Planning for Low-Carbon Urban Transportation Systems

A thesis submitted by

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Abstract

The ability to move freely within and between cities using a variety of transportation modes has greatly enhanced Americans' quality of life but has come at a grave cost to the climate and to public health. The transportation sector in the United States accounts for more than a quarter of all greenhouse gas emissions and is the fastest growing contributor to climate change. It is imperative that transportation emissions level off and begin to decline within the next decade to reach climate goals. Cities across the country have committed and begun to implement climate action plans, all of which include goals for reducing transportation emissions. This thesis explores how urban areas are planning for low-carbon transportation systems by focusing on five U.S. cities to gain an understanding of existing plans and policies to reduce urban transportation emissions, as well as the associated challenges and opportunities therein.

“Next to the air we breathe, or the food we eat, no one thing in city life touches so vitally the comfort and interest of every citizen, of every condition, in every calling, every day, as this question of city transit.” — Sanford E. Church, 1871

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Chapter 1: Introduction

At the Paris Climate Accord in December 2015, 196 countries agreed to reduce greenhouse gas (GHG) emissions in a broader commitment to limit the anthropogenic warming of the planet. On June 1, 2017, the United States voluntarily withdrew from this historic agreement, setting into motion a wave of climate-related commitments from over 1,400 independent U.S. cities, states, and businesses. Together, these commitments represent a 14% reduction in emissions by 2025, which is approximately half of the original U.S. pledge (Kuramochi et al. 2017).

To meet such ambitious goals, cities (which are the largest GHG contributing geographic entities) will need to tackle the fastest growing contributor to greenhouse gas emissions: the transportation sector (Sivak and Schoettle 2016, Bloomberg 2017, C40 Cities 2018). Cities are uniquely positioned to tackle transportation emissions given that residents typically have a suite of transport options from which to choose, when compared to rural areas. And yet, passenger vehicles are still persistent fixtures in urban settings. As cities begin to tackle their own unique climate goals and emissions reductions, a transformation to a low-carbon transportation system is of the utmost importance (Williams 2013). Each urban climate action plan includes goals and policy actions aimed at reducing transportation emissions, such as incentivizing the use or purchase of electric/alternative fuel vehicles; enhancing bicycle and pedestrian infrastructure networks; and encouraging residents to use public transportation. But to what extent do these plans include immediate action and implementation?

How coordinated are cities across agencies that are charged with working on climate action? Are cities galvanized into action by any particular, immediate co-benefits? What barriers to implementation need to be addressed?

The focus of this thesis is on five U.S. cities: Boston, MA; Washington, D.C.; Columbus, OH; Denver, CO; and Seattle, WA. Cities were selected based on whether they have released climate action plans; have mayors that committed to the Paris Climate Accord; and are geographically representative of U.S. cities with populations between 600,000-800,000. The approach specifically examines emissions reduction goals from the transportation sector through case studies of climate action plans and interviews with city staff to build a well-rounded snapshot of the climate-related urban transportation landscape.

The remainder of this thesis contains six chapters. Chapter Two is a literature review that seeks to provide detailed background information on the relationship between the transportation sector, climate and public health. The literature review explores three key themes: first, the correlation between land use, urban form and transportation emissions; second, the existing co-benefits associated with reducing transportation emissions; and third, the policies that have been successful in driving down transportation emissions. Chapter Three explains the detailed methods through which case study cities and interview participants were selected. Chapter Four contains the results of the research, categorized into five themes: first, that there exist both disconnects and overlaps between traditional urban planning and climate action planning; second, across all the case study cities, there exist similar barriers to further investment in low-carbon

transportation systems; third, most of the case study cities share enthusiasm over two specific co-benefits of reducing transportation emissions— the opportunity to enhance air quality and public health, and the opportunity to reduce vehicle congestion; fourth, all five case study cities share a commitment to integrating equity into the transition to low-carbon transportation but have done so at varying levels of success; and fifth, almost all the case study cities recognize that new mobility models and emerging technologies may require new, expanded partnerships with the private sector.

Each city faces unique challenges in mitigating and adapting to climate change. While they may employ different techniques and incentives to reach their goals, cities have the ability to learn from shared experiences and challenges. Ultimately, the urgent need to transition to low-carbon forms of transportation necessitates an unprecedented level of political will; creative solutions from a wide array of stakeholders; and attractive alternatives to the existing car-centric status quo.

Chapter 2: Literature Review

The need to address the anthropogenic warming of the planet has spurred action at every level of national and international government. Over the past 40 years, global urban population grew from 1.51 to 3.91 billion people and is expected to reach 6.3 billion by 2050 (Gately et al. 2015). Cities are the single largest contributors to climate change, and as the world's urban populations continue to grow, so too will emissions if left unchecked (Williams 2013). According to a March 2018 analysis released by the Cities and Climate Change wing of the Intergovernmental Panel on Climate Change (IPCC), cities emit 60% more carbon than previously thought (C40 Cities 2018). The analysis takes into account goods and services consumed by urban residents that are produced outside the city itself, such as food and clothing. This enhanced method of compiling a greenhouse gas inventory deeply underscores the urgency with which cities will need to reduce emissions in order to both mitigate and adapt to climate change. The United States— the second largest contributor to greenhouse gas emissions worldwide— has been slow to enact federal level regulations to reduce emissions (Deakin 2011; World Resources Institute 2017). States, cities and other sub-federal actors, however, have filled the void by committing to, or adopting, their own plans, regulations and programs that aim to cut emissions from various sectors.

Among U.S. states overall, the transportation sector is the fastest growing contributor to greenhouse gas emissions (Sivak and Schoettle 2016; Bloomberg 2017). The transportation sector surpassed the electric power sector in terms of

total emissions for the first time in 2016— partially due to years of de-carbonizing efforts in the electric sector (see Figure 1 below). In 2017, the transportation sector secured its lead once again the largest emitter of greenhouse gas emissions across all sectors (Houser et al. 2018).

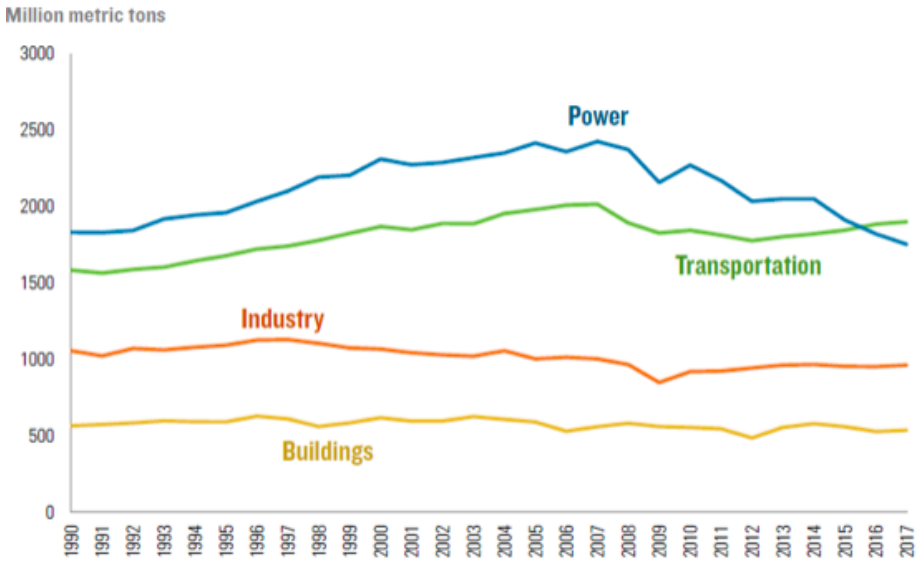

Figure 1: Emissions from the transportation sector exceed those of the electric power sector (EIA 2017)

Simultaneously, annual vehicle miles traveled (VMT) in the U.S. have been steadily increasing, with 2016 on record as the largest annual increase since 1971 when the U.S. Federal Highway Administration started tracking VMT (see Figure 2 below) (U.S. Federal Highway Administration 2016). In 2016, the country's cars, trucks, planes, trains and boats emitted 1.879 billion metric tons of CO2 compared to 1.821 billion metric tons of CO2 from the electric power sector (IEA 2017).

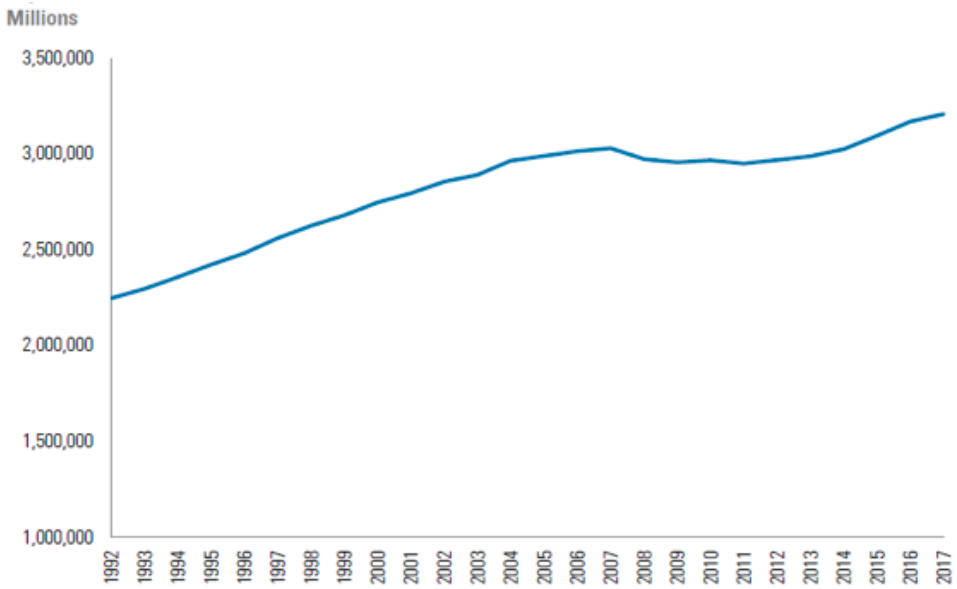

Figure 2: Annual vehicle miles traveled in the U.S. steadily increasing (DOT, Rhodium U.S. Climate Group 2018)

The highest proportion of transportation-related greenhouse gas emissions stem from the personal vehicle— a trend that has consistently grown over the last several decades. Between 1990 and 2003, the greenhouse gas contribution from passenger cars and light-duty trucks in the U.S. increased from 63.8% to 65.0%, and there are few signs that this trend will slow (Sivak and Schoettle 2016). In 2017, Americans purchased 17.25 million cars and trucks, two-thirds of which were trucks and SUVs (Lassa 2018). A growing body of evidence suggests that U.S. states and cities will be unable to reach their climate goals unless emissions from the transportation sector level off within the next decade and then rapidly decline (Dillon 2017; Miotti et al. 2016).

