

Major Research Paper

Low-Emission Zones Around the World and the Possibility of Implementation in Canada

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Abstract

The effects of climate change are rapidly becoming untenable for many communities that the need to take immediate action where most impactful is now the only available course of action. Since the transportation sector is the largest domestic contributor to climate change, countries across the world are attempting to find ways to address the issue and lower current GHG emissions from that sector to protect the environment and sustain life on earth. Using data and research to support evidence-based climate action to maximize results is critical to these efforts. In fact, major cities such as London, Madrid, and Beijing have all attempted to implement this approach by establishing low-emission zones to lower the number of pollutant vehicles circulating the cities and reduce emissions in high-density areas. They have each faced a variety of success and failures, yet the net outcome has been a positive one in terms of economic efficiency, public acceptability, and environmental protection. Lessons with regards to infrastructure, implementation and enforcement are understood through the case studies of those three cities. The main benefit of this policy is the potential reduction in emissions, but a zero-emission zone could also improve air quality, reduce congestion, contribute to climate goals, and raise municipal revenue. Canada is precipitating its efforts to take climate action seriously and is currently considering creating a low-emission zone with the goal of eventually introducing zero-emission zones rather than stay the course with other approaches that have yet to yield the required results. It is recommended that low-emission zone pilot programs begin implementation as soon as possible in Vancouver and Montreal based on the lessons learned in London, Madrid, and Beijing. Both Canadian cities have sufficient infrastructure and capital to back a successful transition to a low-emission zone, which can be used as models for other cities, such as Toronto, following their lead in reducing emissions and limit the deadly rise in temperature.

Low-Emission Zones Around the World and the Possibility of Implementation in Canada

Introduction

Climate change is rapidly becoming the foremost global security threat to human life on earth. As the planet continues to warm and natural disasters become increasingly common, it will become harder and harder to predict conditions to enable human existence. “From shifting weather patterns that threaten food production, to rising sea levels that increase the risk of catastrophic flooding, the impacts of climate change are global in scope and unprecedented in scale” (United Nations, n.d.). Despite some countries facing greater effects than others, climate change is a global concern requiring transnational efforts to combat it. As the world continues to barrel toward a point of no return, an irreversible trend with devastating outcomes, there is an urgency to change and shift toward sustainable development now. Moreover, “without drastic action today, adapting to these impacts in the future will be more difficult and costly” (United Nations, n.d.). It is for this reason that, at an individual and collective level, there is a new-found climate consciousness influencing various governments' will to find cost-effective solutions. This explains the necessity of understanding the various climate action plans and environmental policies that have been attempted or successfully implemented to evaluate which ones serve a community's most pressing needs.

Countries across the world have been signing agreements and promising to prioritize climate change goals, yet agreements continue to break, are disregarded, or unevenly enforced. For example, since 2016, the Paris Agreement has required economic and social transformation based on the best available science to spark low-carbon solutions. Despite the many opportunities for green investments in the transportation sector this has encouraged, the sector continues to be a major polluter. According to the United States Environmental Protection

Agency (EPA), “the transportation sector generates the largest share [28%] of greenhouse gas emissions” (US EPA, 2019). Additionally, “the transportation sector is the largest domestic contributor to climate change [and] is responsible for more greenhouse gas emissions than any other sector of our economy” (US Department of Transportation, 2023). As the largest contributing sector, it is important for the transportation sector to become a priority.

“Greenhouse gas emissions from transportation primarily come from burning fossil fuel for our cars, trucks, ships, trains, and planes” (US EPA, 2019). This explains the recent strides in electric vehicle (EV) technology and why there is a push from all levels of governments to encourage the switch from fossil fuel vehicles to hybrid or electric alternatives. However, encouraging actors is one thing; actual implementation requires research and understanding of not only the environmental benefits but the reaction of individuals as well as other levels of government and states. As such, finding the best approach to reduce fuel emissions in the transportation sector becomes more pressing every day, especially as one of the likeliest sectors to spur social transformation that also supports greener choices. The transportation sector will likely become one of the major sectors to see unprecedented change in the upcoming years as climate action is prioritized. It is for this reason that this Major Research Paper (MRP) explores the question: With the goal of decreasing climate change and increasing zero-emission vehicles (ZEVs), are low-emission zones effective in terms of economic efficiency, public acceptability, and environmental protection – and if so, should they be implemented in Canada?

Methodology

This research question is seeking to explore whether low-emission zones are a suitable option for combating climate change in the transportation sector. It is seeking to evaluate their success in the criteria above to assert whether it is a viable option for Canadian cities. This

question is worth exploring because cities, states, and countries as well as international institutions are facing this precise dilemma when deciding how to effectively address the current climate crisis: what zero-carbon solutions exist that are economically-viable, generate buy-in, and can effectively stem the warming of the planet? Low-emission zones have only recently been developed in a handful of countries, and they are often being considered as a possible solution to climate change but there are not many comparative reports on approaches or reports on its challenges, successes, and failures. In an effort to reap ideal results, the most effective way to approach this question includes retrospectively analyzing policies which are currently in place and assessing if they could successfully be implemented in other areas. Additionally, understanding each degree of economic efficiency, public acceptability, and environmental protection will help determine how well-rounded and the overall effectiveness of the proposed or potential measures could be. Furthermore, to ensure this paper is not outdated and provides a transparent and recent analysis, this paper will solely focus on sources from the last 20 years. It will explore the varying approaches to reduced-emission zones such as low-emission zones, ultra-low emission zones, and zero-emission zones. The sources of this data analysis will be scholarly articles, political debates, news articles, Government documents and scientific journals. The news articles, government documents, and political debates will be found through Google, whereas the scholarly articles and scientific journals will be found through the University of Ottawa's virtual library catalogue of academic journal databases including JSTOR and ProQuest. It is not necessary to use primary sources for this MRP, because the advantage of this retrospective comparative approach is that the data exists and simply requires it to be compiled, structured, and analyzed. This proposal intends to be supplemented by academic rigor but its aim is to be digestible to governments for policy considerations. Since there will be a large sum of

data to filter through as this is a growing topic of conversation around the world, it will be necessary to keep the topic narrow and focused. It is for this reason that varying approaches to reduced-emission zones will be limited to solely being evaluated on the three factors outlined above - economic efficiency, public acceptability, and environmental protection - as they serve as the greatest indicators of whether the policies can be successfully implemented and if they will have a net positive outcome.

This paper will also contain case studies focused on London, Madrid, and Beijing. Case studies are important to explore as they can be used to evaluate qualitative and quantitative data of a real-world application of a low-carbon solution and they are the only evidence of the sustainability of these low-emission zones. Case studies aid in understanding the application of the reduced-emission zone theory. This theory hypothesizes that if implemented correctly reduced-emission zones should diminish current emission levels in the zone. Additionally, case studies are used to learn as much as possible about the outcome of the policy so that the information can be generalized and applied to other similar situations and cases. “Case-control studies are an efficient method for the study of rare outcomes, but suffer various limitations, including susceptibility to bias in recollection about exposure; and reverse causality” (Melamed & Robinson, 2018). Biases often present favourable results. It is for this reason that there will be three case studies that have each had unique experiences with low-emission zones, thereby helping to reduce any bias that would arise from solely exploring successful cases or European cases. On top of this, these cities have all demonstrated great strides in climate action, specifically, in the transportation sector. Yet, they all present their own challenges and benefits, providing a wealth of data diversity. London has had remarkable success in converting a large portion of its low-emission zone to an ultra-low emission zone. Lessons of successful

implementation strategies can be understood through this case study. Madrid, on the other hand, had many political setbacks with its low-emission zone implementation, forcing it to retract and suspend its efforts. Lessons on risk mitigation strategies can be gained from what does not work in this case study. Finally, Beijing's freight low-emission zone will also be examined to provide a successful non-European viewpoint, notably the experience of a country that does not identify with "traditional" liberal western principles and is not part of the global North. It has chosen a more narrow approach to address the worst emitters and ease the transition for its population. Lessons of alternative approaches that have also proven successful will be taken from Beijing's case study. Each case study provides a unique perspective on the methods of approaching the implementation of a low-emission zone and how to overcome the varying obstacles they have faced. This is necessary knowledge to gain, as a Canadian city could face any of the challenges identified in these case studies and would benefit from integrating that understanding into its own action plans and strategies. Additionally, the case studies better prepare Canadian cities to devise robust rollout plans, anticipate its potential challenges, and develop risk mitigation strategies. The comparison of these case studies is simply used to better understand successes and failures, not to be ranked against each other as they all provide insight and cannot be quantitatively ranked but more so qualitatively understood.

The case studies will be followed up by lessons observed on the overall success of reduced-emission zones and it will be determined whether they are worthy of the hassle and additional problems that may arise from implementing such zones. Additionally, specific suggestions and approaches will be explained. The concept of reduced-emission zones will then be assessed as to whether those types of zones could be successfully introduced in one of Canada's major cities, such as Vancouver, Montreal, or Toronto. However, "whenever feasible,

conclusions drawn from case–control studies should be verified” (Melamed & Robinson, 2018).

It is for this reason that pilot programs are recommended for Canadian cities rather than immediately launching a low-emission zone to begin with. Vancouver, Montreal, and Toronto will be explored in more detail as they are currently the most developed in terms of public transportation. By assessing the above mentioned cities, it will provide a helpful understanding about the possible outcomes of implementing emission zones as these cities have yet to be officially publicly evaluated in terms of readiness for a low-emission zone. In a final analysis there will be a conclusion drawn as to the effectiveness of zeros emission zones in these cities with accompanying recommendations for environmental policy-makers pulled from the case studies.

