district, located in the eastern part of the city. The key to the high rate of efficiency was the highly organized linear city growth, which was focused around major roadways in addition to specifically designated land use (Sarasram, 2000). Figure 10, shown below, is a diagram showing the organized

city growth implemented by Curitiba and the disorganized city growth exhibited in cities such as Silicon Valley.

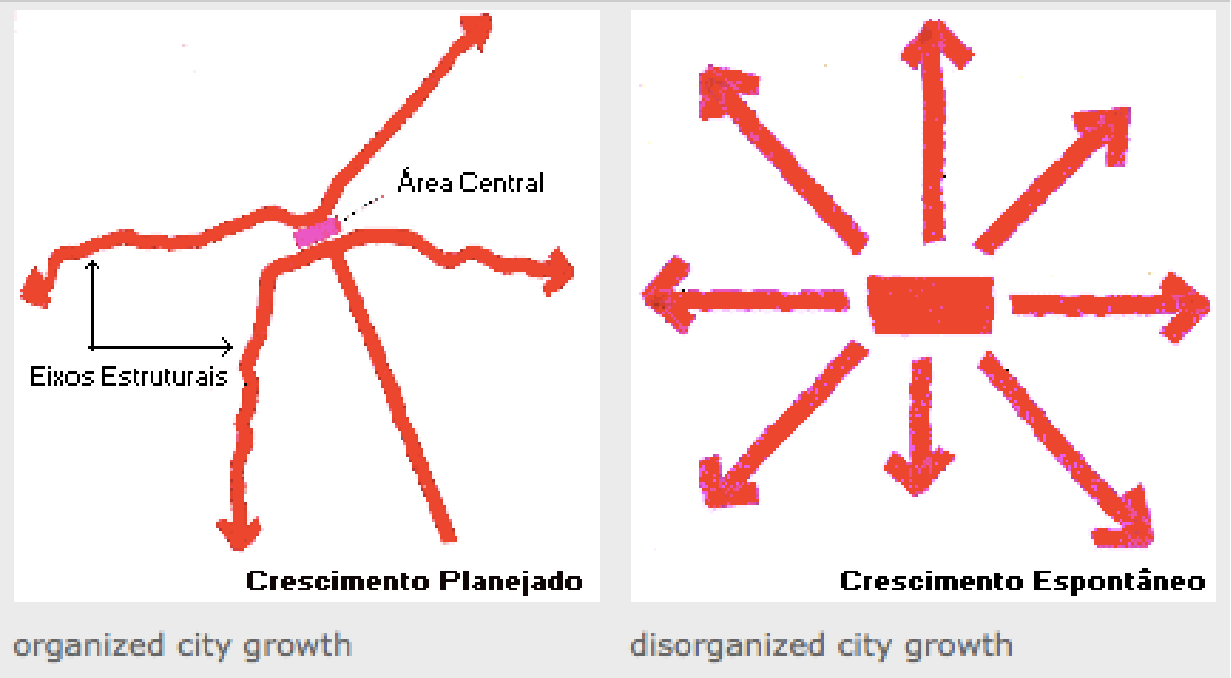


Figure 10. Organized and disorganized city growth models. Curitiba exemplifies the former of these two models. Source: Horizon International Solution Site

Comparison of Energy Infrastructure, Automobiles, and Emissions

In this section, the emissions of both the San Francisco Bay Area and Curitiba will be analyzed. Specifically, the average carbon emissions from automobiles and the source of electricity for each area. Also, information pertinent to transportation systems and/or the physical behavior of emissions in reference to geography/topography from any of the previous sections will also be discussed.

The close proximity to the Pacific Ocean and the low elevation of San Francisco allow for the formation of a Mediterranean climate (Boardsurf California 2016). This climate produces moist atmospheric conditions which for the retention of moisture, the largest contributor in

deciding emission levels for an area (Meixner & Eugster 1999). Furthermore, the Santa Cruz mountains creates allows for the conditions for diurnal sea breezes and nocturnal land breezes (Boardsurf California 2016; Beccario 2017), perpetuating a cycle in which inland winds blow pollution out to sea and offshore winds blow it back out again. Consequently, the Bay Area experiences low wind speeds (San Francisco International Airport 2017), and therefore low emissions dispersal. Greenhouse gas emissions are mainly generated from industry and transportation. For example, in 2007, the Industrial/Commercial Sector contributed to 36.40% of GHG emissions in the Bay Area, while transportation constituted 36.41% (Mangat et al., 2014). Of the industrial sector contribution, oil refining has the largest emissions produced (40% of the total, or 14.2 million metric tons per year) (2014). In 2007, Santa Clara County, which is at the heart of Silicon Valley, had the second highest carbon emissions for both industry and transportation in respect to other districts of the Bay Area (4.7 million metric tons of CO_2 per year for Industry and 7.9 per year for Transportation) (Mangat et al., 2014). As discussed in the previous section, the future expansions of BART routes and additional public transportation serve to mitigate the severe traffic issues. The highlight of these new routes is a high-speed rail line running between downtown San Francisco and Fresno and Los Angeles, which would run right through Silicon Valley (Stokle 2012). Additionally, in 2016 alone, California ranked number-one in terms of Tesla ownership. Furthermore, the metropolitan areas of San Diego, Los Angeles, and San Francisco together have 24,000 plug-in, fully-electric cars (Edelstein 2016). This trend is expected to continue, as the numbers of rebates for electric vehicles in the Silicon Valley area has increased incrementally from 2010 to 2015 (California Air Resources Board Clean Vehicle Rebate Project 2015).