There is no dearth of literature on the transportation sector and its relationship to greenhouse gas emissions, climate change and human health. Broadly speaking, three key themes emerge across the academic literature, all of which can be segmented into further topics for exploration. First, urban form and

land use planning are correlated with transportation emissions. The literature links the need to densify urban areas in order to reduce total vehicle miles traveled (VMT), while recognizing that densification and transit-oriented development often lead to inequity and environmental justice concerns (Zahabi et al. 2012; Rosiers et al. 2016; Handy et al. 2005; Tayarani et al. 2016). The second theme is that a reduction in transportation emissions not only cuts climate change greenhouse gas emissions, but also leads to myriad co-benefits. These benefits include enhanced air quality and less vehicle congestion, among others (Haines et al. 2009; Cifuentes et al. 2001; Xia et al. 2013). The third theme is that there exists a suite of planning and policy options already available that work to drive down emissions (Williams 2013; Chapple 2016; Hymel 2014; Anas et al. 2011). This literature review will focus on three specific existing policies: enhancing active transportation infrastructure; congestion pricing; and deployment of electric vehicles. The remainder of the literature review will follow the four themes sequentially.

2.1 Relationship Between Land-Use and Transportation Emissions

There exists a strong relationship between urban form and transportation emissions. Greenhouse gas emissions that stem from the daily transport of individuals are complex, dynamic and vary by city— but there is no question that densification is directly correlated with a decrease in fuel and emissions (Rosiers et. al 2016, Zahabi et al. 2012). Myriad studies have statistically analyzed the relationship between the built environment and transportation emissions employing a variety of methods such as using disaggregate trip data at the

household level, or census data combined with origin-destination surveys and land use records. Rosiers et. al (2016) note that studying travel behavior must take into account infrastructure options and land use dimensions, as well as individual behavior.

While there is consensus that densification is the primary land use tool with which to reduce emissions, the literature makes clear that further exploration is necessary to determine whether neighborhood design influences travel behavior or if travel preferences influence choice of neighborhood (Handy et al. 2015, Deakin 2011). Compounding this largely unexplored research area is the rising lack of affordability in urban city centers. Densification may be successful in reducing emissions, but it exerts an adverse direct effect on the housing burden, which in turn can lead to further sprawl (Rosiers et al. 2016). The implications of densification on equity are thus crucial to take into account when considering urban solutions to transportation emissions. This highlights the intersectionality of transportation and housing, and the stark reality that no single problem is isolated in origin or solution.

Rowangould (2013) further touches on the issue of equity in an exploration of the uneven distribution of vehicle emissions: minority and low-income populations tend to live clustered near major, high-trafficked roads and highways, which puts them at a higher risk of pollution-related illnesses. The study found that very few air quality monitors used to enforce national air quality standards are located near highway road populations. Smart growth strategies can also inadvertently redirect emissions to another area of a city, as those at the city

core move outward due to affordability issues (Tayarani at al. 2016). Thus, careful attention must be paid to *where* emissions reductions take place and which neighborhoods should be prioritized when it comes to reducing emissions and enhancing air quality. Transportation as a regional network is very much interconnected with the availability of affordable housing and the cost of living in city centers. This suggests that efforts to reduce transportation emissions should not exist in isolation of other pressing social and economic concerns.

2.2 Co-Benefits of Reducing Transportation Emissions

There exist myriad social, health, environmental and economic benefits associated with reducing transportation emissions. These benefits include enhanced air quality; less vehicle congestion; fewer instances of asthma and other respiratory diseases linked to air pollution; and fewer days missed of school and work (Haines et al. 2009; Cifuentes et al. 2001; Xia et al. 2013). By working to reduce transportation emissions through climate mitigation efforts, municipalities will also witness immediate climate adaptation benefits. Enhanced local air quality and public health lead to not only a better quality of life, but also to a reduced burden on the medical system, reduced healthcare costs for individuals, and a redirection of those funds into other local sectors of the economy. It is key to understand that transportation is not only a climate change issue but also a health issue.

2.2.1 Enhanced Air Quality

Combustion of gasoline is highly correlated with negative local health outcomes and a reduction in air quality. Health impacts associated with

transportation emissions are well documented (Haines et al. 2009, Xia et al. 2013). During the process of combustion, motor vehicles emit black carbon, particulate matter, ozone, nitrous oxide, and methane— all of which contribute to respiratory illnesses and preterm births. In 2015, air pollution killed more than 155,000 Americans (Di et al. 2017). Exposure to high levels of air pollutants effects everyone, but a plethora of studies have shown that low-income populations, young children and the elderly are disproportionately impacted (Friel et al. 2011, Pervin et al. 2008). A new study published in the New England Journal of Medicine reaffirms the strong correlation between mortality and exposure to ozone and particulate matter, both of which arise as a result of conventional transportation (Di et al. 2017). This study also focused on minority groups and persons of lower socioeconomic status, as most previous studies traditionally did not include populations that were representative of transportation-related pollution impacts. Di et al. conducted a nationwide cohort study of individuals who received Medicare between 2000 and 2012 (61 million people) and used a survival analysis to estimate mortality from long-term exposure to particulate matter concentrations *lower* than the current national standards. The authors note that even though the study only included people above age 65, two-thirds of all deaths in the U.S. occur at age 65 and above. The authors found that for Medicare recipients, long-term particulate matter exposure is associated with increased risk of death even at levels below current national standards for suitable intake, highlighting a need for enhanced air-quality

standards that protect the most vulnerable members of the population (Di et al. 2017).

Mortality and respiratory illnesses are not the only well-documented health impacts related to transportation emissions. Particulate matter and nitrogen oxide exposure present serious risks to pregnant women, leading to preterm births, low birth weights, and in many cases, infant mortality. Trasande et al. (2016) estimate that 3.32% of preterm births in the U.S. can be attributed to particulate matter associated with transportation emissions. The economic cost of preterm births is significant: $760 million was spent on medical care for preterm births in 2015. These are just a few examples of the negative externalities associated with transportation emissions. Much work has been done to document other respiratory effects, but none of these negative health impacts are accounted for in the cost of gasoline or in the cost of purchasing a conventional vehicle. As congestion in and around metropolitan areas increases, the pollution-related health outcomes will only worsen for those both near roadways and those in the vehicles.

2.2.2. Reduced Congestion

Vehicle congestion, or traffic, is a ubiquitous urban problem. It occurs when a road or road system approaches vehicle capacity (Levy et al. 2010). The number of hours that an individual lost annually in the U.S. due to congestion nearly doubled from 1982 (16 hours/year lost) to 2011 (38 hours/year lost) (Schrank et al. 2012). This trend correlates with steadily increasing vehicle miles traveled annually. Recent data show that congestion causes a total of approximately 5.5 billion hours of travel delay annually in the U.S., and 2.9

billion gallons of extra fuel consumption (Schrank et al. 2012, Fosgerau and de Palma 2013). Fuel consumption while sitting in traffic amounts to lost dollars that consumers in the U.S. could be spending elsewhere, as well as lost work or leisure hours. The associated emissions are also problematic for both health and environmental reasons. Excessive congestion therefore leads to both negative economic and environmental health outcomes. Traffic data suggest that solutions to congestion are not aggressively pursued (Schrank et al. 2012).

Large regional, metropolitan economies tend to increase congestion, while congestion tends to impede economic activities. In an attempt to understand the economic impact of congestion, a 2014 study used panel data from 88 U.S. metropolitan statistical areas to estimate the impact of congestion on employment growth and worker productivity (Sweet 2014). The author found that high levels of congestion are associated with a decrease in job growth rates, but that there was no evidence to support that congestion negatively impacts productivity growth per worker (Sweet 2014). The results suggest that certain policies may be instrumental in alleviating congestion, specifically peak-period road pricing (discussed in the next section).

Perhaps more problematic even than the economic impact of congestion is the environmental and health impact. As vehicles sit in traffic and combust fuel, a high quantity of emissions are released and accumulate at ground level as well as contribute to climate change greenhouse gas emissions in the atmosphere. Vehicles contribute more than one-third of ambient air particulate matter in urban areas, leading to increased health damages, particularly for those who live near or

along freeways and highways, as discussed above. Levy et al. (2010) used a health risk assessment to evaluate the public health impacts of exposure to ambient particulate matter by evaluating 83 individual urban areas. The authors conducted their study under a business-as-usual scenario of predicted traffic congestion and found that particulate matter-related mortality due to congestion was approximately $31 billion in the U.S. in 2000 (Levy et al. 2010). These findings make clear that the health damages associated with congestion may be significant enough to include in future policy scenarios to reduce vehicle congestion and emissions.

Another study analyzed the health and environmental impact of converting car commutes to bicycle commutes in Stockholm, Sweden. The authors found that mean population exposure to both NOx and black carbon would be reduced by 7% if all residents who live within a 30-minute bicycle commute switched from car to bicycle as their primary mode. This decrease in NOx and black carbon corresponded to more than 449 years of life saved annually for the 2.1 million Stockholm residents (Johansson et al. 2017). The additional public health benefits of switching to active transportation are discussed in detail in the next section.

In sum, the literature illustrates that there exist several negative externalities associated with excessive vehicle congestion. By introducing policies to reduce transportation emissions to reach climate goals, cities will experience important co-benefits, including reduced vehicle congestion. Economic signals such as pricing and taxes can help incentivize drivers to seek alternate modes of transport.

2.3 Exploration of Policies that Drive Down Transportation Emissions

There exist a wide range of policy tools with which to reduce transportation emissions. The effectiveness of each tool is contingent upon local conditions, and thus these should not be taken as universally adaptable solutions. This literature review focuses on three specific tools to reducing transportation emissions in municipal areas. First, cities can work to enhance active transportation infrastructure. Better sidewalks and bike lanes can encourage more trips taken using these modes, while simultaneously benefitting public health. Second, cities can enact congestion pricing or low emission zones, which have proven to be successful in certain areas around the world. Market signals such as taxes and road pricing have an impact on behavior. And third, states and cities can harness the growing potential of electric vehicles, both as tools for residents and as tools for municipal vehicle fleets. Electric vehicles alone will not solve the problem of congestion, but since it is likely that individuals will continue to drive cars in some capacity, it is crucial that cities work to encourage deployment of cleaner vehicles. While myriad tools exist at both the federal and state levels to ease the transition from conventional cars to electric ones, there are still many barriers to mass electric vehicle adoption.