Low, Ultra-Low, and Zero-Emission Zones

There are a variety of reduced-emission zones across the world and, at times, with different levels of enforcement within the same city, especially during transition periods. Zero-emission zones are typically the ultimate goal for cities implementing low-emission zones. However, getting to a zero-emission zone is seldom the first target. They often require easing a population into it, making low-emission zones the natural first step to introduce communities to this concept. Following a successful transition to a low-emission zone, the next step has typically been to transition into an ultra-low emission zone and following that, when the time is right, convert to a zero-emission zone. According to the Institute for Transportation and Development Policy (ITDP)’s definition, a low-emission zone “is a contiguous zone that restricts the use of polluting vehicles through priced and non-priced strategies” (Institute for Transportation and Development Policy, 2023). On the other hand, a zero-emission zone (ZEZ) is “an area where ZEVs, pedestrians, and cyclists are granted unrestricted access, [whereas] other vehicles are

either prohibited from entering or permitted to enter upon payment of a fee” (Low Carbon Cities Canada, 2022, 1). From these definitions, it is clear the two share commonalities, including an overall desire to curb the unfettered effect of polluting vehicles on the environment, but zero-emission zones are far more stringent and leave less room for flexibility. Ultra-low emission zones fall somewhere in between the two. In addition, to these varying levels of reduced-emission zones there are also vehicle specific zones. For example, there are freight vehicle low-emission zones, where vehicles over a certain weight or that emit over a certain threshold are specifically targeted and banned from entering the zone. With the above listed in mind, despite thorough efforts, not all types of reduced-emission zones have faced the same issues or the same rates of success since each level of emission reduction has different standards and regulations, and each city has its own rules, regulations, measures of implementation and ways to enforce them.

Unfortunately, there is limited research and documentation available on how to effectively create emission-reduction zones and their impact. Indeed, there are few studies on the efficacy of reduced-emission zones, and none that use the criteria mentioned above or a holistic approach to explore the viability of those types of solutions. Studies that already exist on the matter either focus on a singular element of reduced-emission zones or undertake a review of a particular case rather than the comparative approach that will be taken in this paper. Some studies take on “analytics approach to decision alternative prioritization for zero-emission zone logistics” where an integrated two-stage decision analysis approach is proposed when examining considerations for urban transportation management (Deveci et al., 2022). In those cases, the intended aim is to first weigh out, through scientific research, each criteria that impacts decision-making before then formulating a ranking of the different decisions based on those analytical

results, providing a ranked list of alternatives decision-makers can choose from. These studies focuses on particular logistic and methodology on decision making which differs greatly from the research in this paper, but compliments it well. There are also simulation studies on zero-emission zones which have proven to be successful. Indeed, “calculations confirmed that emissions reduced dramatically, by 90%, inside the zero-emission zone, [and] at the city scale this corresponds to a reduction of almost 10%” (de Bok et al., 2021). However, one of the problematic drawbacks of simulations is their larger margin of error. Incidentally, there exists government reports on individual reduced-emission zones, their effects and outcomes, which will be used in this paper to assist in determining if they are, in fact, efficient. As such, this paper will combine various elements of these approaches and studies, adopting the practicality of defining the relationship between criteria, weighing the impact of decisions, and supplementing the anticipated results of those potential decisions with existing data on low-carbon solutions in the transportation industry to produce a more holistic report.

This paper explores reduced-emission zones as a climate action solution because they are a relatively new concept. Information regarding how accessible and convenient they can be has yet to be consolidated to a degree that would secure scientific and political consensus. The subject was also chosen because there have been recent discussions about it being piloted in Canada, but implementation has yet to be decided. The hope is that updated studies on the matter could help generate momentum and support for a decision. Notably, reduced-emissions zones are very different from other environmental policies currently in place as they are not based on financial incentives, such as taxes or subsidies, to persuade people to make greener choices. It is a much less flexible approach than those used in Canada’s past. This paper is important because alternative options, such as low-emission zones, should be considered as addressing the climate

crisis can no longer rely on personal motivations and individual choices that are undermined from the outset by the rigid structures of our globalized system which is driven by profit-seeking behaviors and fails to place human life at the centre of all decision-making.

Implementation

The cost of establishing a low or zero-emission zone can vary depending on implementation and enforcement policies such as parking space removal, implementing cameras and legal enforcement, congestion charges, restricting road access, and establishing infrastructure to accommodate EVs. However, all zones would require communications costs to make the standards, regulations, and the benefits of the measures clear to the public. This could be in the form of media coverage as well as providing physical and virtual resources detailing the plans, who it will affect, and how. Typically, the people living within the zone are exempt, and the conditions only apply to those entering the zone. If the zone allows for fossil fuel vehicles to enter at a fee, toll booths are sometimes installed to charge visitors day passes. Where there is a strict policy against all fossil fuel vehicles, the use of additional signage, cameras, and enforcement agents at times are implemented in order to block access and strictly monitor those coming in, like a border patrol. Enforcement agents such as police officers could also be dispatched to ticket fossil fuel vehicles that are not exempt and that have not been entered in the system with day passes. The city's infrastructure often requires some form of retrofitting or improvement to aid in the adoption and the transition to reduced-emission zones. Parking lots would require remodelling to support the need for charging stations, and depending on the zone, buses would have to be converted to ZEVs. There would have to be an increase in pedestrian and biking paths, as well as investments to improve public transit to support those who cannot afford switching to ZEVs. The revenue from tickets and day passes could be reinvested in the city's

infrastructure spending, especially once the initial costs of implementation are covered and if there is such a surplus. That is why zero-emission zones are typically part of a gradual process as they may begin as solely a ban against passenger fossil fuel vehicles before progressing to include commercial vehicles and eventually eliminating the use of day passes/tolls, forcing people to park and ride at public transit hubs to enter the city centre or drive around the city altogether.

Benefits & Drawbacks to Low/Zero-Emission Zones

Reduced-emission zones are increasingly being evaluated as an option for implementation across the world. The main benefit of this policy is the potential reduction in GHG emissions, but a zero-emission zone could also improve air quality, reduce congestion, contribute to climate goals, and raise municipal revenue (Reichmuth, 2021). Air quality in cities is frequently poor due to pollution from vehicles, buildings, and other sources. In fact, a recent major concern in air quality has been caused by natural disasters such as wildfires creating air quality warnings (Government of Canada, 2023). Zero-emission zone implementation has been shown to reduce the overall number of vehicles within a city's borders, lessening air pollution from gasoline exhausts and resulting healthcare problems and costs. Additionally, as ZEVs are a significant investment for the average individual or family, commuters may opt for public transit or other green travel means instead, further lessening the use of polluting vehicles. With less congestion across the city, there may also be a reduction in noise pollution. Furthermore, studies have shown that reducing vehicles on multi-use roads and pathways contributes to better overall safety outcomes for cyclists and pedestrians (Reichmuth, 2021). Finally, as these policies are likely to be enforced through fines and penalties, city revenues may increase. When possible, the

additional revenue can be reinvested in public transit and/or active transportation infrastructure, bolstering environmental, social, and health benefits.

Nevertheless, there can be drawbacks to zero-emission zone implementation. As residents are not penalized for gasoline-vehicle usage, they may continue to pollute, which risks lowering buy-in from others toward the policy. However, in Canada, as most traffic originates from suburbs outside of municipal limits, the policy stands to be effective (Harris, 2018). Another drawback may stem from political challenges and unease from this intervention as commuters using gasoline-powered vehicles may feel inconvenienced or unprepared for a transition, and fines when failing to switch to lower-emission transportation options may prove unpopular. However, with careful planning to support successful implementation, environmental, health, and social benefits often mitigate political pushback to these kinds of innovative policy options.

Case Studies

This paper will include three case studies of places that have experience in low, ultra-low, and zero-emission zones. The three case studies will be those of London, Madrid, and Beijing. These cases were chosen as they all offer different perspectives on reduced-emission zones and affect communities from vastly different cultural, financial, and political backgrounds. London has experienced great success in transitioning a majority of its low-emission zone to an ultra-low emission zone. Madrid, on the other hand, experienced a political failure with its low-emission zone implementation as they had to backtrack and pause its attempts. Providing a non-European perspective and, more specifically, that of a country that does not identify with “traditional” liberal western ideals, Beijing’s low-emission zones will also be explored.

Case Studies—London

To begin, The City of London, UK introduced their Low Emission Zone (LEZ) in 2008 and Ultra Low Emission Zone (ULEZ) in 2019 (Greater London Authority, 2019). “The LEZ covers most of Greater London and is in operation 24 hours a day, every day of the year” (Transport for London, 2023). The LEZ is distinct from the ULEZ, “which is in place inside the North and South Circular Roads and operates 24 hours a day, every day of the year except Christmas Day” (Transport for London, 2023). However, “the ULEZ is expanding from 29 August 2023 across all London boroughs” (Transport for London, 2023).

London—Economic Efficiency

As the LEZ is the first step in the greener transition, it has provided those traveling to London with some options. Other than purchasing, leasing, or retrofitting current vehicles that do not meet the LEZ standard, people may pay the daily fee to drive within the zone. Lorries (commercial trucks), vans, or specialist vehicles pay £100-£300 (CAD\$160-CAD\$503) daily to enter the LEZ (Transport for London, n.d.). The difference between the LEZ and ULEZ is that “lorries, vans, or specialist vehicles that exceed 3.5 tonnes do not need to pay the ULEZ charge but will need to ensure that they meet the LEZ emission zone criteria” (Hirefleet, 2023). In the ULEZ, cars, motorcycles, vans, and specialist vehicles (up to and including 3.5 tonnes) and minibuses (up to and including 5 tonnes) do however, have to pay £12.50/day, whereas they are exempt from paying in the LEZ (Transport for London, 2023). Therefore, despite the daily charge being significantly lower, it is adapted to take into consideration vehicles that are less harmful to the environment. Additionally, those being charged £100-£300 in the LEZ will have paid these charges for the day already and thus can enter the ULEZ, which is within the LEZ,

without being charged twice. Penalty charges for not complying in the LEZ ranges from £500-£2000, and penalty charges in the ULEZ are £180 (Transport for London, 2023).

However, prior to generating money from these charges and penalties, the costs of establishing the ULEZ was estimated to be between £6 and £10 million with running costs of £5M to £7M each year (Watkiss et al., 2003). This is nothing compared to the estimated £93.6M of additional revenue that the ULEZ has generated from non-compliant commuters according to London's Annual Report from 2019 to 2022 (Lancefield, 2022). Furthermore, between November 2021 and June 2022, an average of 1.9 million journeys per month were made into the ULEZs, acquiring a total of £112.5M of revenue from non-compliant drivers (Lancefield, 2022). Total costs to British drivers are estimated to be £64M to £135M (Watkiss et al., 2003). Therefore, London has without a doubt seen economic profit derive from this environmental policy and has been able to reinvest this money into other environmental policies and programs such as expanding public transit and increasing bike paths, which has encouraged its continued expansion of the ULEZ. It has successfully combined economic and environmental gain for the City of London.

