SOOT FREE URBAN BUS FLEETS PROJECT

Final Report

September 2017

Acknowledgments

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Introduction

More than 4 million lives were lost to outdoor air pollution in 2015. Meanwhile, the year 2016 was the hottest in the global instrumental record. Rapidly growing transportation systems in countries where vehicles do not meet best practices for emission controls, including diesel engines without particulate filters, are contributing to the air quality and climate challenges we face. Urban bus fleets are investment targets for rapid low-carbon emissions deployment, but the climate and air quality benefits of urban bus fleets are off-set by high diesel particulate and black carbon emissions. Soot-free urban bus fleets are part of the near- to medium-term solution to these challenges. Investments in the technical and human capital today to transition to the cleanest 'soot-free' urban bus fleets enable a transition to low-carbon fuel and engine systems over the long-term.

Our definition of "soot-free" is based on the findings from a 2011 report by UN Environment, which found that installation of diesel particulate filters as part of a Euro 6/VI emission control package for on-road diesel engines was among 16 win-win measures to control both the health and climate impacts of diesel black carbon. [1]Multiple technology pathways are available to achieve soot-free emissions performance, including any diesel or alternative fuel engine that meets Euro VI or US 2010 emissions; and any diesel engine with a diesel particulate filter, gas engine, dedicated electric drive engine; and any other engine that delivers a 99 percent reduction in black carbon emissions compared with pre-Euro VI diesel engine technology. Manufacturers know their technologies best, so they should respond to the demands for soot-free emissions from city officials and procurement offices with the solutions that satisfy the demands in the local market. Further reductions in climate

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[1] Shindell, D., Ramanathan, V., Raes, F., Cifuentes, L., & Kim Oanh, N. T. (2011). *Integrated assessment of black carbon and tropospheric ozone* (pp. 1–285). Nairobi: UNEP and WMO. Retrieved from http://www.unep.org/dewa/Assessments/Ecosystems/ClimateChange/tabid/7002/Default.aspx

impacts are achievable with low-carbon fuels and engines that deliver the lowest lifecycle greenhouse gas emissions.

Approximately 75 percent of uncontrolled particulate matter emission from all pre-Euro VI or US 2007 diesel buses and coaches consists of black carbon, a harmful ultrafine particle that operates as a universal carrier of a wide variety of toxics directly to the lungs and into the bloodstream. Black carbon is also a short-lived climate pollutant whose climate impacts are concentrated over the time span of a single generation, causing more than three thousand times greater warming than an equivalent amount of carbon dioxide over a twenty-year period. Our project seeks to address these harmful impacts in cities where intake of vehicle emissions is greatest. This work achieves this by transitioning urban bus fleets to soot-free engine technology through minimum emission performance standards in new bus procurements. As part of the overall strategic vision of the CCAC Heavy-Duty Diesel Initiative, this work advises and supports cities to make public commitments to shift procurement of public transit vehicles to include minimum "soot-free" emissions performance requirements.

The aim of the Heavy-Duty Diesel Initiative of the Climate and Clean Air Coalition is to virtually eliminate black carbon and fine particulate emissions from the on-road vehicle fleet by 2030. The Soot-Free Urban Bus Fleets Project puts this aim into practice with a focus on eliminating diesel black carbon emissions from coach and transit buses in 20 megacities. The cities targeted are: Abidjan, Accra, Addis Ababa, Bangkok, Bogotá, Buenos Aires, Casablanca, Dar es Salaam, Dhaka, Istanbul, Jakarta, Johannesburg, Lagos, Lima, Manila, Mexico City, Nairobi, Santiago, Sao Paulo, and Sydney. These cities all have a population of 3 million or greater, have access to a wide range of fuel quality, are geographically disperse, and at the time of project initiation had no requirements for soot-free emission in the urban bus fleet.

Figure 1. Target cities supported by the soot-free urban bus initiative. Not Committed indicates cities that have not yet committed to procure only soot-free buses.

Just 20 percent of all new coach and transit buses sold today meet our definition of "soot-free," according to our estimates. They include buses sold in the United States, Canada, Japan, the European Union, South Korea, and Turkey[2] where national laws require soot-free emissions performance from new buses. Certain local laws such as those in Beijing and in Delhi also require soot-free engines in public transit buses today.

This report summarizes the major activities, policy milestones, technical developments, key challenges, and lessons learned over the course of this project.

[2] Turkey is the most recent country to require national soot-free emissions, implemented in Jan 2015. By gaining access only to soot-free bus technologies without any new local laws or policies, Istanbul became the first of 20 targeted cities to shift to soot-free bus procurement.

Major Activities and Milestones, 2015-2017

City Policy Milestones and Activities

This project engaged many cities in a technical and policy dialogue to encourage commitments to shift to a soot-free urban bus fleet. Mexico City provides the best example of this. In June 2016, Mexico City Secretary of Environment Tanya Müller García submitted a written commitment to the ICCT that states the following:

We hereby express to you the commitment of Mexico City to undertake programs of urban bus fleet renewal for soot-free vehicles that significantly reduce emissions of particulates and black carbon, in accordance with emission technology provided under Euro VI or EPA.

As a demonstration of this commitment, the Environment Secretary reached a voluntary agreement with the Red de Transporte de Pasajeros (RTP), now called M1, to shift all future bus purchases to Euro VI or US 2010 engine technology. Following this letter, the ICCT on behalf of the Soot-Free Urban Bus Fleets Project and the CCAC organized a two-day workshop in Mexico City at the invitation of the Mexico City Environment Secretariat (SEDEMA). This workshop served to promote the efforts of SEDEMA, the office of the Mayor, and local fleet operators to shift to filter-equipped diesel engines and other soot-free technologies.