2.3.1. Enhancing Active Transportation Infrastructure

A mode shift to active transportation (walking and bicycling) naturally achieves a reduction in the number of trips taken in a vehicle, and thus reduces emissions. But the impetus for enhanced active transportation is often linked and attributed to public health and transportation planning motivations, rather than

climate motivations. Woodcock et al. found that emissions reductions can be achieved through technological improvements (such as electric and hybrid vehicles), but that these improvements have an overall smaller impact on health than do active transportation policies (Woodcock et al. 2009). This is an important policy implication given that the majority of policies to reduce urban transportation emissions focus on electrifying vehicles. While electrification is still a key tool, there may exist more room for emissions reduction policies to incorporate active transportation as a tool, especially considering that vehicle electrification does not address the issue of traffic congestion.

The benefits of increased walking and cycling can be evaluated both quantitatively and qualitatively. On a quantitative level, it is possible to estimate the amount of money saved due to reduced healthcare costs associated with inactivity, as well as environmental benefits (Rabl et al. 2012, Woodcock et al. 2009, de Hartog et al. 2010). On a qualitative level, communities that witness an increase in the number of people walking and bicycling may experience positive impacts such as increased social cohesion, a sense of wellbeing, increased economic activity and in some cases a decrease in crime (Rabl et al. 2012).

Prevalence of physical inactivity and the associated burden of chronic disease can both be mitigated by increasing walking and cycling (Woodcock et al. 2009). By walking and cycling, a person reduces their chance of premature morbidity, reduces the likelihood of coronary heart disease, stroke, hypertension, and type 2 diabetes (Rabl et al. 2012). Physical activity is also associated with lower rates of cancer and improved mental health (U.S. ODPHP 2008). In some

cases, cycling as a primary mode is not feasible due to long distance commutes, but when it is possible, tremendous benefits occur.

Rabl et al. (2012) estimate the monetary impacts that could arise as a result of a shift from driving to work five days/week to cycling to work one-way five days/week. Using the health benefits of walking and cycling based on the most recent World Health Organization review, the authors found that for an individual who switches to cycling three miles (five kilometers) one-way to work five days/week, 46 weeks/year, the health benefits are equal to about $1,600/year. The estimated value of reduced air pollution due to the removal of that one car from the road part of the week is approximately $37/year (Rabl et al. 2012). Overwhelmingly, the greatest impact of a shift to active transportation is the health benefit, but on a larger scale, the benefit begins to shift to climate goals as air pollution steadily decreases.

Evidence on the effectiveness of implementing policies that encourage an increase in walking and cycling is limited, but some preliminary studies link an increase in active transportation with successful policy and advocacy measures. As previously mentioned, achieving systemic change within the existing, car-centric transportation system requires a level of commitment and sustained effort not often accomplished by cities. Chapman et al. (2014) reinforce this idea and note that efforts to change long-standing and complex behavior patterns in the face of social, economic and environmental forces is extremely difficult. Nonetheless, there exist steps that policymakers, planners, advocates and coalition groups can take to encourage increased active transportation such as adopting

complete streets ordinances, seeking community input on bike lane infrastructure, and prioritizing projects that enhance the pedestrian environment.

2.3.2. Congestion Pricing

One of the most promising solutions, yet often least utilized, to reduce transportation emissions is congestion pricing. Simply put, congestion pricing relies on market forces—the price mechanism—to reduce travel demand and congestion at peak times. In economic terms, if road space is unpriced, traffic will increase until congestion limits further growth (Litman 2011). Congestion pricing has proven to be successful in reducing vehicle trips in cities such as London (Broaddus 2015, Liu 2014). But in many other places around the world—including New York, Hong Kong and Copenhagen— the policy concept has run into political roadblocks (Broaddus 2015). Few individuals want to pay more tolls or taxes, and drivers who rely on driving to commute to work thus tend to vehemently oppose congestion pricing. The lack of congestion pricing in many cities is often a question of political will.

In 2000, Ken Livingstone won the mayoral race in London on a platform that included, among other things, congestion pricing and implementation (Litman 2011). Initially the plan was highly criticized by politicians, motorist groups and other various interest groups. Since implementation, though, the policy has seen success. The number of cars that enter London city center each day decreased by 44%, even as the total number of people entering grew by 23% (Komanoff 2017). Recent data also show that without the congestion pricing scheme in London, travel speed would be one-fifth to one-third slower—a

tremendous amount of time and money saved by residents. By funneling revenue from congestion pricing into transit expansion, London experienced economic and population growth without an associated increase in emissions from vehicle trips.

It is important to note that congestion pricing does not necessarily always have a direct causal relationship with emissions reductions, and most studies cannot say with certainty that London's congestion pricing scheme resulted in a significant emissions decrease. One study did find a reduction in three of the most common tailpipe pollutants (carbon monoxide, particulate matter, and nitrous oxide), but also found an increase in nitrogen dioxide (Ryan 2018). The increase in nitrogen dioxide, though, was likely due to an increase in the number of diesel vehicles. This point highlights that there is no single policy solution that can work alone to reduce emissions. Congestion pricing may be more efficient to reduce gridlock traffic but may not be the best solution to slash emissions. It is crucial that cities look to complementary policies that can holistically address transportation emissions.

Given the political challenges that are also associated with congestion pricing implementation, some studies suggest cities focus on parking prices as a way to reduce travel demand (Fosgerau and de Palma 2013). Studies have shown that increasing the price of parking leads to a decrease in the number of cars idling while looking for a place to park and can also lead to a mode shift to transit. One recent study analyzed parking costs in 107 U.S. cities and found that transit ridership in larger cities increased by 2.3 times as a result of higher parking costs (Auchincloss et al. 2014). Altering the price of parking may indeed be more

politically feasible in the short-term but given the urgency with which cities need to reduce transportation emissions, a longer-term vision that includes congestion pricing may be necessary.

2.3.3. Encourage and Incentivize Deployment of Electric Vehicles

The technology and momentum surrounding electric vehicles continues to accelerate at an impressive rate. Largely driven by innovation in the private sector, global car companies have announced more than $70 billion in planned investments into electric cars and batteries since 2017 (Colias and Spector 2018). Across the world and within the U.S., policymakers increasingly view electrification of the transport sector as one of, if not the most, crucial steps in reducing emissions. Electric vehicles present an opportunity to not only reduce climate-change related tailpipe emissions, but also to help achieve energy security, improve air quality and increase energy efficiency (Nanaki and Koroneos 2016). While the benefits of vehicle electrification abound, there exist several significant barriers to their continued deployment. These barriers include: a larger up-front cost; lack of sufficient charging infrastructure and models; and lack of consumer education. The next section will explore the benefits of electric vehicles before moving on to address some of the barriers.

There exist myriad benefits associated with introducing electric vehicles into the larger mix of conventional vehicles. First, electrification leads to petroleum displacement. Conventional U.S. passenger vehicles are 97% dependent upon petroleum to operate, over half of which is imported (Skerlos and Winebrake 2009). A recent analysis from Bloomberg New Energy Finance found

that by 2028 electric vehicles are expected to displace two million barrels of oil per day (BNEF 2016). The represents enormous potential for greenhouse gas reductions in connection with the transportation sector. Of course, the emissions associated with an electric vehicle are highly dependent upon the mix of fuels used to generate electricity. The average new car in the U.S., assuming it achieves approximately 29 miles per gallon of gasoline, emits about 400 grams of carbon dioxide per mile; an electric vehicle using an *average* mix of U.S. power generation sources (coal, natural gas, nuclear and renewables) emits about 300 grams of carbon dioxide per mile, or 25% less than a conventional vehicle (Union of Concerned Scientists 2015). On the cleanest electric grids (i.e. some parts of California and New York), electric vehicles result in cutting emissions by 70% or more— and this figure is only improving (Union of Concerned Scientists 2015). In Massachusetts for example, an increase in the mix of renewable energy resources and natural gas combined with a decrease in coal to power the electric sector has led to a cleaner grid.

Electric vehicles represent an opportunity to witness cost savings over the lifetime of the vehicle due to reduced fuel costs and maintenance. At a gas price of $2.50/gallon, the savings translate to $3,500 over the car's life, and at $3.50/gallon, the savings increase to $9,000 (Utility Dive 2018). Oil prices are incredibly volatile and dependent upon the global market. The ability to rely on locally sourced, cleaner energy to power not only buildings but also vehicles represents an opportunity for energy independence, reduced emissions, and greater predictability in energy costs. In addition to cost savings related to fuel,

electric vehicles also save money thanks to decreased maintenance costs. A battery electric vehicle has only one moving part— the electric motor. They also have simpler transmissions and do not require fluid replacement (Midwest EVolve 2018).

The maintenance cost savings could be significant with a switch to electric vehicles. According to AAA's annual "Cost to Own a Vehicle" report, average annual ownership cost for a conventional vehicle (which includes fuel, maintenance, insurance and depreciation) amounts to $9,122 annually, assuming 15,000 miles of driving (AAA 2017). The size of a vehicle corresponds with the annual ownership cost: a pickup truck costs approximately $10,054 annually to own, whereas a small sedan costs approximately $6,354 annually to own (AAA 2018). In contrast, an electric vehicle costs approximately $8,439 annually to own, but this cost takes into account the typically higher up-front cost to purchase the vehicle (AAA 2018). The overall cost to fuel and operate an electric vehicle is much lower than a conventional one due to fuel-cost savings and reduced maintenance. The average EV owner will save approximately $770 annually on fuel costs (Reichmuth 2017).

Despite the many promising benefits associated with electric vehicles— which still only represent 1% of all on-road U.S. cars— several significant barriers still exist. First, despite the available federal and state rebates, tax credits, as well as a lower life-cycle cost, electric vehicles cost more up-front than conventional vehicles. This is largely due to the cost associated with battery production. However, due to economies of scale and increased efficiency, the cost

of batteries is rapidly declining. By 2025, Bloomberg New Energy Finance estimates that electric vehicles will reach up-front cost parity with conventional vehicles in the U.S. and Europe (Shankleman 2017). The Bloomberg analysts expect battery prices to fall by 77% between 2016 and 2030 (Shankleman 2017). However, this doesn't help solve the immediate cost barrier. A shift to electric vehicles will be a slower transition but represents an important medium- and long-term strategy for slashing emissions from the transportation sector. Ensuring that electric vehicles are accessible and benefit all, regardless of income level, is an ongoing challenge. Skerlos and Winebrake (2010) note that subsidies for electric vehicles would have higher social benefits if the tax credits were offered at different levels depending on income and location of purchase, or if the subsidies came in the form of direct rebates either for the dealer or at the point of purchase for the buyer.