London—Public Acceptability

London has fortunately gained public acceptability. These funds, however, are coming directly from the citizens. Even if those living in the zone are exempt, they are still indirectly impacted if they are expecting visitors or require something delivered to them. Thus, despite the municipality bearing the initial cost of implementing the policy, small businesses may be overly affected by this policy as deliveries and general business activities will become expensive. In fact, in the first five months of the ULEZ, for example, businesses and private motorists paid more than £30M to drive into Central London, and another £10M in late fee penalties (de Prez,

2019). Therefore, it is somewhat surprising that these zones continue to gain public and political acceptability.

Interestingly, with the expansion of the ULEZ recently announced, it was found that “nearly twice as many Londoners believe the Mayor’s proposed expansion of the Ultra Low Emission Zone should go ahead than oppose it, a representative YouGov poll commissioned by City Hall has revealed” (Greater London Authority, 2022). Moreover, the “same percentage of Londoners as last year see the ULEZ as positive (54 per cent), demonstrating that support has not been affected by the cost-of-living crisis” (Greater London Authority, 2022). A leading motivating factor for Londoners is the quality of the city’s air. In fact, “around 4,000 Londoners died prematurely in 2019 because of long-term exposure to air pollution, with the greatest number of deaths attributable to air pollution in outer London boroughs” (Greater London Authority, 2022). The London boroughs are not a part of the ULEZ, so Londoners may very well be associating the non-ULEZ air quality to these deaths. “Air pollution is also permanently stunting children’s lungs and leading adults to suffer a range of illnesses, including lung and heart disease” (Greater London Authority, 2022). Indeed, “over 500,000 Londoners live with asthma and are more vulnerable to the impacts of toxic air, with more than half of these people living in outer London boroughs” (Greater London Authority, 2022). This further proves the difference in air quality and its impact on Londoners’ health, an issue that is unlikely to improve with time. “While those living in central London are breathing cleaner air due to the ULEZ, with roadside nitrogen dioxide (NO₂) levels down by 44 per cent, those in outer boroughs are not benefiting to the same extent” (Greater London Authority, 2022). It is for this reason that the mayor has been called on to make this fairer by expanding the ULEZ London-wide and a leading reason for the widespread support for the expansion of the ULEZ and low-emission zones in

general. This has been demonstrated in polls that show “a vast majority of Londoners (68%) think higher-polluting vehicles should pay more than other vehicles for travelling through the capital” (ClientEarth, 2021).

Londoners are not only concerned about air pollution, they have also noticed the improvement in congestion thanks to the ULEZ. Londoners living outside of the city centre have expressed concerns that they are being “overlooked in the outer boroughs, where traffic congestion seems far worse” (ClientEarth, 2021). The ULEZ encourages the use of public transportation rather than personal transportation. While this may be a deterrent or inconvenience for some, “more than 3 million Londoners use public transport in the capital every day” (Freston-Clough, 2012). In 2022, it was found that 70% of Londoners prefer to use public transport for their daily commute (Intelligent Transport, 2022). Furthermore, it is not only Londoners that recognize the efficiency of their public transport system; in 2007, the London subway was voted the best in the world (Dugan, 2007). Interestingly, “a poll of world travellers by TripAdvisor reveals that people outside the UK believe that the capital's transport system is one of the safest and most efficient public transport networks in the world” (Dugan, 2007). This is one year prior to the creation of the LEZ in 2008 and precedes all the improvements and expansions it has undergone in the last fifteen years. It is easier for people to adapt to low or ultra-low emission zones when there is such an efficient alternative for people to commute. In fact, “alongside the expansion of the ULEZ, the Mayor has outlined a number of plans to improve public transport in outer London” (Greater London Authority, 2023). These “enhancements include:

1. The brand new Superloop bus network, which will connect outer London, faster.
2. A further 1 million km expansion of bus routes in outer London.

3. Plans for a new West London Orbital Overground service (subject to funding).

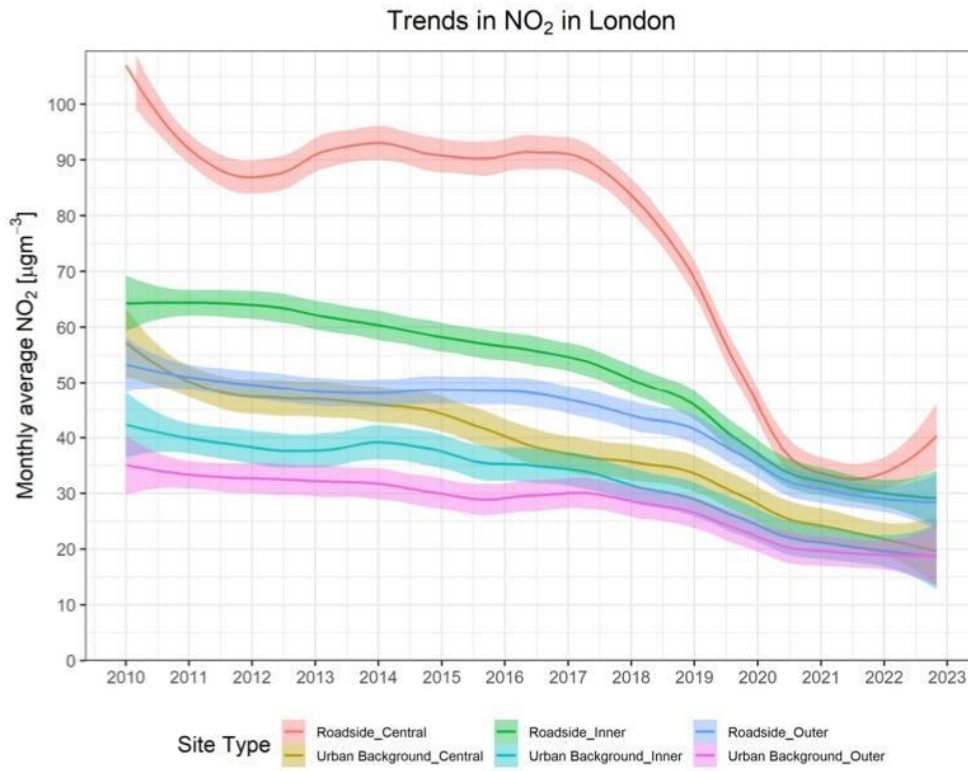
This is alongside other recent public transport enhancements, such as the launch of the Elizabeth line across east and west London and DLR service enhancements benefitting people in outer London” (Greater London Authority, 2023). Therefore, if people are not inconvenienced by the ULEZ and reap health benefits, then it becomes clearer how the ULEZ gained widespread public approval and therefore political acceptability.

London—Environmental Protection

London has also seen great reduction in emissions due to its LEZ and ULEZ. In the ten months after expanding the ULEZ across Greater London, Nitrogen Oxides (NO_x) dropped by 35% and CO₂ emissions by 6% (London Assembly, 2023). Indeed, continued expansion in 2021 dropped NO_x emissions by 23% (13,500 tonnes) across the city (London Assembly, 2023). Nitrogen oxides (NO_x) are a family of poisonous, highly reactive gases that form when fuel is burned at high temperatures such as by automobiles, trucks, and various non-road vehicles (US EPA, 2023). While “fine particulate matter (PM_{2.5}) is an air pollutant that is a concern for people's health when levels in air are high” (New York State Department of Health, 2018). Furthermore, as depicted in Figure One and Two, Nitrogen Dioxide (NO₂) levels dropped significantly, including close to 46% within Central London (London Assembly, 2023). Although traffic has risen post-pandemic in London, NO₂ levels have not returned to pre-pandemic levels (London Assembly, 2023). Additionally, the ULEZ has reduced 800,000 tonnes of CO₂ emissions from vehicles since 2019 and fine particulate matter (PM) levels have also continued to drop, with a 41% reduction in average concentration across London since 2017 (London Assembly, 2023). Therefore, it is evident that London has seen great results in its goal of reducing emission with the development of low and ultra-low emission zones.

Figure One

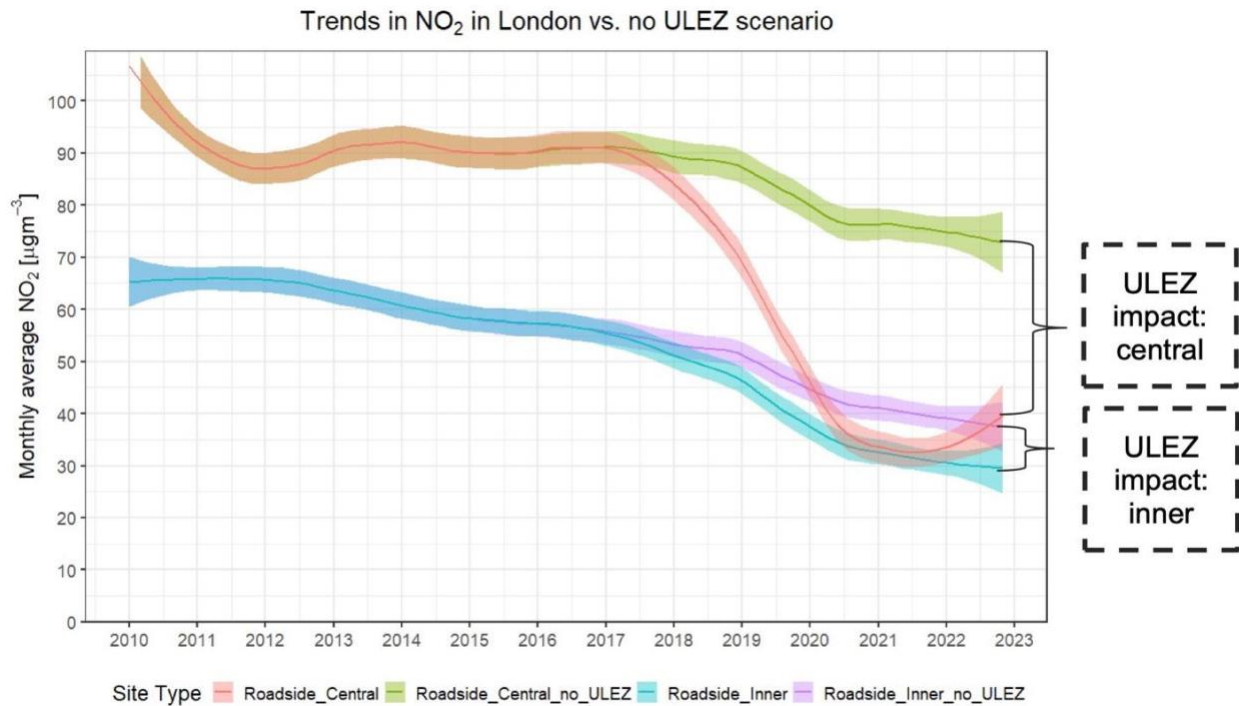
Trends in NO₂ in London after ULEZ implementation