Curitiba's issues with emissions are much less severe than that of Bay Area. Firstly, the city's flat terrain would lead to quick dispersal of emissions (Meixner & Eugster 1999). Second, the low automobile use and low industrial emissions have led to Curitiban greenhouse gas emissions (particularly that of carbon dioxide) ranking among the lowest in Brazil (Boselli et al. 2010). As discussed in the previous section, Curitiba is located on a wide plateau of the neighboring *Serra do Mar* mountain range. The terrain and size of the plateau, because of a low leads to low wind dispersal, and subsequently low emissions dispersal cycle (Meixner & Eugster 1999). Additionally, car use in Curitiba is much lower when compared with other Brazilian cities. Specifically, the city is known to have a car-to-human ratio of .5 to 1 (Boselli et al. 2010). As discussed in the previous section, Curitibans rely far more heavily on the RIT public transport than on automobiles. The emissions production of the RIT buses is also much lower, as many of the buses are now running on biofuels and there is even a step toward fully electric buses (Boselli et al. 2010). As a result of these programs, Curitiba's levels of carbon dioxide (in kilogram per person) are 65% less than the Brazilian average (Boselli et al. 2010).

In both the San Francisco Bay Area and Curitiba and its surrounding area, renewable energy comprises a significant percentage of the energy produced and consumed. In both cities, this reliance on renewable energy comes as a result of suitable geography and innovation.

Between 1980 and the present day, Bay Area growth in alternative energy has seen significant growth. For Santa Clara, at the heart of Silicon Valley in particular, simultaneous investment in natural gas and renewable began long before other cities did so. This helped to facilitate the switch to renewables far more easily than the transition performed by other Californian cities (Silicon Valley Power). Figure 11, shown below, is a timeline showing the energy infrastructure development in Santa Clara County.

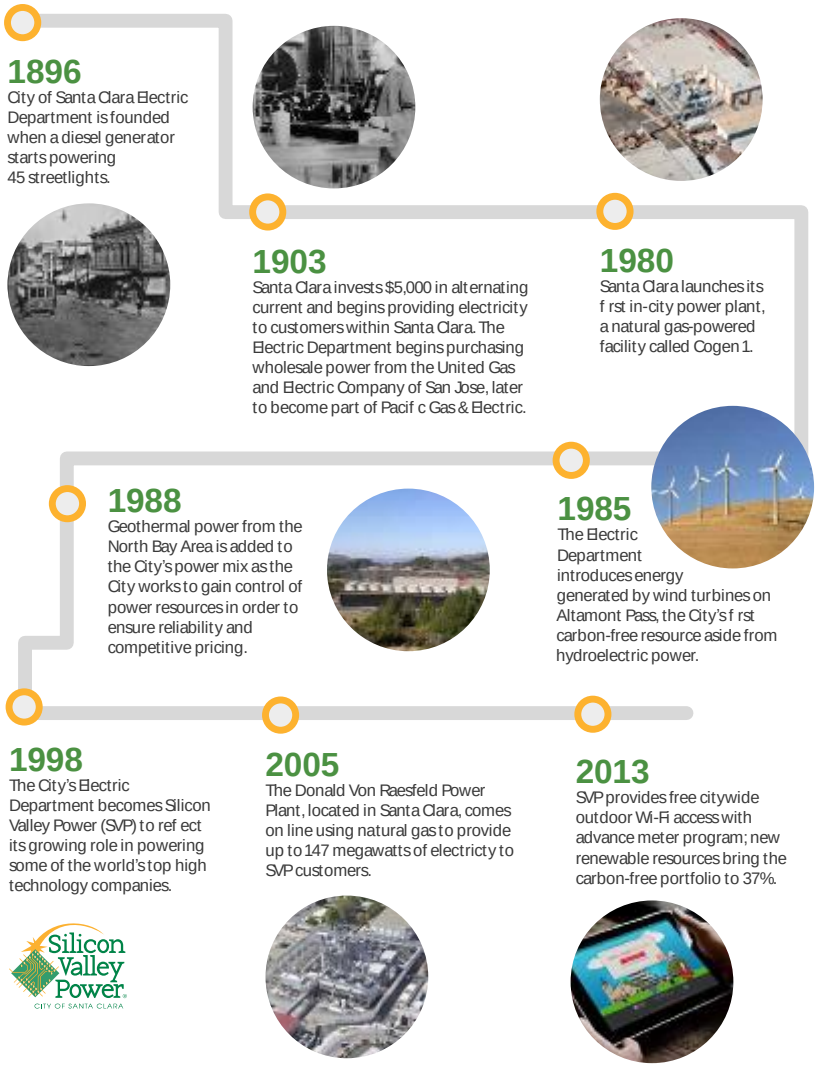


Figure 11. A timeline showing the evolution of Santa Clara County's energy infrastructure from the late nineteenth century to the present day. Source: Silicon Valley Power