A second barrier associated with electric vehicle uptake is the lack of sufficient charging infrastructure and lack of sufficient model variety from which to choose (Madina et al. 2016). For example, if 500 million electric vehicles went on the roads tomorrow, the world would have to spend $2.7 trillion on charging infrastructure (The Download 2017). The question of responsibility thus arises: should governments— that seek to reach climate goals and reduce transportation emissions—invest in charging infrastructure to incentivize greater electric vehicle use? Or does the responsibility fall to the private sector, whose innovation led to the existence of this new vehicle technology? Several studies point to the potential for public-private partnerships as an effective path for advancing charging

infrastructure (Yang et al. 2016, Madina et al. 2016). In any case, private charging companies must work with municipalities in some capacity to determine the optimal locations for infrastructure. For example, in a neighborhood where the majority of houses have private garages and/or chargers, a public charger might not make sense. Rather, putting a public charge point closer to multi-unit dwellings or as a street-parking option may be a better use of resources. Much work has yet to be done on this front across the country and across the globe. A recent study also pointed out that a lack of electric vehicle models inhibits consumers from purchasing them. The analysis, based on the European car market, showed just 20 battery models compared to more than 400 conventional ones (Vaughan 2018). Projections and commitments by individual automakers drastically increase the total number of electric models available, but again it will take time before these vehicles achieve mass market penetration.

The last notable barrier is lack of consumer education on electric vehicles. Preliminary data collected on automobile advertising in 2015 by the Northeast States for Coordinated Air Use Management (NESCAUM) demonstrates a drastic difference in the dollars spent by car companies marketing conventional vehicles versus electric vehicles. As an example, Ford Motor Company advertised its conventional Ford Focus 4,750 times on national cable TV in 2015, while it only advertised it Ford Focus Electric 200 times (Coplon-Newfield 2016). Data from the Union of Concerned Scientists also show that the automobile industry restricts its electric vehicle inventory, and that depending on location in the U.S., one may not ever be exposed to an electric vehicle. As of 2015 in California, drivers could

choose from 22 different electric vehicle models at dealerships, while drivers in six other states had zero options (Reichmuth and Anair 2015). The study also found the difference between metropolitan areas to be even more stark: between January and June 2016, Boston had 90% fewer electric vehicle listings at car dealerships than Oakland (Reichmuth and Anair 2015). And yet according to a Consumers Union survey, interest in electric cars was virtually the same between California and the Northeast. This all goes to show that cities, if committed to reducing transportation emissions, can take concerted action to inform residents about the benefits and opportunities of switching to electric vehicles. Cities also have a role to play in ensuring that education about this relatively new technology is accessible and equitably disseminated. As time progresses, new incentive structures may come into existence, accelerating this important trend.

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The effects of transportation emissions on the environment and public health are well-documented across academic literature and the solutions are not insurmountable, as demonstrated by the many policy options available to cities. Why, then, has the shift to low-carbon transportation been so slow at a time when it is crucial to scale back these emissions? What other political, social, environmental and economic factors are at play? It is critical to examine work being done on the ground across the U.S. to determine how much progress cities have made in reducing transportation emissions, understand the opportunities and challenges, and look for ways in which cities can share in the learning experience.

Chapter 3: Methods

The goal of this thesis is to examine existing trends in reducing urban transportation emissions and to identify the most salient opportunities and challenges therein. Nationally, transportation is the fastest growing contributor to greenhouse gas emissions (Sivak and Schoettle 2016, Bloomberg 2017, Houser et al. 2018). Among U.S. cities committed to climate action plans, how do they plan to tackle emissions from the transportation sector? What types of plans and policies are already in place and what are the barriers to further investment? Do cities see potential co-benefits of reducing transportation emissions? The methods for this thesis involve case studies of climate action plans for five U.S. cities and interviews with relevant city staff, described below in more detail.

The case studies serve to highlight the ways in which cities intend to reduce greenhouse gas emissions, specifically from the transportation sector. No two cities face the same set of challenges, and thus, the case studies highlight the uniqueness and complexity of each case, while noting any similarities and ways in which cities can learn from each other (Stake 1998). The purpose of the interviews is to triangulate, or validate, the information gleaned from case studies (Johansson 2003). The researcher utilized the interviews to delve deeper to learn how much progress has been made, as well as gain an understanding of the challenges and opportunities inherent in the implementation of transportation related climate plans.

3.1 City Selection Process

Case study cities were selected using four criteria. The first criterion was that a city be formally committed to the Paris Agreement through the U.S. Climate Mayors alliance (392 U.S. mayors representing 69 million Americans) (Climate Mayors 2017). The second criterion was based on population size: the researcher focused on midsize cities with populations between 600,000-800,000 people. The population size was based on the initial case study city— the City of Boston— and thus the researcher sought to identify cities of a comparable size. The third criterion was that the selected case study cities be spread geographically across the contiguous United States, with at least one from each Census Region that met all other criteria (Northeast, Midwest, South and West; see Figure 3 for visualization of census regions) (U.S. Census Bureau 2017). The fourth and final criterion was that the case study city already have a climate action plan that included a focus on reducing transportation emissions.

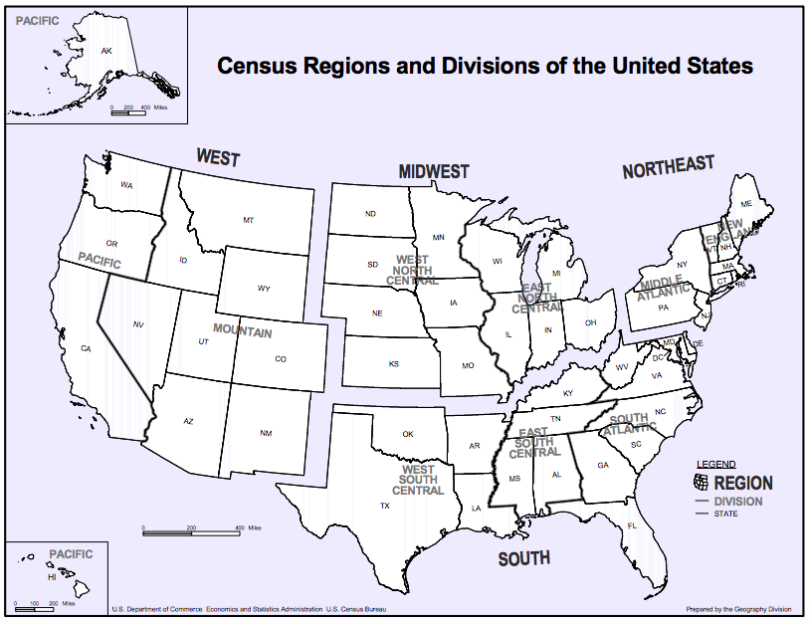

Figure 3: U.S. Census Regions (U.S. Census Bureau 2017)

Cities that initially met all four criteria can be found in Appendix A. The researcher started with a larger pool of cities, seven in total, to ensure that the final four to six case cities presented enough data and information to build successful case studies. Due to time constraints, the researcher succeeded in completing five full case studies, including at least one interview in each of the five cities. The final case study cities were: Boston, Massachusetts (Northeast Census Region); Columbus, Ohio (Midwest Census Region); Washington, D.C. (South Census Region); Denver, Colorado (West Census Region); and Seattle, Washington (West Census Region).

To visually compare a selection of attributes across the selected cities, the researcher collected data including population density of each city (population per square mile) and total square miles (see Table 1 below). From each city's website, the researcher collected climate action plans to thoroughly understand overall climate goals— specifically each city's transportation-related GHG reduction goals (see Table 1 below).

The one exception to the emissions reduction goals was the city of Columbus. At present, Columbus has a climate action plan that focuses on adaptation (rather than mitigation) as well as a robust smart cities initiative known as Smart Columbus that aims to transform the transportation sector. The city is very actively engaged in reducing transportation emissions for both air quality, public health and climate reasons. Columbus also recently joined the U.S. Climate Mayors and is required to complete a GHG inventory in the near future. The researcher felt that it was important to include a Midwest city to demonstrate the

wide range of work and various angles taken when it comes to reducing transportation emissions.

	Pop. (2010 Census)	Sq. Miles	Pop. Density (People per Sq. Mile)	Transportation-Related GHG Reduction Goal	Target Reduction Year
Boston	617,594	48.28	12,792.7	Reduce transportation GHG 25% below 2005 levels	2025
Columbus	787,033	217.17	3,624.1	N/A	N/A
Washington, D.C.	601,723	61.05	9,856.6	Reduce transportation GHG 50% below 2006 levels	2032
Denver	600,158	153.00	3,922.6	Reduce transportation GHG 80% below 2005 levels	2050
Seattle	608,660	83.94	7,250.9	Reduce transportation GHG 82% below 2008 levels	2030

Table 1: Comparison of selected attributes across case study cities (U.S. Census Bureau QuickFacts 2010; Case Study Cities' Climate Action Plans)

Climate action plans also shed light on the variation and unique complexity of each case, underscoring the importance of triangulating the case studies with interviews. The plans likely did not have perfect information or details on the implementation process to date. Interviews with relevant city staff

served to fill in the gaps and delve deeper into the implementation process, as well as built an understanding of challenges and opportunities related to transportation sector emissions goals.

3.2 Interview Selection Process

The researcher identified individuals in each city government who ideally focus on the intersection of transportation and climate goals, and who have knowledge of the city's climate action plan. Interview participants included environmental planners, city sustainability staff, energy planners and individuals in roles that did not necessarily meet predefined categories. Two to three individuals were selected for each city, and ultimately the researcher interviewed at least one individual from each of the five cities who was willing and able to participate in the study. To identify individuals, the researcher visited city websites; researched the planning and sustainability department staff; read recent news about transportation-related topics; and use LinkedIn. The researcher found relevant evidence that demonstrated that the interview participants are actively engaged in issues that center around the intersection of transportation emissions and climate goals. In some cases, it was not as clear who the relevant city staff were, and in such instances the researcher asked multiple sources within the city government for help in identifying the best interview participants.

The interviews ultimately served to supplement and triangulate the information gleaned from climate action plans. From an online plan it can be difficult to ascertain which aspects have been implemented or are likely to be implemented in any given city. Each city began to understand the climate change

problem at a different time and each city has varying levels of political will, budgetary constraints and competing priorities. The interviews enabled the researcher to create a well-rounded snapshot of the case study city and to identify the most salient themes and best practices across all of the case study cities. A copy of the interview questions can be found in Appendix B.