(Mayor of London, 2023)

Figure Two

Trends in NO₂ in London, UK with a ULEZ vs no ULEZ scenario



(Mayor of London, 2023)

Overall, London is a proven success case for reduced-emission zones. It has become economically self-sustaining and has even turned a profit for the city. London found a way to price charges high enough to create revenue, but not too high for it to be prohibitive to its most important stakeholders, ensuring the population did not object to the transition. Londoners have accepted the LEZ and ULEZ and continue to support the expansion of the ULEZ. The City of London has successfully anticipated needs, and promoted and branded the ULEZ to gain public acceptability. They also have and continue to improve the public transportation system to support the progression of the ULEZ and ease the transition for a greater number of Londoners. There has been a significant improvement in air quality as well as reduction in emissions in the atmosphere, thus proving that environmental protection can be balanced with economic

considerations. London's LEZ and ULEZ should without a doubt be used as an exemplar for the rest of the world.

Case Studies—Madrid

'Madrid Central' is a Low-Emissions Zone (LEZ) implemented in certain parts of the metropolitan area of Madrid. The initiative was introduced in November 2018 to meet the EU's rules on clean air (PlanUp.eu, 2020). Madrid was considered a particularly bad polluter and needed to establish change quickly to meet the EU's rules on clean air. The plan, known as Madrid Central, established a "low-emissions zone that covered 472 hectares (1,166 acres)" (Jones, 2018). All petrol vehicles registered before the year 2000 and diesel vehicles registered before 2006 were banned from the area, unless they were used by residents of the area or met other exemptions (Jones, 2018). The goal was to "cut nitrogen dioxide levels by 23% in 2020 and put people – rather than the internal combustion engine – at the heart of transport policy" (Jones, 2018). Madrid's proposal was a bold and environmentally-forward policy. The policy aimed to ensure that the only vehicles allowed to drive freely around the downtown area were those that produced zero-emissions (Jones, 2018). However, there were some additional rules and regulations in place to allow some fossil fuel vehicles in the core at certain times of day or for allotted time periods. Hybrid and LPG (liquefied petroleum gas) vehicles were allowed into the area to park for a maximum of two hours, and more modern diesel and petrol vehicles were only allowed in to park in public car parks or private garages (Jones, 2018). Truck drivers, on the other hand, were subject to a timetable: the oldest, most polluting heavy motor vehicle were only admitted from 7am to 1pm, while more modern vehicles were given a window that extended until 9pm (Jones, 2018). These laws were enforced by "115 cameras that record and cross-reference vehicle license plates" (Cities Today, 2021).

However, the zone was not as successful as Madridians had initially hoped and was subjected to many challenges and changes between 2018 and 2023. The zone was initially “suspended in July 2019 by Mayor Martínez-Almeida, only to be reinstated by a court a week later” (Cities Today, 2021). “It was then suspended again in July 2020 after two appeals by the mayor’s administration” (Cities Today, 2021). In 2021, residents believed the zone would be completely scrapped for good; however, since January 2022, Madrid has reactivated the low-emission zone, forbidding passenger cars with an A label from entering the M-30 (orbital motorway circles the central districts of Madrid) unless they are residents of Madrid in the DGT (Dirección General de Tráfico) Registry and are registered in the Tax Register (Fundación CEA, 2023). Vehicles with an A label are those with a gasoline engine registered before the year 2000 and those with a diesel registered before 2006 (Carvajal, 2022). This scenario has been complicated by the restriction that took effect most recently on January 1, 2023, stating these A label vehicles are no longer able to circulate on the M-30 (Fundación CEA, 2023). Furthermore, Madrid’s administration plans to prohibit vehicles from circulating in the rest of the city beginning in 2024. By 2025, no A label vehicle may circulate through Madrid, even if they are residents of the city (Fundación CEA, 2023). Until March 21, 2022, the economic penalty for entering or driving through the Central District’s low-emission zone with an unauthorized vehicle or when restrictions were in place due to high pollution protocol, was limited to €90 (CAD\$130) and was considered a minor infraction. With the implementation of the new Traffic Law, these violations are considered serious infractions, carrying a financial penalty of €200 (CAD\$288) (Fundación CEA, 2023). According to the Protocol for High Pollution in Madrid, there are three levels of action based on the concentrations of nitrogen dioxide registered. When any of these levels are exceeded, coupled with an unfavourable weather forecast - a contamination episode is

said to have occurred, leading to increased vehicle regulations and restrictions (Linea Directa, n.d.). Although these regulations are different from those established and reversed in 2018, 2019, and 2020, the increase in yearly regulations is still quite ambitious, and worrisome for policy-makers.

Madrid—Economic Efficiency

Spain has made significant investments into the implementation of low-emission zones. It has spent 1.5 million euros solely on establishing controls on low emissions (European Commission, 2023). However, when implementing a low-emission zone, the city also has to introduce other measures that properly support the low-emission zone and the behavioral change that is required for it to succeed. As a result, Madrid spent an additional €16M on electric buses and another €9.2M on building new cycling paths on top of its initial €1.5M (European Commission, 2023). Overall, they have spent €26.7M on setting up a low-emission zone and the infrastructure to support it. Investing in such initiatives requires a considerable number of resources and effort. The City of Madrid has demonstrated its resilience in its multiple attempts to implement a reduced-emission zone. It is a lot of city spending to give up on to prepare the zone, let alone enforce it. Even if bike paths and electric buses aren't viewed as a financial loss, there is a strong desire to fulfill the net zero goal it has set out for itself which requires funding. However, emission zones are not typically a financial burden. Despite the initial costs, the fines become revenue to reimburse the initial investment. In fact, over the course of seven months, from January to July 2022, Madrid generated €81.9M in fines from Madrid's low-emission zone (El Debate, 2022). Moreover, the fines for driving with a vehicle not authorized in the low-emission zone already exceed 40% of the municipal collection in penalties (El Debate, 2022). Therefore, despite the initial cost of €26.7M, Madrid made a net profit of €55.2M in seven

months. This reinforces the city's positive perception of the low-emission zone, and explains its continued effort to overcome public and political disapproval.

Madrid—Public Acceptability

As mentioned, Madrid Central, Madrid's low-emission zone, has unfortunately been poorly received, with low public acceptability, and has been rather politically contentious. Firstly, with a total of 81.9 million euros in fines already levied against individuals, it is not surprising that the public has voiced concern regarding the financial burden this zone has created. Individuals are being financially impacted by Madrid Central's approach. Additionally, this is not the sole point of contention, nor is it even the main one. A total of 799 individual questionnaires were used to identify the factors affecting the levels of buy-in from the public toward the Madrid Central low-emission zone. Interestingly, "results indicate that socio-economic and demographic variables are weakly related to the level of public acceptability towards the LEZ" (Tarrío-Ortiz, Soria-Lara, Gómez & Vassallo, 2021, p. 1). Contrarily, it was found that "the political ideology of individuals, their environmental awareness, their primary transport mode, the use of shared mobility systems, and the frequency of access to "Madrid Central" have a higher explanatory power" (Tarrío-Ortiz, Soria-Lara, Gómez & Vassallo, 2021, p. 1). In this survey, 36.2% of respondents showed a very positive opinion of "Madrid Central", 31.7% stated a positive opinion, and 8.3% provided a neutral position. Only 14.6% pointed to a negative view of the low-emission zone, and 9.5% of respondents recorded a very negative view (Tarrío-Ortiz, Soria-Lara, Gómez & Vassallo, 2021, p.10). While there is an overall favourable view of the low-emission zone according to the survey, there is still nearly a quarter of respondents that held a negative opinion of the measure. This means that, if the survey accurately

represented the population of Madrid, over 800,000 people are opposed to the Madrid Central low-emission zone, which explains the political contention. “Participants with a negative or very negative acceptability of “Madrid Central” pointed out: the need for a higher supply of collective transport services (49.7%) and the activation of financial support for renewing private vehicle fleet (46.1%)” (Tarrío-Ortiz, Soria-Lara, Gómez & Vassallo, 2021, p.10). It can be inferred that the modes of transportation offered play a significant role in determining the perception people have of the low-emission zone. Indeed, if a city’s public transportation infrastructure cannot support a low-emission zone’s needs, it is difficult for the public to support the project. Constituents that used to drive through the low-emission zone on a regular basis and no longer can would be the first to expect efficient and adequate alternatives should they support the policy. This is their primary concern.