In 1965, when the initial stages of the computer revolution were taking place, and would soon form the recognizable Silicon Valley, Santa Clara started to reconcile its energy infrastructure under the supervision of the Northern California Power Agency (NCPA). In 1980, Santa Clara and the NCPA started their first geothermal power plant in the city, with an initial capacity of 115 megawatts. In recent years, one prominent regional energy company has had a profound impact on the energy economy of the Bay Area; Silicon Valley Power, which has many

incentives in place for renewable energy. and among both Silicon Valley residents and non-residential enterprises, installed solar capacity in Santa Clara County has increased incrementally from 2007 to 2016 (Palo Alto Municipal Utilities et al. 2016). Additionally, methane capture and burning, preformed primarily at landfills, has significantly contributed to the continuation of low-emissions (Silicon Valley Power).

Energy production in Curitiba is generated predominantly by renewables as well, specifically hydropower (_____). A total of six rivers transect Curitiba, including the Iguaçu River, one of the seven from which from which electricity is generated. The Iguaçu River is itself a tributary of the larger Paraná River, which has been significantly mitigated over the years. The largest hydropower station along the Paraná is, by far, the Itaipu Dam, the second-largest dam in the world, located in Foz do Iguaçu. (Fanfa 2004) The dam provides 17% of Brazil's renewable energy, which further constitutes around 75% of the country's total energy production (Samek & Garay 2004.) . While much of the electricity generated by Itaipu's twenty generators is transmitted to the metropolitan areas of both São Paulo and Rio de Janeiro, a significant figure of the power supplies Paraná (Fanfa 2004). Curitiba's metropolitan area, which is located much close to the dam than either São Paulo or Rio, is included in Paraná's power grid. With power from Itaipu and other power stations spread out across Paraná, Curitiba has managed to efficiently and effectively provide sustainable and clean energy to power its growing industries. As discussed in Part I, there is also a high rate of investment in clean energy technology in Curitiba, as well as research into that industry being conducted at universities such as PUCPR and UFPR, which serves as an indication that clean technology development is only expected to increase as time goes on.

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Analysis

An analysis of the development of Curitiba and the Silicon Valley districts of the Bay Area, in terms of technology, geography, transportation systems, fuel efficiency, and energy production provides many lessons. Many of the environmental issues (specifically greenhouse gas emissions) can be traced to a predictable source and steps can be put in place for mitigation. In the case of both Silicon Valley and Curitiba, majority of greenhouse gas emissions originate primarily from transportation and energy, albeit in different proportions. While Santa Clara County, the county at the heart of Silicon Valley, has some of the Bay Area's highest emissions, Curitiba has some of the lowest emissions in Brazil. This contrast comes as a result of the difference in the implementation of the two locations' public transportation systems. In Silicon Valley, the implementation of the Bay Area's BART network has been limited, and consequently the use of automobiles and traffic congestion is much is higher than in other Bay Area districts.

In Curitiba, the RIT bus system is extremely efficient, as it not only is composed of different bus lines which traverse the city, but also connect the residents of the city outskirts to the central business district and the industrial parks. The high-technology industries of the two cities factor into the emissions control by serving as a nexus for the development of clean energy and electric vehicles, which, when implemented, can drastically reduce emissions. In both Silicon Valley and Curitiba, there is a high degree of collaboration between high-technology industries and research institutes and universities. This partnership furthers new research and development, helping to solve issues in energy and fuel efficiency and grow the clean technology industry.

Where the two areas differ is the role of the local government in controlling urban growth. In Silicon Valley, municipal and county governments have played a minor role in restraining urban growth in the industrial and corporate districts (Streitfeld, 2016). Curitiba, on the other hand, has maintained a comprehensive Master Plan for decades, which strictly zones particular areas and maintains urban growth in specific directions along primary transportation routes. Additionally, the Master Plan has gone through multiple updates and revisions.

The lessons for city planners who want to assure efficiency are many: First, in both Silicon Valley and Curitiba, collaboration between universities and private companies have been very successful in generating economic and technological development. However, unlike the problems which have faced Silicon Valley such as excessive traffic jams because of BART's limited reach into the area, Curitiba has a high level of efficiency in their public transportation (RIT), which led to a decreased reliance on automobiles. It is also important to point out that Silicon Valley has not efficiently zoned its corporate and industrial districts (Ferenstein 2016), while Curitiba has very specific zoning designations by municipal organizations, which when combined with the RIT system, allow for efficient commuting for Curitibans working in the business and industrial districts.

Curitiba's model of transportation, land zoning, business incentives, and research collaboration has resulted in it being a world-renowned urban planning model. However, this comparison between Silicon Valley and Curitiba has shown that Silicon Valley's issues with traffic congestion and inefficient public transportation should be avoided and that the efficiency of Curitiba's system be embraced, as it will ultimately significantly reduce greenhouse gas emissions.

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