Chapter 4: Results and Discussion

Throughout the reading of climate action plans and subsequently through the interviews, five primary themes emerged. First, there exist both disconnects and overlaps between traditional planning and climate action planning. Individuals whose jobs fall at the intersection of climate and transportation are not necessarily involved in the writing of the climate action plans. Such plans often emerge as a result of a mayoral executive action or through an office of sustainability, but do not always follow the same planning or implementation process as other, more traditional plans. At the same time, many climate action plan strategies to reduce transportation emissions include action items that are traditionally considered transportation *planning* tools. Second, cities face similar barriers when it comes to further investment in low-carbon transportation. Examples of barriers include lack of monetary resources; lack of resources to adequately inform the public about low-carbon technologies such as electric vehicles; the inherent nature of transportation systems as regional networks; and the difficulty in achieving mass-behavior change in travel mode preferences. Third, regardless of geographic location, all case study cities value the co-benefits that occur as a result of a reduction in emissions from the transportation sector. While the climate action plan may spell out specific actions for reducing emissions, many other aspects of transportation planning inherently benefit air quality. For some cities, the greatest additional benefit as a result of reduced transport emissions is enhanced air quality while for others it's a decrease in vehicle congestion. The fourth theme that emerged was that all case study cities

value and seek to integrate equity into the climate and transportation space, but often struggle to make progress on this front. And fifth, case study cities all agree that new mobility models (vehicle electrification, ridesharing, autonomous vehicles) and new partners from the private sector are likely to transform existing transportation systems. Many of the case study cities have taken advantage of funds from the Volkswagen diesel emissions settlement to invest in electric vehicle infrastructure, and many have also used this window of opportunity to work with new or unusual partners in the private sector to bring about an increase in low-carbon transportation technologies.

4.1 Disconnects and Overlaps Between Traditional Planning and Climate Action Planning

The first theme that emerged across all case study cities was that there exist both disconnects and overlaps between traditional planning and climate action planning. This plays out in two specific ways: first, those working on implementing strategies to reduce transportation emissions may not necessarily be the same individuals who worked on or wrote the climate plan. As a result, it can be difficult to identify the right city staff with whom to speak. Second, many transportation-specific plans include action items that naturally involve a mode shift away from cars, but the explicit purpose of this mode shift is not necessarily climate-driven. And yet climate action plan strategies to reduce transportation emissions include many of the same mode shift goals and ideas found within traditional urban transportation plans (for a summary of all five case study cities' climate action plan transportation goals see Appendix C).

The process of identifying the right city staff with whom to speak proved to be a difficult one. This was because those who were charged with writing climate action plans are not necessarily the ones actively engaged in the implementation process. The researcher initially set out to identify individuals whose work falls at the intersection of climate and transportation, and yet only one of the case study cities— the city of Seattle, Washington— has a staff person whose job is solely dedicated to the intersection of climate and transportation. Seattle is unique in that it has one of the largest city sustainability offices in the country. With 32 employees working on issues that range from food policy to urban forestry, Seattle has borne witness to unusually strong political will for sustainability action (City of Seattle Interview 2018). The specific climate and transportation position has existed since 2015 and was created as a result of the findings of the climate action plan. The plan demonstrated that not only were transportation emissions the largest share of the city's GHG pie (67%), but also that population growth was expected to rise sharply in the next decade (City of Seattle Interview 2018). Thus, one particular challenge for Seattle going forward is how to balance population growth with a continued decrease in emissions and vehicle miles traveled. At present, the city's primary electric utility provider is carbon neutral and therefore focusing on electrification of all modes of transport is a high priority. Seattle historically focused on reducing emissions from buildings and has now shifted to a focus on reducing emissions from the transportation sector.

Seattle, with a long history of climate action and a strong municipal commitment to sustainability issues, is on the opposite end of the spectrum from the city of Columbus, Ohio. Identifying the right Columbus city staff persons with whom to speak about the intersection of climate and transportation proved to be challenging. The first inherent challenge was that the authors of the climate action plan (which, in this case, is a climate adaptation plan rather than a climate mitigation plan), were from the Byrd Polar and Climate Research Center at the Ohio State University (Columbus Climate Change Action Plan 2017). It was unclear from that document which city staff were the most relevant. The researcher first contacted members of the Columbus Green Spot team, which appeared to be the equivalent of an office of sustainability. One of the Green Spot team members then forwarded the researcher on to the manager of the municipal green fleet. Columbus initially began tackling transportation emissions by converting much of the municipal fleet to electric or alternative fuel vehicles. However, a municipal fleet is only one step toward the overall reduction of emissions from a metropolitan area's transportation sector. The manager of the municipal fleet subsequently passed the researcher on to an Air Quality Program Coordinator at the Mid-Ohio Regional Planning Commission (MORPC). After an initial conversation with MORPC, the researcher was given the name of an individual who works for the city of Columbus under the Smart Columbus initiative, but is housed within the Public Service Department.

As one can clearly see from this chain of events, there exists a wide variety of methods and ways in which to plan for low-carbon transportation

systems. In this case, unlike traditional planning, efforts to reduce transportation emissions in Columbus have taken place on an ad-hoc basis rather than as part of a comprehensive process (MORPC Interview 2018). This is not to say that the political will does not exist – it certainly does – but the birth of a climate action movement can take very different shapes depending upon one's location in the United States, as well as the general public's understanding of the issue. Columbus won the Smart City Challenge in 2016—a national competition in which cities applied to win $40 million from the U.S. Department of Transportation to work on sustainable transportation solutions—and this grant was the catalyst for myriad city actions to address pollution from transportation (City of Columbus Interview 2018).

Across the remaining three case study cities (Boston, MA; Washington, D.C. and Denver, CO), the researcher encountered similar difficulties identifying city staff whose job fell directly at the intersection of climate planning and transportation (see Appendix D for a summary of interview participants and their city agency/department). This highlights a need for enhanced cross-agency coordination and communication. While some cities, such as Boston, have delegated climate action tasks throughout various agencies under the Greenovate Boston initiative, others such as Denver and Columbus, have not been witness to as much cross-agency coordination. Those charged with writing climate action plans are not necessarily the same individuals whose job meets the description of the actions set out in the climate plan.

The second common finding within the first theme was that there is noteworthy overlap between climate action plan strategies to reduce transportation emissions and the mode shift goals and ideas typically found within comprehensive urban transportation plans. The story of transportation emissions reductions in most cities to-date is the story of mode-shift away from single-occupancy vehicles to other modes such as transit, walking, car-sharing and bicycling. As such, most climate action plans adopt strategies historically utilized in traditional transportation planning.

In both the Boston and Denver Climate Action Plans, specific reference is made to comprehensive transportation plans as key strategies to address emissions from the transportation sectors in those cities. In Boston's case, the transportation section of the CAP announces the launch Go Boston 2030, a mobility visioning and planning process that was completed in 2017. While many of the actions spelled out within Go Boston 2030 naturally reduce auto dependence and have climate benefits, the exclusive purpose of the plan is not climate-related. Go Boston 2030 lists three primary guiding principles: equity, economic opportunity and climate *responsiveness* (Go Boston 2030 Plan 2017). Similarly, the Denver Climate Action Plan points to and reinforces the importance of Denver's Strategic Transportation Plan as a way to reduce emissions from the transportation sector. A key overarching element of that plan is the need to "move people rather than cars" (Denver Strategic Transportation Plan 2008). In doing so, it places a heavy emphasis on mode shift and lays out a plan in which the city can provide convenient, comfortable and affordable mobility options that encourage residents

to use low-carbon forms of transportation such as mass transit, carpooling, bicycling, and walking (Denver Strategic Transportation Plan 2008). It does not, however, list climate goals and GHG emissions reductions as a driving force for change. The importance of transportation planning in developing efficient, low-carbon, affordable solutions to urban transportation challenges is critical. However, listing climate goals as an impetus to develop better urban transportation systems is largely missing from traditional transportation plans. This highlights a need for enhanced cross-agency coordination at both the municipal and state levels, and the political will to integrate climate planning into all other sector planning offices.

4.2 Barriers to Investing in Low-Carbon Transportation Systems

Across all the case studies, many of the same barriers to investing in low-carbon transportation systems exist. First, each city has a different municipal budget and varying levels of political will. This can lead to resource constraints, and thus a general lack of financial and personnel resources with which to effectively transform transportation networks (for a summary of each case study city's FY17 operating budget see Appendix E). Second, urban transportation systems are inherently regional. As a result, emissions inventories for urban areas take into account those emissions released within municipal boundaries, but many cities serve large commuter populations that drive into and out of the city each day. The regional nature of transportation is thus a key factor to take into consideration when systemically reducing transport emissions. Third, cities face difficulty in knowing how to achieve mass behavior-change. Policies and plans

can help reach a new status quo by providing attractive alternatives but asking individuals to change personal preferences in mode choice can be challenging. The average life of a car is 8-10 years, and it can be unreasonable to ask car owners to simply dispose of their older, inefficient vehicles. And finally, interviews with the case study cities brought to light the issue of short-sightedness in the political process, which can hamper progress on long-term goals such as climate action.

Lack of financial and personnel resources represent a key challenge in low-carbon transportation investment, especially when it comes to vehicle electrification. Vehicle electrification emerged as a salient opportunity with which to reduce the total share of urban transportation emissions. All five case study interviews specifically mentioned the difficulty associated with the initial up-front cost and lack of education for both municipalities and residents in purchasing electric vehicles. Consumer education about low-carbon alternatives is not necessarily a task that is covered under a city planner or staff member's job description. In some cases, the private market holds responsibility for accurately marketing and educating consumers about the benefits of electric vehicles (Washington, D.C. Interview 2018). One way that cities can begin to model good practice in vehicle electrification is by procuring a higher percentage of electric vehicles in municipal fleets or by producing electric buses for the city transit fleet (City of Boston Interview 2018 and City of Columbus Interview 2018). Columbus in particular has made noteworthy strides in greening its fleet. In 2016, the city was awarded the #1 Leading Fleet in the U.S., largely due to their alternative fuel

program, but also thanks to a large share of electric vehicles. Columbus has borne witness to unusually strong political will for greening the fleet, and this action has helped the city model good practice for its outward-facing vehicle electrification programs (City of Columbus Interview 2018). In Washington, D.C., however the process of procurement has slowed down the move to vehicle electrification. For example, the city hopes to procure new school buses immediately, but it can take up to two years before electric school buses are ready for use (Washington, D.C. Interview 2018). This presents the city with a challenge: instead of waiting for electric school buses, they may need to purchase regular school buses right away which have a longer life, and thus further delay the electrification process. In Seattle, barriers to electric vehicle adoption include cost, a perception of inconvenience, lack of consumer awareness and acceptance (City of Seattle Interview 2018).