It is also important to recognize that some biases continue to profoundly impact public and political acceptability of low-emission zones. It is not surprising that “respondents with a left-wing political ideology show a much higher acceptability in comparison with other political ideologies, especially supporters of right-wing parties” (Tarrío-Ortiz, Soria-Lara, Gómez & Vassallo, 2021, p.13). People who identify with political parties are more likely to support or dismiss policies along party lines. It follows that due to all the controversy surrounding Madrid Central, individuals will align with the political actors that support their position and contribute to the polarization of the issue. Climate deniers also tend to be exploited by parties seeking to get into power and these parties will unsurprisingly put forward anti-climate action rhetoric and oppose solutions such as low-emission zones. Unfortunately, since Spain tends to have a lot of shifts in elected officials each election, they almost inevitably experience the same kind of back and forth on large-scale initiatives such as Madrid Central. This political uncertainty contributes

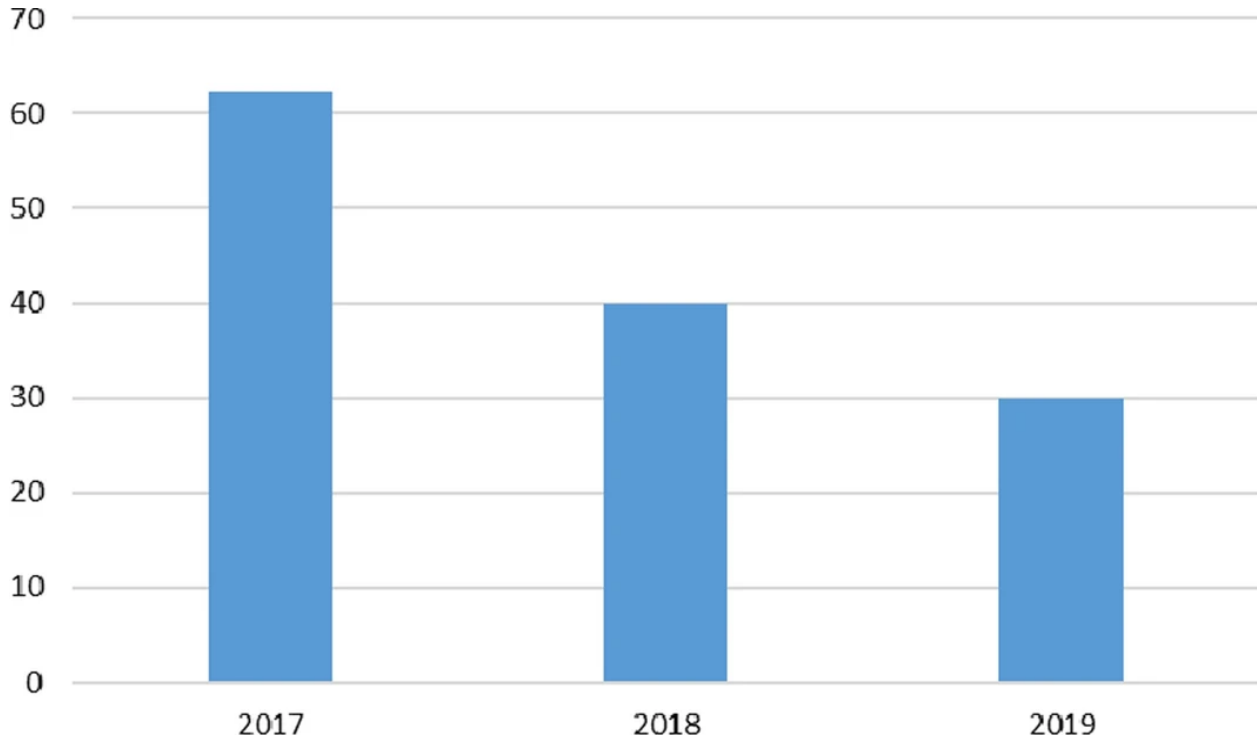
to the uncertainty of the people, so it will be interesting to see if this new iteration of the low-emission zone lasts.

Madrid—Environmental Protection

Despite all the mixed reviews, Madrid Central has produced positive results in emissions reduction. According to Acción (2020), “Madrid Central lead to a 32% reduction in NO₂ pollution in June 2019 vs. 2018” (Moral-Carcedo, 2022). Again, “in Lebrusán and Toutouh (2021) the authors conclude that Madrid Central significantly reduced the NO₂ concentration in the air” (Moral-Carcedo, 2022). Furthermore, as demonstrated in Figure Three, there was a significant reduction in the average NO₂ (µg/m³) pollution value. In fact, measurements demonstrate that the average NO₂ recorded in 2019 was the lowest since 2000 (Moral-Carcedo, 2022). This means that there have been pronounced improvements in emission reduction.

Figure Three

NO2 monthly average level ($\mu\text{g}/\text{m}^3$) recorded in November in Madrid, Spain



(Madrid City Council, 2019)

However, there is debate whether this is simply the natural progression with regards to advancements in green infrastructure or if there's been a significant positive trend in Madrid specifically. Interestingly, "the number of zero-emissions vehicles in use in Madrid increased from 13,343 in 2018 to 21,762 in 2019 (+ 63.1%)" (Moral-Carcedo, 2022). This aids in explaining the decrease in emissions, which is a net positive. Yet, this seemingly enormous increase is comparable to the increase observed in the rest of Spain (+ 62.3%); thus, no differential impact is observed in the case of Madrid (Moral-Carcedo, 2022). Therefore, it is unclear whether this drop in emissions was truly caused by Madrid Central or the ever-growing shift to zero-emission vehicles. However, upon further research, it was found that despite

limitations, “the Madrid LEZ has been effective in reducing traffic in the affected area” (Moral-Carcedo, 2022). Less traffic means less emissions. Although the low-emission zone may not have directly impacted the number of zero-emission vehicles purchased, it has impacted the number of vehicles on the roads creating emissions. Therefore, Madrid Central has been effective in reducing emissions.

Overall, Madrid is somewhat of a contentious case. It was successful in becoming economically self-sustainable, although the return on investment for the taxpayers is a bit harder to measure. It did aid in the reduction of emissions, but that trend is being observed across the country at similar rates. It has received support from the vast majority of the public but has faced great political instability and public scrutiny. Nearly a quarter of the sample size population rejected the transition and continue to disapprove of Madrid Central. However, there are still opportunities for redress. As the main criticism of this project is that the transportation alternatives and public transit infrastructure do not support the needs of the people who frequent the low-emission zone, additional infrastructure investments can remedy this. While the City of Madrid has been unsuccessful in promoting Madrid Central as a result of a revolving door of elected governments abolishing and restoring the project, it has not yet completely abandoned the concept of a low-emission zone. Despite its contribution to the decrease in emissions, clean air may not be enough to keep Madrid Central in place if there’s another major change in elected officials and the public has not categorically pronounced itself in favour of it. The city should reinvest many of the funds in educational and awareness campaigns for the population to have a better understanding of the regulations as well as the many unspoken benefits they stand to gain from having the low-emission zone established.

Case Studies—Beijing

Beijing is an interesting case study as historically it has followed very different political decisions than Europe. Nevertheless, China is one of few countries outside of Europe with a low-emission zone. China has not always been as forthcoming with environmental policies as Europe or other G7 nations have. China's struggle with environmental pollution is "associated with both alleviate poverty and control population growth" (Chunmei & Zhaolan, 2010). In the past, China has struggled to prioritize environmental policies competing with short term economic gains. Indeed, "China was the biggest emitter of carbon dioxide (CO₂) emissions in 2021, accounting for nearly 31 percent of the global emissions" (Tiseo, 2023). However, it is becoming increasingly evident that it is imperative for China to address this problem and continue its environmental push should it want to preserve the prosperity of its country beyond economic wealth.

In 2017, Beijing launched a low-emission zone, banning heavy-duty freight vehicles with emissions below national IV standards from entering the city (World Resources Institute, 2023). Following that, in December 2018, the freight vehicles for other cities in accordance with the national III emission standard for motor vehicles were also banned (C40 Knowledge Hub, 2020). "The zone was later extended to the whole city and stricter emission standards were introduced in 2019" and they are in effect all day (Petzhold, 2019). It is not yet a zero-emission zone, but it is leading toward that. Unlike the European examples, there are no day passes or toll fees in Beijing's low-emission zone. Instead, vehicles require special permits to enter the zone. Demand for access permits in Beijing is extremely high (C40 Knowledge Hub, 2020). In Beijing, electric freight vehicles have road access restrictions and need to apply for city access permits whereas for diesel freight vehicles, there is a merit-based system to distribute city access permits (C40 Knowledge Hub, 2020). Having strict restrictions and not allowing day passes ensures that

Beijing can meet its emission targets; Maintaining restrictions for electric vehicles helps address traffic congestion concerns (C40 Knowledge Hub, 2020).

Beijing—Economic Efficiency

In order to enforce these regulations, Beijing has used two primary methods. The first is the use of cameras that read license plate numbers and can issue fines to those illegally entering the zone (C40 Knowledge Hub, 2020). The second is having checkpoints where vehicles without authority to enter are once again easily identified and fined (C40 Knowledge Hub, 2020). Beijing has successfully implemented strong enforcements to ensure the low-emission zone regulations are respected. It already used the cameras and checkpoints for other matters, so the city did not have to invest additional resources into these measures. However, “Beijing’s budget to fight air pollution jumped from just over 3 billion yuan (US\$434 million) in 2013 to more than 18 billion yuan (US\$2.6 billion) in 2017” (United Nations Environment Programme, 2020). Therefore, they were able to fund any required updates the cameras, checkpoints, educational campaigns, as well as financial incentives to support the zone. Yet, the financial burden, for the most part, remained on the consumers. In fact, their low-emission zone driving restrictions policy has resulted in an annual loss by consumers of more than 17.84 billion RMB, which is equivalent to USD \$2.5 billion (Xiao et al., 2019). Thus, it can be argued that the low-emission zone in Beijing is generating revenue for the city much like a tax on polluting vehicles.

This is especially interesting as Beijing was criticized for having the lowest penalty charge of low-emission zones of RMB¥100, which is around USD \$14 (Ellis, 2022). This would support the argument that the low fine does not do much to deter non-compliant vehicles from entering the zone. Yet, the zone seems to be working as it has seen a significant increase in electric vehicles, from 25% to 90% in just a year as demonstrated in Figure Four below (C40

Knowledge Hub, 2020). Moreover, in 2020, the proportion of freight vehicles from other cities entering Beijing, in accordance with the national III emission standards for motor vehicles, was only 1%, a full 29% lower than what was recorded in 2017 (C40 Knowledge Hub, 2020).

Figure Four

Proportion of licensed electric vehicles in Beijing

| timing | Electric proportion of licensed vehicles |
|---------|--|
| Q4 2019 | 25% |
| Q1 2020 | 50% |
| Q2 2020 | 65% |
| Q3 2020 | 80% |
| Q4 2020 | 90% |

(C40 Knowledge Hub, 2020)

Beijing—Public Acceptability

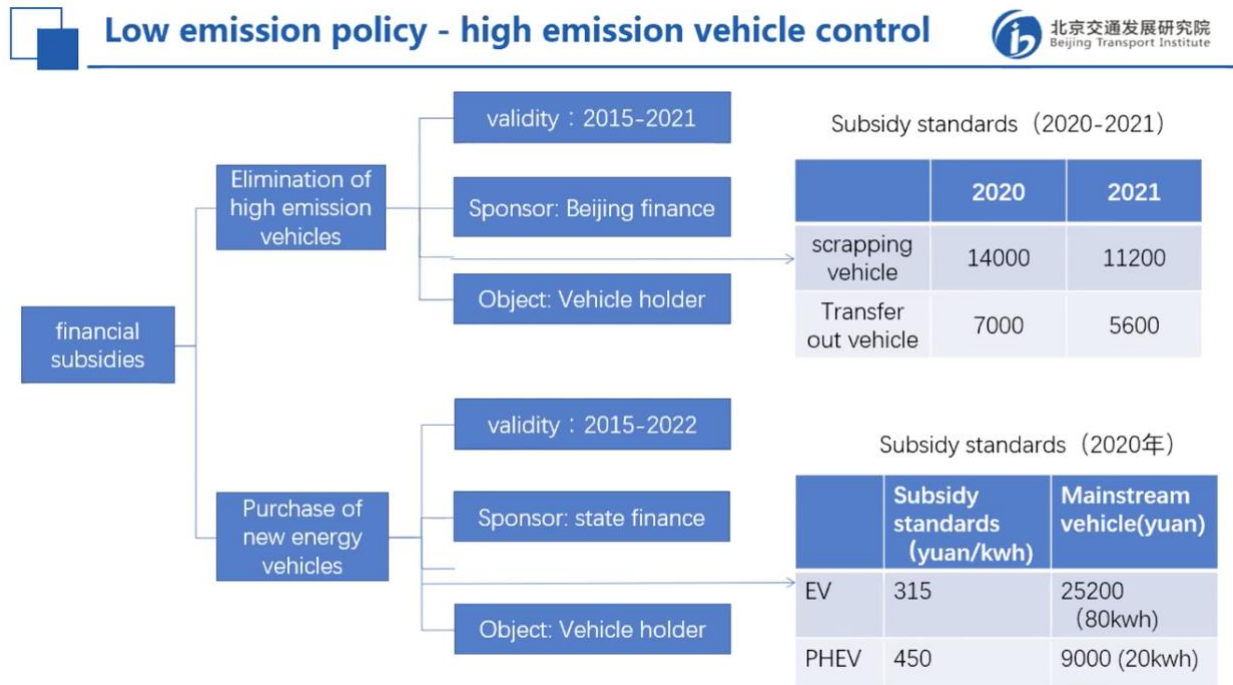
This could be the result of numerous factors. Chinese citizens may not respond to fines as they do the law, meaning fines are not as effective as a deterrent compared to the pressure exerted by the political regime. The Chinese Government does have a stronger hold on its people than many European and Western countries with democracies. On the other hand, it could simply be due to the fact that the financial incentives to switch to electric vehicles are stronger than the deterrents. The government has offered many financial incentives to its people to switch to ZEVs in order to lessen the financial burden imposed by the low-emission zone.

In fact, according to Lulu Xue, Urban Mobility Manager at WRI-China, the reasoning behind Beijing's low-emission zone is two-fold. Firstly, freight vehicles are major polluters. Secondly, it boosts the economy as the vehicle manufacturing industry has been a major pillar of

economic growth for China's economy (C40 Knowledge Hub, 2020). Businesses are carrying most of the financial burden of the low-emission zone and are forced to make the switch from freight vehicles to electric freight vehicles. It is for this reason that Beijing is considering introducing operational subsidies (C40 Knowledge Hub, 2020). Indeed, in order to lessen the burden on the consumer, Beijing offers financial incentives such as local purchase subsidies, subsidies on charging infrastructure provision, and diesel vehicle scrapple subsidies (C40 Knowledge Hub, 2020). A majority of the funding for these subsidies if from the increase in budget, as well as revenue from the low-emission zone. In Figure Five, the breakdown of the financial subsidies is presented. It is important to note that Beijing is reinvesting its profits into assisting citizens to adapt to these changes.

Figure Five

Subsidies for eliminating high emission vehicles and purchasing new energy vehicles in Beijing



(C40 Knowledge Hub, 2020)

Prior to the implementation of the low-emission zone in Beijing, the World Resources Institute also polled public opinion and increased awareness through educational campaigns and public outreach (World Resources Institute, 2023). It is evident that Beijing has placed (and continues to place) significant effort in building up public and political acceptability for the low-emission zone. Despite this, it has not gone without criticism. In fact, electric freight vehicles use newer technology and have frequent breakdowns (C40 Knowledge Hub, 2020). Interestingly, in order to combat these criticisms, China is looking into greater research and investments in hydrogen vehicles (C40 Knowledge Hub, 2020). China is clearly listening to the concerns of its main stakeholders – its citizens - and is actively trying to find alternative solutions to ensure they

can maintain their support. Manufacturers and warehouse operators also had concerns regarding relocation needs. In response, Beijing is now considering operation subsidies to aid those who are the most affected and most in need (C40 Knowledge Hub, 2020). Solely targeting freight vehicles allows Beijing to focus not only the problem, but those on the receiving end who may end up being the biggest detractors to a low-emission zone. By slowly enlarging the group affected, Beijing eases the population into the transition and can target any improvements they deem necessary. However, it is not surprising that China is not facing too much criticism regarding this shift to a low-emission zone, because China's political regime does not allow much room for criticism from its people. Their regime, unlike the democratic ones previously explored, does not prioritize its citizens opinions as much because they do not hold their fate through elections as seen by the overturn of governments in Madrid for example. Moreover, there are repercussions for speaking out against the government and its decisions, so it is not surprising that any criticism is minor and more so a suggestion for where it can be improved rather than a complaint.

Beijing—Environmental Protection

The reason Beijing decided to start with freight vehicles over private, other than the ease in transition, is that they are the biggest polluters. As presented in Figure Six below, freight vehicles are overwhelmingly responsible for nitrogen oxides and fine particulate matter (C40 Knowledge Hub, 2020). Figure Six exposes freight vehicles for contributing to 52% of NOx and 73.5% of PM2.5. This is extremely detrimental not only to the environment but has a huge effect on the population's health.

Figure Six

Nitrogen oxides and fine particulate matter emission per vehicle in Beijing

| category | NOx | PM2.5 |
|---|--------------|--------------|
| Freight | 52.0% | 73.5% |
| public transport | 11.6% | 3.3% |
| private | 9.1% | 0.0% |
| taxi | 0.8% | 0.0% |
| rental | 0.2% | 0.5% |
| environmental sanitation+postal service | 0.1% | 0.5% |
| tourism | 1.4% | 1.6% |
| provincial transportation | 1.7% | 2.3% |
| others | 22.9% | 18.3% |

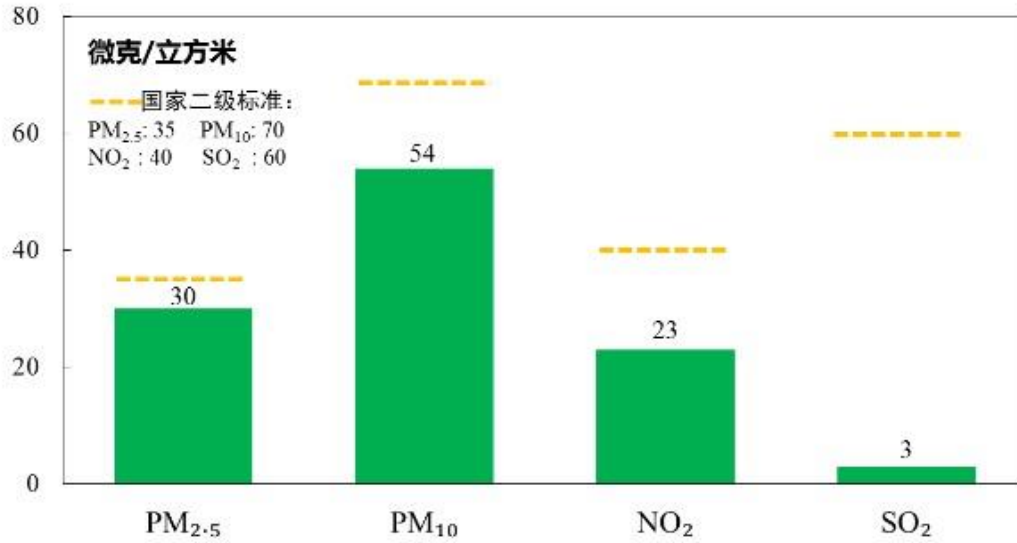
(C40 Knowledge Hub, 2020)

Since its introduction, Beijing has reported that the low-emission zone restrictions resulted in “annual emissions reductions of 12,000 tons of CO, 845 tons of NOx, 1356 tons of hydrocarbons HC, 53 tons of PM2.5, and 57 tons of PM10” (Xiao et al., 2019). This strongly suggests that Beijing’s low-emission zone is a success case. Moreover, with the additional financial incentives of eliminating old polluting vehicles in Beijing, it resulted in “annual emissions reductions of about 22,600 tons of CO, 1330.2 tons of NOx, 2197 tons of HC, 78.6 tons of PM2.5, and 81.3 tons of PM10” (Xiao et al., 2019). As demonstrated in Figure Seven below, in 2022, the emission levels decreased well beyond the national standard in all categories (PM2.5, PM10, NO2, and SO2) (Beijing Municipal Ecology and Environment Bureau, 2023). Figure Eight also identifies the percentage at which pollutants dropped from 2021 to 2022, which proves to be positive (Beijing Municipal Ecology and Environment Bureau, 2023). Thus, the

combination of the low-emission zone along with financial incentives to transition produced incredible reductions in emissions and toxins in the air.