Another key barrier to low-carbon transportation investment is the inherent regional nature of such networks. Historically cities have always been hubs of economic activity, and as metropolitan areas continue to expand both outwardly and in terms of population, emissions will grow as more people live on the edges and commute into the urban core. In Boston, for example, nearly 300,000 more people have jobs within city limits today than in 2010— a difference of just eight years (Ramos 2018). Within that same time frame, little change occurred within the transportation infrastructure network. Advocacy groups such as the Livable Streets Alliance and Transportation for All have been pushing for congestion pricing, while others continue to advocate for enhanced

regional and urban rail. In Seattle, by contrast, 65,000 new jobs were added downtown within the last decade, but thanks to a $54 billion investment in rail and bus rapid transit (BRT), commute trips have largely been absorbed by other modes (City of Seattle Interview 2018). Such investments have been key to reducing single occupancy vehicle trips. In Washington, D.C., 200,000-400,000 individuals commute into and out of the District daily, and thus it is hard to assess total vehicle trips within the District when such a large portion come from outside areas (Washington, D.C. Interview 2018). As the states that border Washington, D.C. begin to improve their own transportation systems, the District will be a natural beneficiary of those changes. This added layer of regional complexity calls for regional cooperation. In the Northeast, a group of states are currently considering a regional cap and trade program for transportation, similar to the Regional Greenhouse Gas Initiative (RGGI) which has been successful in slashing emissions from Northeast power plants. If such a system were to be successful in reducing transportation emissions in the Northeast, it could potentially serve as model for other areas of the country.

A third barrier to investing in low-carbon transportation alternatives is the difficulty in shifting urban residents' travel mode preference and choices. Case study cities approach this challenge in a variety of ways. In Columbus, there has been little interest in punitive policies. Instead, the onus has been placed on the idea of public-private partnerships and making low-carbon options appear as feel-good opportunities (City of Columbus Interview 2018). The City of Columbus worked with large city employers to develop incentives for employees to enter

commuter challenges. For example, some companies instituted a challenge in which each time an employee logged a sustainable commute, they entered to win a prize. Shifting the habitual day-to-day behavior of individuals en masse requires a level of resources that most cities simply do not have.

Seattle, Boston and Denver face similar challenges when it comes to large-scale behavior change. In Seattle, the city government is beginning to seriously consider congestion pricing and other policies that residents generally do not support. This type of prescriptive policy is a difficult but necessary step once a city has completed the easier, less punitive options in reducing transportation emissions (City of Seattle Interview 2018). Boston faces a similar challenge in the debate surrounding resident on-street parking. Currently, there is no fee or annual registration for Boston residents to park on neighborhood streets. In previous mayoral administrations, strong political will existed in support of free parking. However, things have changed, and the current administration is considering an annual fee for on-street resident parking, even though residents would prefer to maintain the freedom to park anywhere, anytime with no associated cost (City of Boston Interview 2018). Shifting the price of parking can have a dramatic effect on vehicle miles traveled and car ownership. By increasing the cost of parking, residents may be encouraged to use other modes such as mass transit. In Denver, changing the status quo mindset on modal priorities has been challenging. The city has not modeled ideal practice in its continual allocation of heavy funding toward road and car-centered projects (City of Denver Interview 2018). If the city

doesn't set a strong precedent, shifting the modal mindset of residents overall will prove to be nearly impossible.

Finally, a fourth barrier to investing in low-carbon transportation alternatives is lack of adequate political will. Even in cities such as Seattle that historically demonstrated strong political will and allocated significant resources toward investing in low-carbon alternatives, much work remains to be done. The solution to this barrier has yet to be determined, but to a certain extent it will depend upon robust integration of long-term climate planning into all aspects of municipal government. Almost all of the case study interview participants expressed frustration with the underlying cultural tendency toward short-sightedness— arguably one of the very reasons climate change exists in the first place. Fiscal years and political cycles are inherently short in the grand scheme of things, and this presents a fundamental long-term challenge to investment in low-carbon transportation.

In sum, there exist substantial barriers to investing in low-carbon transportation, but these barriers are not insurmountable. It is likely that the efforts to integrate low-carbon alternatives will take time, and thus one should not expect a rapid transformation of urban transportation systems, but rather a long-term, slower systemic change. Each of the case study cities should be commended for identifying transportation emissions as a problem and beginning to work on solutions that will undoubtedly take time, political will and creative policy solutions.

4.3 Co-Benefits of Reducing Urban Transportation Emissions

As evidenced in detail in the literature review, there is no dearth of co-benefits that arise as a result of reducing transportation emissions. Cities are well aware of these benefits and have integrated them at various levels into their thinking around the climate and transportation nexus. Urban residents' quality of life is very much impacted by heat, noise, air quality and congestion. Depending on the geographic size, population density, and existing alternative transportation options, co-benefits vary in importance from city to city. Throughout all the case study interviews, participants regularly mentioned the importance of two key co-benefits: enhanced air quality and a decrease in vehicle congestion. Throughout the conversations, it became abundantly clear that there is universal excitement about the potential to leverage the co-benefits as a way to accelerate climate action.

All five case-study interview participants stressed the need to enhance urban air quality, especially in low-income communities. It is well-known that poor air quality does not impact an entire city in uniform patterns and varies by air pollutant. Those who live closer to freeways, highways, and heavy-duty freight routes—often low income and minority communities— face an unequal burden in pollution-related health impacts. While cities recognize this as an issue, many have been slow to make concrete changes. In most cases, alleviating congestion is the primary co-benefit associated with reducing transportation emissions by focusing on a mode shift. Columbus, however, was galvanized into action on

transportation and climate largely due to air quality concerns and infant mortality rates among black communities (City of Columbus Interview 2018).

According to recent national data, six out of every 1,000 babies born in the U.S. will die before they reach their first birthday; in Columbus, that number exceeds 24 out of every 1,000 babies born (Bliss 2016). The leading causes of infant mortality in the Columbus area are premature births and low birth weights—two health impacts that are highly correlated with poor air quality. While other stress factors impact low-income communities in Columbus such as lack of fresh food, the air quality issue is particularly acute and was the primary impetus for the Mayor to apply for the Smart Cities program grant. By expanding connected, efficient mass transit to the areas most affected by inadequate service and air quality issues, Columbus hopes to connect residents to better employment, healthcare and education opportunities (Bliss 2016). While most other cities that entered the Smart Cities grant challenge focused on the need to alleviate congestion, Columbus focused almost exclusively on environmental justice and air quality. As the recipient of the grant, Columbus has been working to implement new bus rapid transit (BRT) lines. There is strong political will from the Mayor, and as a city that joined the Global Compact of Mayors, it is likely that Columbus will continue to work on this issue (City of Columbus Interview 2018).

Denver, Boston, and Washington, D.C. also hope to enhance air quality in low-income communities in the process of reducing transportation emissions overall. In Denver, school district choice often dictates how far parents will drive

their kids to school (City of Denver Interview 2018). Families that can choose a particular district will drive across the city rather than staying in their own district. This has led to the city installing air quality monitors at several schools in an effort to find an ideal time of day for recess, when air quality is best (for example, several hours after the morning commute but before the afternoon commute). Boston and D.C. both recognize asthma as a serious concern among certain communities. Both cities hope, in-part, to alleviate the burden of air pollution as more electric vehicles hit the roads. In Washington, D.C., a key criterion for receiving settlement funds from the Volkswagen case (discussed in Appendix G) is that the city integrates environmental justice and environmental health into the plan for electric vehicle infrastructure and deployment (Washington, D.C. Interview 2018).

The co-benefits of reducing transportation emissions may be a way to harness and grow momentum around climate action, if framed the right way. It is difficult for anyone to argue against efforts to reduce congestion and improve air quality. After all, these are both factors that contribute to quality of life and the livability of a city. When residents see that investing in climate action is about more than just emissions, they will be more likely to accept paying additional costs for certain activities, such as driving (City of Seattle Interview 2018). As Seattle begins to seriously consider congestion pricing as a means to reduce transportation emissions and reduce congestion, people are more likely to respond positively if revenue from that policy is reinvested into high capacity transit (City of Seattle Interview 2018). A clear articulation of the benefits (both short- and

long-term; qualitative and quantitative) of a potentially unpopular policy is critical to successful implementation.

The co-benefits of reducing transportation emissions thus extend beyond simply reducing vehicle congestion. As climate change continues to impact urban areas, it is likely that a higher number of 90 degree+ days will lead to exacerbated heat island effects (EPA 2017). Heat islands occur in urban areas when paved surfaces trap heat and lead to higher surface temperatures. Heat islands also lead to elevated ground-level emissions of air pollutants and greenhouse gases (EPA 2017). By reducing dependence on vehicles, cities can ultimately rely on reducing transportation emissions as a climate adaptation strategy in addition to a mitigation strategy. It is key that cities continue to bring climate into the conversation when discussing future transportation policy, not just the added benefits such as reduced congestion.

4.4 Integrating Equity in the Shift to Low-Carbon Transportation Systems

Each of the five case study cities incorporate the idea of equity into climate planning as either a core piece of the plan or as a cross-cutting theme (see Appendix F for a summary of case study cities commitment to equity within climate action plans). The interviews made clear that in reality on the ground, cities have achieved varying levels of success in addressing equity issues associated with reducing transportation emissions. Indeed, a true incorporation of equity into planning for low-carbon transportation systems necessitates a level of political will and resources that many cities lack. Regardless of whether or not the case study cities have made progress in incorporating equity, they all share in the

belief that as government, they have a duty to make sure that the benefits that arise from a transition to low-carbon transportation accrue to all residents, and not just those who are wealthy or who have had the privilege of learning about new low-carbon technologies first. Ensuring that the transition is a just one will be an ongoing challenge and will require a deep level of understanding and commitment on the part of local government at all levels.

Both Boston and Denver make explicit mention of equity as a cross-cutting theme in their climate action plans. Yet in conversation with staff from both of those cities, it became apparent that neither is doing a sufficient job when it comes to reaching underserved communities in which air pollution is an acute issue. In Boston, the link between high asthma rates in children and environmental factors is well established (ACE 2008). While the city recognizes this as a priority on paper, little concrete action has been taken on the ground. Outreach to affected communities is crucial, but limited time and resources have prevented the city from truly prioritizing equity in emissions reductions (City of Boston Interview 2018). Denver faces a similar problem. Equity is a core tenant of the city's climate action plan, and yet there are ongoing expansion and improvements projects on highways that cut through low-income areas. The city has done some air quality monitoring work along highway expansion projects, but it is insufficient and does not address the root of the problem (City of Denver Interview 2018). Both of these examples highlight that a true integration of equity into the climate and transportation space has yet to be realized.