Figure Seven

Annual average concentration of four major pollutants in 2022 in Beijing

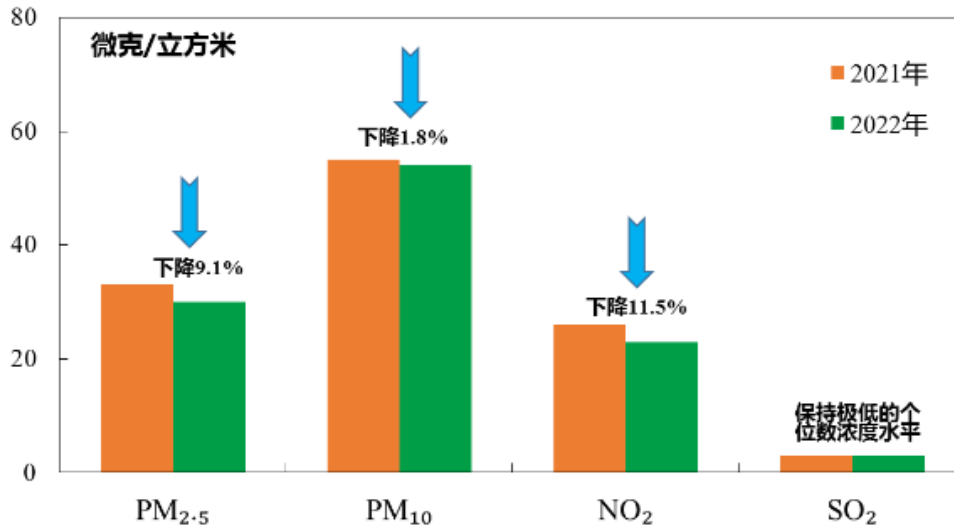


(Beijing Municipal Ecology and Environment Bureau, 2023)

Figure Eight

Changes in the annual average concentration of four major pollutants from 2021 to 2022 in

Beijing



(Beijing Municipal Ecology and Environment Bureau, 2023)

Needless to say, Beijing's low-emission zone is another success case if the numbers are to be taken at face value. It is economically self-sustainable to the point of reinvesting in itself and creating greater financial incentives for the population to comply. Due to the carefully planned implementation of this zone, the educational awareness campaigns, and the administration's financial support, Beijing has facilitated the transition for residents and businesses alike. In doing so, they have witnessed great results in lowering emissions and improving air quality in Beijing. Beijing continues to expand and implement greater and more stringent restrictions with the hopes of eventually becoming a zero-emission zone. In addition, this success has led to many other varieties of low-emission zones being implemented around the country as China continues to progress in an environmental direction. China has proven it is

finally seeking to change its habits and significantly reduce the number of emissions it produces starting with their congested transportation sector.

Lessons

The overall efficiency and success of zero-emission zones is dependent on economic efficiency, political acceptability, and environmental protection. All three reduced-emission zones explored in the cities of London, Madrid and Beijing, have proven to be economically efficient. They did so through pricing fines, toll fees, and exemption passes at a price that would generate a profit. As long as initial costs are low and the financial burden is passed on to consumers to make greener choices, low-emission zones can generate a profit and, in the medium-term, provide more affordable alternatives to people so as not to be seen as solely a cost-generating measure to the taxpayer. However, these fees and fines must be carefully leveraged to ensure the public does not view them as unjustly punitive. It is also for this reason that it is important to find a balance with what is accessible to residents in the cities in question. If successful, with the surplus in revenue, cities have been reinvesting in making the zone more adaptable by improving transit, increasing charging stations, and offering subsidies. Reinvesting in the city and facilitating the transition for the population has proven effective not only in terms of being cost effective but for public acceptability as well.

In order to ensure public acceptability, it is imperative for cities to provide a smooth transition for residents and businesses. As seen in China, prior to implementing a low-emission zone, it is important to introduce awareness campaigns to educate and familiarize the population with the concept of reduced-emission zones and transitions prior to their implementation (World Resources Institute, 2023). First, thorough education for both local residents and businesses should be conducted to ensure buy-in for the initiative, and to clarify local exemptions to the

zone. These education campaigns should outline the public benefits of a zero-emission zone, how the city will be managing equity around the project, and financial incentives such as the rebates and subsidies available to offset personal and business costs. Public support will ensure that the zone will have longevity and not become a one-term political issue as seen in the downfall of Madrid's ZEZ (Neslen, 2019).

Second, the policy should have a clear enforcement model. In London, for example, a low-emission zone covers the majority of Greater London, operates 24 hours a day, and utilizes cameras to check number plates of all vehicles to assess their emission potential (Transport for London, 2023). Vehicles must be registered prior to entering the city and those that do not meet the emission standards (Euro IV) are charged £500 or a reduced fee of £250 if paid within two weeks (Transport for London, 2023). It is necessary to issue clear policies to ensure that the zero-emission zone is followed and outline these clearly to residents prior to the zone being implemented. Furthermore, the policy should state the exact specifications for vehicles that do or do not meet the emission requirement, and how vehicles will be tracked and fined if they travel within the zone.

It is also important to increase restrictions slowly, not all at once, to allow time for people to adapt. The most important factor is also to have the city ready, not only politically, but also pragmatically. The infrastructure must respond to the needs of residents and businesses in the low-emission zone. If people can no longer drive into the city, the alternatives must be accessible. This includes having a strong public transit system, adequate charging stations, safe pedestrian, and bike lanes, and more. For example, there should be better urban development and zoning laws for new builds. The public should not feel that this zone is prohibitive, disruptive, or simply a burden that has been passed on to them. Local residents and businesses need to be

assured that alternative transportation methods will be as reliable, safe, and accessible as personal vehicles to ensure the continued support of the zero-emission zone. Without public support, the zone risks being dismantled every time there is an election as witnessed in Madrid. If people are well-informed, have viable alternatives, and are made aware of the progress, the zone is much more likely to remain in place.

The people should know about the benefits of reduced-emission zones such as improved air quality and the decrease in emissions. Reduced-emission zones have been proven effective as an environmental protection policy and yield considerable health benefits. These are some of the most important reasons why reduced-emission zones are critical to any green policies in urban centres. As such, the benefits should be highlighted and promoted regularly. Once public acceptability has been secured, the most important aspect to showcase success is the scientific proof that reduced-emission zones should be here to stay. The increase in public health as well as the reduction in congestion and noise, are all secondary positive effects from implementing a low-emission zone and it is important for the people to know of these improvements as well to encourage public acceptability. If executed properly, with adequate upfront funding, constant improvements, and proper infrastructure, these zones are worth the transition. Despite being dismantled all these times, Madrid continues to try to reimplement a low-emission zone because they know the potential benefits Madrid stands to gain. However, Canada should be cautious. Like Madrid, it has seen governments swing from one party to another. This would put at risk of dismantlement any progress toward low-emission zones should a new government opposed to the idea be elected, especially if it is a party that saw political gains from promising to reverse the initiative. This is indeed something that has been witnessed in Canada with previous green initiatives such as the Carbon Tax. If Canada were to choose to implement low-emission zones,

it should aim to make the proposal the least politically contentious one and eliminate the risk of it overturned following an unfavourable election result. Unlike China, in a democracy like Canada, citizens hold far more power to sway political decisions even if they go against the best interests of the country. Therefore, financial incentives and subsidies for bikes and zero-emission vehicles should be highly considered when the city begins to turn a profit from the zone, or even beforehand. Often, bikers and pedestrians are forgotten when it comes to subsidies but it is important to not only reward those who can afford zero-emission vehicles - especially those that reduce congestion. Overall, there are many lessons learned from the three case studies, but the principal lesson is that they can be successful and more must be implemented.

Canadian Perspective

Canada is different from the case studies in the sense that it is a much larger and far more sparsely populated country than the UK, Spain, and China. This means that it has a lot more territory to protect but also cover. Canada has struggled in the past to prioritize climate change and put in place sustainable climate policies. For example, in 2011, Canada “formally withdrew from the Kyoto Protocol on climate change, abandoning the world's only legally binding plan to tackle global warming” after failing to meet its climate target (Curry & McCarthy, 2011). Unfortunately, this was not the first nor the last time Canada would fail to bring climate policies to the forefront. In fact, Canada has a long history of failing to abide by its climate change goal as “Canada has had nine climate plans since 1990 and has failed to hit any of the targets in them” (Thurton, 2022). Furthermore, “federal Environment and Sustainable Development Commissioner Jerry V. DeMarco said Canada has been the worst performer among G7 nations on climate targets since the landmark Paris Agreement was adopted in 2015” (Thurton, 2022).

Reasonably, there is great skepticism among the population regarding Canada's climate change approach and its commitment to reaching its next target.

However, in light of recent climate change natural disasters, Canada has had a shift in its priorities. Canada is seeing the increased frequency and intensity of costly natural disasters, such as floods and wildfires, as well as growing risks to infrastructure, supply chains and communities. These are a direct result of sustained changes to the environment exemplified through permafrost thaw and coastal erosion (Government of Canada, 2023). There is no doubt that these are a chain reaction of events caused by emissions and climate change. The effects of these human-caused natural disasters have been detrimental to many communities, especially with the wildfires causing air quality warnings across North America recently.

Thus, Canada is attempting once again to set a new target with fortified measures, broken down by sectors, with the aim to break the pattern and achieve a different result. One approach seeks to include greater focus on the transportation sector, which is "responsible for 27 percent of greenhouse gas (GHG) emissions in Canada" (Government of Canada, 2016).

In 2021, Canada launched its first Emissions Reduction Plan, issued under the Canadian Net-Zero Emissions Accountability Act. The 2030 Emissions Reduction Plan uses economic modeling to generate a pathway for the country to achieve its 2030 targets, including the potential for each sector of the Canadian economy to reduce emissions by the end of the decade (Environment and Climate Change Canada, 2022, 12). Canada set specific targets for the transportation sector, and more specifically for light-duty vehicles (LDV), which also known as passenger vehicles. Canada will develop a zero-emission vehicle (ZEV) sales mandate for light-duty vehicles, which will set requirements that will "increase yearly toward achieving 100% LDV ZEV sales by 2035, including mandatory interim targets of at least 20% of all new LDVs

offered for sale by 2026 and at least 60% by 2030” (Environment and Climate Change Canada, 2022, 57).

Despite setting sales mandates, along with many other ambitious goals, reaching these targets will require extensive policy changes and regulations. Canada will have to dedicate funding to measures that will help enforce the mandate and affect consumer approaches to light-duty vehicles. These changes will most likely change the behaviour of Canadians toward a major aspect of their lives and impact those who either rely on or plan on purchasing light-duty vehicles in the coming years. These measures will also affect policy makers and the entire automotive and automotive-adjacent industry, such as dealerships, mechanics, and auto part technicians – to name a few – as their careers will deeply be affected.

As it currently stands, the mandate does not outline the steps and policies that will need to be put in place to reach the target of 100% LDV ZEV sales by 2035. Without regulations to support the mandate, it will likely face difficulty being enforced. This approach to reducing emissions requires a clearer policy and rollout plan. Which is why Canada should consider a low-emission zone. A low-emission zone could help support their goals, and there are many city options for Canada to try as a pilot program.

Potential Canadian cities that could be considered viable options for low-emission zones are Vancouver, Montreal, and Toronto. All three have been applauded globally for having strong public transit infrastructure, with Vancouver ranking 4th in North America (globally #22), Montreal 6th in North America (globally #31), and Toronto 8th in North America (globally #34) (Chan, 2023). As previously discovered through the case studies, the existing infrastructure, prior to implementing a low-emission zone, must be able to sustain the transition. These three cities are currently the only ones in Canada that pass this first test and could potentially support the

increase in public transportation demand they would face with the introduction of a low-emission zone.

Vancouver

The province of British Columbia (B.C.), and more specifically, the City of Vancouver, has demonstrated its ambition to tackle climate change. In fact, B.C. is investing more than \$2.4B in Metro Vancouver transit improvements for more convenient travel options, cleaner air, and less climate pollution (Environment and Climate Change Strategy, 2022). Vancouver is making investments in the city's infrastructure that could support a transition to a low-emission zone. In fact, in 2022, "for the fourth year in a row, the province [of British Columbia] is first overall in Efficiency Canada's annual ranking of provinces and territories" (Osborne, 2022). Thus, it is to no one's surprise that Vancouver has been considering implementing zero-emission zones that would eventually ban gas-powered vehicles since 2019 (Little, 2019). The biggest challenge acknowledged by the city is that it may prove difficult for the citizens to endorse this change. There is strong recognition that there is a climate emergency, and the public realizes action needs to be taken now. However, change and the rate of change is difficult for them to grasp (Little, 2019). To combat this potential resistance, the City of Vancouver is prioritizing building the proper infrastructure prior to implementing the zone. Vancouver is ensuring it will be a smooth transition and keeping the population aware of its plans to secure support for this change. It is important to consider this transition sooner rather than later because if zero-emission vehicles account for half the kilometres driven in the city by 2030, they could be saving up to 283,000 tonnes of carbon emissions from being released into the atmosphere (Little, 2019). These are incredible savings that could significantly improve the air quality in Vancouver, which has seen a steady increase in forest fires polluting the air.

Montreal

Montreal has also considered implementing a low-emission zone. For Montreal, “the problem of air quality is less acute, so the reason for creating a zero-emission zone is more to reduce GHGs” (Blais, 2022). The City of Montreal understands the urgency of climate change and, for that reason, is evaluating all its options. Thus, “on March 28, during a press conference where Quebec Environment Minister Benoit Charette announced \$117 million in funding to the city of Montreal for the fight against climate change, [Mayor Valérie] Plante touched on the subject of a zero-emission zone” (Blais, 2022). Montreal has signaled it will be investing significant funds to support its climate action plans. However, it is unclear whether the population is completely open to the idea yet. Mayor Valérie Plante feels that the population is open to hearing about a zero-emission zone, which was not the case 10 years ago, but that it is still too early to provide details on the project (Blais, 2022). Therefore, there has been progress with awareness-raising and trust-building with the population, but it is not yet where it needs to be to implement the zone. First, the infrastructure has to support the needs of the population, which might require significant improvements and expansions to the public transit system in Montreal as well as more LEV charging stations in the city. As Montreal continues to spread awareness of their potential transition to a low-emission zone, they will pay heed to the demands the public want addressed, such as making sure the REM de l’Ouest is up and running (Blais, 2022). The city must continue to work with the population if they are ever to make the transition. In fact, the city is starting by testing three electric buses which will each result in a reduction of 285 tonnes of GHGs annually (Société de transport de Montréal, 2017, p. 12). The possibilities of GHG reductions with an eventual zero-emission zone are incredible, and Montreal should continue to explore this option as a viable green policy.

Toronto

Like the other two metro centres, Toronto has also set aside funds to support its transition to a greener future. In fact, the Toronto administration has issued a new green bond for \$300M to help finance key capital climate action projects (City of Toronto, 2022). The City of Toronto can financially support a transition to a low-emission zone and has set the goal to reach net zero by 2040, which is an ambitious goal. To ensure they are on track, the 2030 goals for the transportation sector are for 30% of registered vehicles in Toronto to be electric and 75% of school/work trips under 5 kilometres to be walked, biked, or done by transit (City of Toronto, 2017). While these are great goals, they are far from a low-emission zone standard. Indeed, “transportation is the second largest source of GHG emissions in Toronto, accounting for 33 per cent of total emissions” (City of Toronto, 2017). Therefore, the city could significantly benefit from implementing a low-emission zone. Unfortunately, Toronto is not there yet. They have not even considered the possibility of transitioning to a low-emission zone in the next ten years. The infrastructure is not up to par with the needs of the population should a zone be implemented in the near future and would be far too much of an ambitious goal compared to the ones previously set. Additionally, since Toronto has not considered implementing a low-emission zone, it would come as much of a surprise to Torontonians. This would require significant spending on awareness campaigns. In addition, the city might face push back from residents who are not yet prepared for a transition and would voice their position, either through their political vote or financial decision-making. As the city progresses closer to reaching its net zero goals, a low-emission zone could eventually be in the cards, but for now, Toronto has much more work to do with its infrastructure and green planning.

Implementation in Vancouver & Montreal

Overall, out of the three possible cities to implement a low-emission zone in Canada, only Vancouver and Montreal are recommended to move forward with the transition at the moment. Both Vancouver and Montreal could be used as Pilot Programs for low-emission zones in Canada and become models for other cities such as Toronto who may be ready for a transition in the future. In order to reach their goals, the implementation process would have to be a slow transition, perhaps starting with certain vehicles that pollute the most like Beijing and its freight vehicle ban or targeting light duty passenger vehicles to support the Zero Emission Vehicle Act. They could also follow London's model by starting with a smaller region before expanding the zone as they see fit. As London has experienced the greatest amount of success in achieving an expansion of the ULEZ, Vancouver and Montreal could follow its approach in more ways than one. They could start by implementing similar toll fees for entering the zone to both generate revenue and still provide people with alternatives if they need to enter the city via passenger vehicle. They can install cameras to fine those entering the zone and violating regulations, which is a commonplace thing for Canadians. These fines should be high enough to deter people from breaking the law. Unlike China, Canada's governance, similar to the United Kingdom's, operates most efficiently on financial incentives that deter citizens from breaking the law. They can also boost awareness through education and awareness campaigns to ensure residents understand available alternatives, subsidies, and incentives to transition. This is very important as it is what Madrid was lacking and what inevitably came to be one of its biggest weaknesses in sustaining the feasibility of the low-emission zone. Moreover, these cities can continue to reinvest revenue from fees and fines to improve and expand public transportation to meet the needs of the citizens. Most importantly, Canadians can learn from the successes and failures of London, Madrid, and Beijing's low-emission zones to ensure that they do it right the first time around.

Conclusion

When it comes to climate action, being able to consolidate scientific research with political considerations into implementation recommendations is increasingly critical. Through thorough research and case studies, it is evident that when adopting the goal of mitigating the effects of climate change and increasing the use of zero-emission vehicles (ZEVs), low-emission zones are effective measures. This is true on multiple fronts, both in terms of how accessible and convenient they can be to policy-makers as well as the affected populations, and in terms of the emission reduction outcomes they can generate. It was demonstrated that they are policies that can achieve economic efficiency, secure public acceptability, and provide significant environmental protections that tackle one of the most severe issues communities face: the warming of the planet. Summarized in one sentence, if properly implemented, a low-emission zone can successfully generate revenue for the city while lowering GHG emissions. It is also possible to do so with widespread public buy-in with the help of education, awareness campaigns, and the proper infrastructure in place to support the change. Taking into considerations the applicability of the lessons learned from other nations, similar to Canada and not, it was also determined that a low-emission zone pilot could be implemented in Vancouver or Montreal as those two cities continue to invest the funds they need to in sustainable infrastructure. Moreover, given the experience observed in the case studies from across the world, Canada is in better shape to find success, which would only help grow the body of evidence on the advantages of reduced-emission zones. It is also clear that zero-emission zones are in line with the Paris Agreements Net Zero goals, and it is only a matter of time before other cities follow suit if they are serious in achieving those goals.

As mentioned at the start of this paper, countries have often prioritized economic growth over environmental sustainability. However, given that climate change can no longer be

dismissed as an issue with adverse effects “further down the line”, countries have recently begun to accept there is less leniency available when tackling the urgency of climate action. It is important for Canada to not fall behind in this environmental race against the eradication of human life as we know it, and transitioning to low-emission zones has proven to be a useful step in the right direction. It is recommended that Canada continue to prioritize its 2030 and 2050 environmental goals and lead by example through the implementation of pilot low-emission zones in both Vancouver and Montreal. These cities should not let the fear of public fault-finding or resistance delay implementation any longer. As explored in the case studies, it is possible to garner public acceptability through proper implementation. It is not a matter of when, but more so a matter of how and which model to base the zones on.

Canada also has the opportunity to lead the shift to low-emission zones in North America and take a decisive stance as an environmental leader on the global stage rather than being shamed for trailing behind. Canada can demonstrate its commitment to climate action and become the environmentally-conscious and forward-leaning model of governance it has stated so many times it desires to be. Since the success of such an initiative hinges on support from all levels of government, it is important for buy-in to be secured early on. Governments considering a green transition should work together to offer financial incentives to the population embracing the movement and highlight the importance of cooperation writ-large. The smoother the transition and the greater the financial incentives, the greater the public buy-in which makes the policy far less contentious across the political spectrum. The initial investment will prove profitable if implemented carefully and efficiently. These are all parts of the considerations studied in this paper to develop recommendations that leave little room for pushback. It is

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evident that low-emission zones are imminently needed in order to mitigate the effects of climate change and Canada should not hesitate to tackle this ambitious goal.

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