Seattle stands out in its understanding and commitment to integrating equity into climate planning and decision making. In the 1940s Seattle was home to Japanese internment camps, and the government has spent decades attempting to restore justice and correct those mistakes (Kinoshita 2012, City of Seattle Interview 2018). As a result, racial justice has become a core part of Seattle's city government outlook on all fronts. This translates clearly into Seattle's climate action planning and even into the annual municipal budget, which has a chapter and budget line dedicated to race and social justice (Seattle 2017 Adopted Budget). The city has embraced to key concepts that form the bedrock for the current and future success of integrating equity into the transition to a low-carbon transportation system. First, the city recognizes that the process of trust building between local government and grassroots, community-based organizations is a slow one that takes time, patience, and sometimes failure before success (City of Seattle Interview 2018). Local community groups can help the city understand the various needs on the ground and which mobility solutions will work best given different contexts. Seattle knows that to be most effective, some policies cannot be prescriptive, but rather must come from the bottom up. For example, putting electric vehicle charging infrastructure in a community without doing effective outreach to see if this is the best low-carbon solution is problematic. The second idea that Seattle has internalized is the understanding that transportation and new mobility solutions tend to be digital, and left to the private sector, these solutions would likely develop in a way that only provide benefits to wealthier communities (City of Seattle Interview 2018). If some residents do not have smartphones or are

unbanked, they will automatically be left out. The challenge for Seattle, and most other cities, is how to bridge all of these divides. As local government, cities will have to work to ensure that the benefits of technological solutions accrue to all communities.

Seattle has already taken two concrete steps to ensure that equity is integrated into low-carbon transportation implementation. First, the mayor recently provided free transit access to all students. As evidenced in Appendix F, expanding low-cost transportation options (especially for lower income residents) was a transportation goal in the city's climate action plan (Seattle Climate Action Plan 2013). While this policy benefits everyone, it will especially benefit those who come from low-income communities that may have had previous difficulty affording transit. Second, as part of the city's mobility permitting, Seattle has a list of requirements that interested parties must meet before they can enter the marketplace. For example, if an electric car sharing company wants to operate in Seattle, the company must meet the city's permitting requirement that stipulates that any new mobility technology benefit the whole community. The city can enforce this by monitoring where charging stations are installed and ensuring that they are widely distributed throughout the city and don't end up clustered in one area (City of Seattle Interview 2018).

Friel et al. (2011) note that addressing structural distributions of power, money and resources involves fostering a process of "political empowerment." Especially when it comes to urban health and climate equity, political empowerment of individuals is vital. Cities that, on paper, commit to ensuring

that environmental justice and equity will be core parts of the transition to a low-carbon future must endeavor to work especially diligently in the future. As elected officials and city staff work to secure more sustainable futures for their cities, an equitable transition is of utmost importance, otherwise existing inequities will be further exacerbated.

4.5 New Mobility Technologies and New Partners

If there is one thing that transportation experts across the country can agree on, it's that the U.S. is in the midst of a "transportation revolution." New mobility models and technology—specifically vehicle electrification, ridesharing, and autonomous vehicles— have taken hold and do not appear to be slowing down. This innovation has largely emerged from the private sector, and thus cities now find themselves in a position in which working with private partners in a new, more enhanced capacity will be necessary to ensure that the whole public fully reap the benefits of new mobility solutions. Across all five case study interviews, this trend was most apparent in the nascent shift from conventional to electric vehicles.

All five case study cities hold that vehicle electrification is an indispensable strategy to reduce transportation emissions. This is inherently challenging for cities to accomplish alone because adoption of electric vehicle requires coordination with state and federal policy, subsidy and incentive structures. Electric vehicles alone will also not solve the problem of congestion. Nonetheless, almost all of the interview participants mentioned that their cities have made use of a strategic window of opportunity to advance the deployment of

electric vehicles. John Kingdon's famous "policy streams" approach posits that when three "streams" converge— the problem stream, the policy stream and the politics stream— a window of opportunity emerges and allows for the facilitation of policy change (Guldbrandsson and Fossum 2009). In this case, the streams converged to allow cities to take advantage of funds from the Volkswagen diesel settlement and channel those funds into electric vehicle charging infrastructure and deployment (see Appendix G for a summary of the diesel emissions scandal). Under the settlement terms, Volkswagen agreed to pay $2.7 billion into a fund specifically dedicated to help states reduce transportation emissions (Energy Collective 2018). The fund will be allocated according to the prevalence of illegal diesel engines in U.S. states. All five case study cities exist in states that will be recipients of settlement funds.

As cities prepare to use these new funds, careful attention will be paid to where charging infrastructure should be placed and how else the funds might best be spent. In Washington, D.C., the plan to implement the settlement funds actively includes a focus on neighborhoods with acute air quality concerns and high rates of asthma (Washington, D.C. Interview 2018). One promising solution is to invest in electric municipal transit buses, which can help educate riders about electrification but also reduce emissions associated with buses. In Boston and Seattle, interview participants echoed the sentiment that the funds will be incredibly beneficial if resources are allocated correctly and certain neighborhoods are prioritized for educational events in multiple languages (Boston Interview 2018, Seattle Interview 2018). While there exists a tremendous

opportunity with the settlement funds, cities are also very much aware that as other new mobility trends grow in popularity, city governments have a responsibility to ensure that the benefits of new trends reach all residents.

If left entirely to the private sector, new technologies primarily benefit wealthier urbanites. This is true of bike share programs just as much as it is true of electric and autonomous vehicles (Ursaki and Anultman-Hall 2016). The challenge for cities, thus, is how to engage in the market and work with the private sector to ensure that equity is integrated into new mobility systems. Boston University's *Initiative on Cities* has examined transportation's impact on inequality extensively. Co-founder Graham Wilson, a professor at Boston University, emphasizes that the core challenge for cities is achieving the right combination of government and free market while adapting to new changes (Frazier 2017). Each of the case study interview participants echoed this idea as their cities grapple with rapid change in the transportation sphere and try to balance that change with climate and equity planning.

Columbus has been highly successful in partnering with the private sector on many fronts, but most notably on the electric vehicle deployment front. As part of the Columbus Smart Cities Challenge grant— a grant funded by both the federal government and private partners— the city has been able to dedicate resources toward working with private partners (large employers, CEOs in the area etc.) to jointly educate the public about electric vehicles (City of Columbus Interview 2018). The "Electrify Columbus" plan outlines five priority objectives: first, decarbonization of the energy and transportation sectors; second, electric

vehicle fleet adoption; third, ensure a comprehensive, multi-modal approach to decarbonizing the Columbus region's mobility options; fourth, increase electric vehicle market adoption; and fifth, support the acceleration of electric vehicle adoption through installation of charging infrastructure (Smart Columbus Electrification Plan). Implementation of the electrification plan requires input from private partners such as American Electric Power Company and major Columbus area employers. Historically, Columbus has been recognized for its successful public private partnerships as a means to increase economic development, and this success has been dubbed "The Columbus Way" (Fischer 2017). Building off other successful public private partnerships, the city hopes to continue the momentum and achieve a reduction in transportation emissions by harnessing the power of both the public and private sectors. Given that Columbus won the Smart Cities grant by emphasizing air quality as an environmental justice issue, the city will continue to work on enhancing mobility through an equity lens (City of Columbus Interview 2018).

New mobility trends will be a key challenge for cities moving forward. Cities will have to continue to work with states on electric vehicle incentive programs, balance scarce resources and competing priorities. Yet, the potential to partner with the private sector presents an opportunity to ensure that new mobility trends continue to act in the whole public interest, and not just in the wealthy public interest.

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In sum, the results of this thesis indicate that cities are aware of the challenge inherent in reducing emissions from the transportation sector. All five case study cities demonstrated a sound understanding of the problem as evidenced in each climate action plan; and all five cities share enthusiasm for the potential co-benefits that will arise as a result of reduced transportation emissions. But in most cases, cities have yet to understand the best way to tackle the problem due to the complex nature of transportation systems. The barriers are not insurmountable, but solutions will necessitate robust commitment, vigorous political will, and continued pressure from residents and advocacy groups. The rapidly changing transportation and mobility sector presents an opportunity to reshape the status quo and usher in a new era of equitable, low-carbon transportation alternatives. Creating and incentivizing a new transportation reality that shifts individual choice away from conventional single occupancy vehicles is of the utmost importance if cities are to reach any climate goals.

Chapter 5: Conclusion

The freedom to move and the legacy of automobiles in the United States is a deeply rooted, complex, and emotional story. Mass adoption of the personal vehicle as the foremost mode of transport has drastically increased the quality of life for generations of Americans but has come at a grave cost to the planet and to public health. As a problem that emerged as a result of decades of policies that encouraged automobile use, so too will the solutions take time. Given the rate at which transportation emissions have increased, and the urgency that cities, states and nations face to meet climate greenhouse gas reduction goals, it is critical that policymakers and planners utilize every tool available to reduce transportation emissions.

Four lessons can be gleaned as a result of the research completed for this thesis: first, that robust integration of climate planning into every level and agency of city governments is necessary in order to most effectively reach greenhouse gas reduction goals; second, as a long-term problem, reducing transportation emissions will require long-term solutions grounded in immediate action; third, without enhanced regional planning tied to smart growth strategies, urban centers will be unable to effectively reduce car dependence and transportation emissions; and finally, that unless equity is fully internalized as the bedrock of all urban climate action, existing injustices will be exacerbated.

Robust Integration of Climate Planning into Every Aspect of City Government

To be truly effective, the goals and ideas within an urban climate action plan must be disseminated and fully integrated into the decision-making processes

of every level and agency of city government. This will necessitate a level of political will that currently does not exist in most cities. The language and framing of climate plans can be easily transferred to other, more traditional plans. For example, transportation planning strategies must be reframed as climate solutions, rather than existing in isolation. Urban systems are deeply interconnected, and climate considerations should inform every piece of the puzzle.

A Long-Term Problem Requires Robust Long-Term Solutions

Election cycles and fiscal years are inherently short. This often leads to short-sighted decision making, which will not work in the face of a long-term problem like climate change. The existing state of transportation systems is the result of decades of policies at all levels of government. To reshape such a deeply rooted system will likely also take decades. In order to be most effective in reducing transportation emissions, city governments should endeavor to make short-term decisions using a long-term lens that will enable progress to continue.

Enhanced Regional Planning and Smart Growth Revisited

Transportation systems are intimately linked to other structural, economic and social factors at play in urban areas. Decisions about new housing growth, without taking both transportation and climate into account, will slow progress on reducing emissions and potentially lead to more congestion even if all new vehicles were to be electric. As a regional problem, the solutions, in part, must also be regional. Urban areas expected to experience increased population growth in the coming years, and without a regional plan to address this with enhanced

low-carbon transportation options, cities will likely face even more transport-related emissions.

An Equitable Transition

Existing urban inequalities in income, education, technology, health and transportation will be exacerbated unless climate action plans truly encompass and prioritize the idea of an equitable transition. In order to do so, cities will need to integrate equity into every level and agency of government and work to educate staff on how to make decisions using an equity lens. Building trust with communities will take time and will necessitate long-term partnerships with grassroots groups. Low-income communities are already disproportionately impacted by environmental hazards, and climate change will be no different. Even if cities identify equity as a cross-cutting theme, it will be necessary to aggressively channel resources toward neighborhoods and people who are most impacted.

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In the absence of climate and transportation leadership from the U.S. federal government, cities face a growing opportunity to fill the void with creative, multi-stakeholder driven transportation solutions. To say it will be easy would be fallacious— but the tools and commitment do exist and can be further cultivated. The time has come for freedom of movement to take new forms, embrace new solutions, and pave the road toward cleaner, more equitable and resilient transportation future that works for people and works for the planet.

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Appendices

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Appendix A

Initial list of cities that met all criteria.

	Population (Census 2010)	Climate Action Plan	U.S. Climate Mayors	Census Region
Boston, MA	617,594	Yes (most recent update: 2014)	✓	Northeast
Washington, D.C.	601,723	Yes (most recent update 2011)	✓	South
Baltimore, MD	620,961	Yes (most recent update 2013)	✓	South
Austin, TX	790,390	Yes (most recent update 2015)	✓	South
Columbus, OH	787,033	Yes (most recent update 2017)	✓	Midwest
Denver, CO	600,158	Yes (most recent update 2015)	✓	West
Seattle, WA	608,660	Yes (most recent update 2013)	✓	West

Appendix B

List of Interview Questions

1. Which parts of the climate action plan do you think have the most potential for implementation in the near-term, medium-term, long-term?

2. What kinds of plans and/or policies are in place currently that specifically target the transportation sector?

3. The goals set out in the climate action plan set an emissions reduction goal from the transportation sector. Do you see this as a realistic goal? Why or why not?

4. In the next 5 years, what types of programs or incentives do you see as having potential to reduce emissions from the transportation sector?

5. Do you think some measures to reduce transportation emissions are likely to benefit certain people or neighborhoods? If so, which ones?

6. In what ways do you think the city can most equitably address transportation emissions reductions?

7. Does the city see transportation emissions reductions as a priority over other sectors? If not, what are the competing interests? If so, how is the city addressing transportation emissions?

8. In your opinion, are there barriers to investing in low-carbon transportation? If so, what are some barriers to implementation?

9. What role do local advocacy groups play in collaborating with or advocating for low carbon forms of transportation?

10. What are some of the biggest challenges of addressing emissions from the transportation sector and what are some of the greatest opportunities?

11. In what ways might your city be able to learn from or collaborate with other cities on transportation emissions reductions?

12. What potential co-benefits of reduced transportation emissions are most important in this city? (I.e. less congestion; better air quality; fewer instances of asthma and other respiratory diseases).

13. To what extent is the city modeling good practice in its transportation-related operations?

Appendix C

Summary of Case Study Cities' Climate Action Plan Transportation Goals

Boston, MA	"Boston's Climate Action Plan will inform transportation decision making through *Go Boston 2030*, a mobility visioning and planning process" (Boston Climate Action Plan 2014). Main goals of the CAP transportation section: • Continue to implement complete streets • Enhance the bicycle network • Increase the total share of low-emission vehicles • Increase the total share of car/ride-sharing (reduce SOVs) • Implement bus priority lanes
Washington, D.C.	"Efficient and reliable transportation will support a growing, diverse and resilient economy while lowering GHG, obesity, and cardiovascular disease rates as well as traffic congestion" (Sustainable DC Plan 2011). Main goals of the Sustainable DC Plan transportation section: • Improve connectivity through efficient & affordable transit • Expand safe, secure networks for cyclists and pedestrians • Reduce traffic congestion to improve mobility • Improve air quality along major transportation routes
Denver, CO	"Coordinated land-use and transportation planning will be necessary to reach our 2020 Climate Goal and decrease emissions in the long term" (Denver CAP 2015). Main goals of the Denver CAP transportation section: • Support multi-modal regional transportation district (RTD) build-out • Strategic transportation plan and complete streets • Implement successful transit-oriented development • Increase electric vehicle infrastructure • Reduce parking demand through car sharing • Community-wide EcoPass feasibility study • Align BluePrint Denver (integrated land-use/transportation plan) with climate goal

Columbus, OH	"The City of Columbus, along with an extensive network of public and private partners, has aligned around the vision to reduce the region's GHG emissions through decarbonization of the electric and transportation sectors" (Smart Columbus Electrification Plan 2017). Primary objectives of the Electrification Plan: • Decarbonization of the grid • Work with public, private and academic partners to adopt 780 EVs into their fleets • Ensure a comprehensive, multi-modal approach to decarbonizing Columbus' mobility • Increase EV market adoption through consumer EV adoption • Support the adoption of EV charging infrastructure
Seattle, WA	"Taken together, the transportation and land use actions reduce climate pollution from transportation by prioritizing transit, bicycling, walking, and freight mobility over passenger vehicles" (Seattle CAP 2013). Main actions of the Seattle CAP transportation section: • Fund efficient, effective, accessible, and well-maintained transit, bike, pedestrian networks • Enhance mobility, access and safety through a range of transportation choices to reduce auto dependence • Enhanced transportation demand management • Reduce climate impacts of the remaining cars, buses and trucks through cleaner vehicles and fuels • Coordinate transportation and land use planning • Implement comprehensive roadway pricing to reduce GHG and congestion through tolls and parking pricing

Appendix D

List of Interview Participants

	Interview Participant	Department/Agency of Interview Participant	Job is a Direct Result of Climate Action Plan
Boston, MA	Haidee Janak	Climate and Environmental Planning Department	Yes
Columbus, OH	Norman (Bud) Braughton	Public Service Department VIA Smart Columbus Initiative	No, but job is a direct result of Smart Columbus transportation initiative
Columbus, OH	Brooke White	Mid-Ohio Regional Planning Commission (MORPC)	No
Washington, D.C.	Eric Campbell	Department of Energy and Environment	No
Denver, CO	Alyssa Alt	Public Works Department	No
Seattle, WA	Chris Bast	Office of Sustainability and Environment	Yes

Appendix E

Case Study Cities' Operating Budgets FY17

City	FY17 Operating Budget
Boston, MA	$2.98 billion (City of Boston 2016)
Washington, D.C.	$13.4 billion (Government of the District of Columbia 2016)
Denver, CO	$1.93 billion (City and County of Denver 2017)
Columbus, OH	$1.8 billion (City of Columbus 2017)
Seattle, WA	$5.6 billion (City of Seattle 2017)

Appendix F

Summary of Case Study Cities' Commitment to Equity in Climate Action Planning

City	Incorporation of Equity into Climate Action Plan
Boston, MA	"The 2014 Climate Action Plan Update will be implemented with two guiding principles around social equity inspired by the environmental justice movement. 1. The first principle holds that Minority and low-income communities must not be disproportionately impacted by climate hazards. 2. The second principle holds that benefits from climate mitigation and preparedness efforts should be shared equally among all groups of people." (Boston Climate Action Plan 2014)
Washington, D.C.	"Increasing equity and opportunity: 1. A sustainable future will ensure equity and prosperity for every District resident. 2. Conversations on education, jobs, health, and equity help further refine visions and goals, identify underlying barriers to sustainable outcomes, and define better ways of connecting with hard to reach communities. 3. Ensure that all school-aged children in the District are educated in sustainability and prepared for a changing green economy (specific goal: teach at least 50% of children in the District about sustainability concepts). 4. Ensure transparency in the District's sustainability agenda including future plans and past progress (specific goal: expose 100% of District residents to Sustainable DC events and initiatives in their neighborhood). (Sustainable DC Plan 2011)
Denver, CO	"Many of the strategies to address climate change provide additional benefits to our economy, public health and social safety net. Denver will ensure climate equity and environmental justice is prioritized in climate action planning:

	1. Climate action needs to be all-inclusive. Denver's CAP includes many key strategies that not only mitigate GHG emissions, but provide equitable social, economic and health benefits." (Denver Climate Action Plan 2015)
Columbus, OH	"Transportation is not just about roads, transit and ride sharing. It's about how people access opportunity. And how they live." – Mayor Andrew J. Ginther "To implement an aggressive outreach strategy partnering with key external stakeholders in the areas of business, industry, academia and governmental and social service agencies, to enhance the Workforce Diversity and Supplier Diversity Missions of the Office of Diversity and Inclusion. Working in partnership with the Department of Neighborhoods and the Community Relations Commission, strive to elevate the diversity and inclusion proficiency of all Columbus entities and organizations within Central Ohio to help Columbus become 'America's Equal Opportunity City.'" – City of Columbus Office of Diversity and Inclusion Mission.
Seattle, WA	"To equitable transition to a low carbon transportation system, we must design and implement transportation and land use actions so that they work for the full range of Seattle residents, which requires designing the actions to: 1. Meet the needs of families, immigrant communities, an aging population, people with disabilities and lower income residents. 2. Assist existing residents and businesses to remain and thrive in walkable, transit-oriented communities. 3. Expand low-cost transportation options to mitigate the impacts of economic signals that increase the cost of transportation, especially for lower income residents." (Seattle Climate Action Plan 2013)

Appendix G

Summary of Volkswagen diesel emissions scandal

For approximately seven years, the auto maker Volkswagen sold cars that ran on diesel fuel across the United States that released 40 times the legal limit of smog-forming pollution. The company advertised the cars as "clean diesel" options, misleading the public and regulators. Volkswagen retrofitted the vehicles with devices that were designed to pass emissions tests. In September of 2016, the U.S. Environmental Protection Agency (EPA) issued a notice of violation making the public aware of the truth—that 580,000 Volkswagen cars on the road in the U.S. spewed dangerous levels of nitrogen oxides (NOx) (Smith and Parloff 2016). The U.S. Department of Justice and EPA filed a civil suit against the auto maker that would subject Volkswagen to up to $45 billion in fines. Ultimately, Volkswagen agreed to pay $14.7 billion to settle the allegations of cheating the U.S. emissions standards, $2 billion of which must be spent on zero emission vehicle investments and $2.7 billion used to establish an Environmental Mitigation Trust to help states invest in projects to reduce NOx emissions (National Association of State Energy Officials 2017). States and cities across the country are now tapping into the settlement funds, hoping to use some of it to invest in clean vehicles (including passenger cars, trucks, and electric municipal buses) and electric vehicle charging infrastructure. Out of an unfortunate situation may arise the opportunity to accelerate investment in low-carbon transportation.