The City of Bogotá has engaged in dialogue with the ICCT and its partner C40 Cities on the question of technology choice for the next procurement of buses to enter the TransMilenio fleet. Over the course of 2016 and 2017, TransMilenio has organized a series of dialogues with the private sector and national officials to understand the potential to shift from current Euro V technology to soot-free engine technology, including Euro VI diesel and zero emission electric drive. This includes a meeting in December 2016 organized by TransMilenio and attended by the ICCT to deliver a presentation on Euro VI technology. Since that time, the City of Bogotá and TransMilenio have continued to explore the availability of Euro VI technology, the enabling 10ppm S fuel, and cost-effective soot-free technology pathways. As of this report, the City of Bogotá has begun to integrate discussions of soot-free technology into a dialogue around an air quality management strategy for the City.

The City of Johannesburg engaged the ICCT and its partners throughout the duration of the Soot-Free Urban Bus Fleets Project. This engagement has been captured in a series of informal memoranda that represent a joint technical workplan between the ICCT and the Johannesburg Department of Transportation. Under Mayor Mpho Parks Tau, the City of Johannesburg has invested in diesel dual-fuel engine retrofits as a transition measure towards dedicated gas-powered engines. This began with a retrofit of 30 Mercedes Euro I engines using a NOVO diesel dual-fuel retrofit kit and continued with a retrofit of 150 Mercedes Euro V engines using a Bosch diesel dual-fuel retrofit system. These systems inject gas into the combustion cylinder in proportion to the engine load, allowing the vehicle to displace diesel fuel with cleaner burning gas. The ICCT organized on behalf of the City of Johannesburg a one-day workshop on soot-free urban bus fleets during the October 2015 EcoMobility Festival hosted by the City. The ICCT further assisted with a market study of soot-free engine technology availability. And the ICCT undertook, with in-kind support from the Swiss government, two technical assessments of the performance of diesel dual-fuel technology and recommended actions for emissions optimization, change management, and a shift to Euro VI dedicated gas engines, taking advantage of locally available low-carbon biogas from landfill methane. The two reports were issued in August 2016 and September 2017 and will be available through the CCAC website.

Finally, the ICCT advised and supported the City of Sao Paulo. Until recently, Sao Paulo operated under a local climate law that requires 100 procurement of fossil-free buses beginning in 2018, but the local transit agency SP TRANS has run the risk of not achieving this. Through development of a technology procurement model, the ICCT has prepared procurement scenarios for SP TRANS to develop a 10-year procurement timeline both to shift to soot-free emissions and to fossil-free emissions. In September 2017, the Climate Committee of São Paulo approved a proposed amendment to Article 50 of the city's Climate Change Law, one of several proposals now under discussion to improve the environmental performance of the city's transit bus fleet. The proposal would require the fleet to be 100 percent fossil free by 2037, including a 10-year target to reduce fleet wide CO2 emissions 50 percent and PM emissions 90 percent. Other proposals put forward by other elected officials and civil society organizations are even more aggressive.

The ICCT has developed a procurement scenario model to advise and support SP TRANS. This procurement scenario model is a standardized resource now available to all cities. As an example, the scenario model shows that a shift to battery electric buses can deliver the greatest long-term reduction in lifecycle greenhouse gas emissions (see Figure 2). But from an air quality perspective, the benefits of battery electric buses are minor compared to Euro VI engines (see Figure 3).

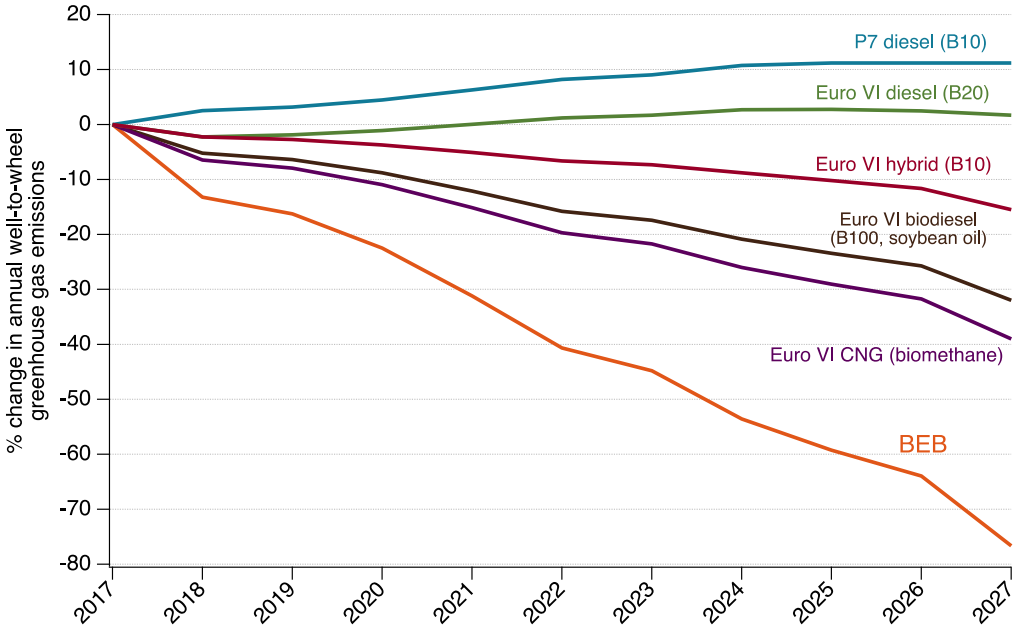

Figure 2. Annual reduction in lifecycle greenhouse gas emissions from a shift to soot-free technologies in Sao Paulo, compared against baseline P-7 (Euro V) engines today. Battery electric buses are potentially the most favorable climate mitigation strategy.

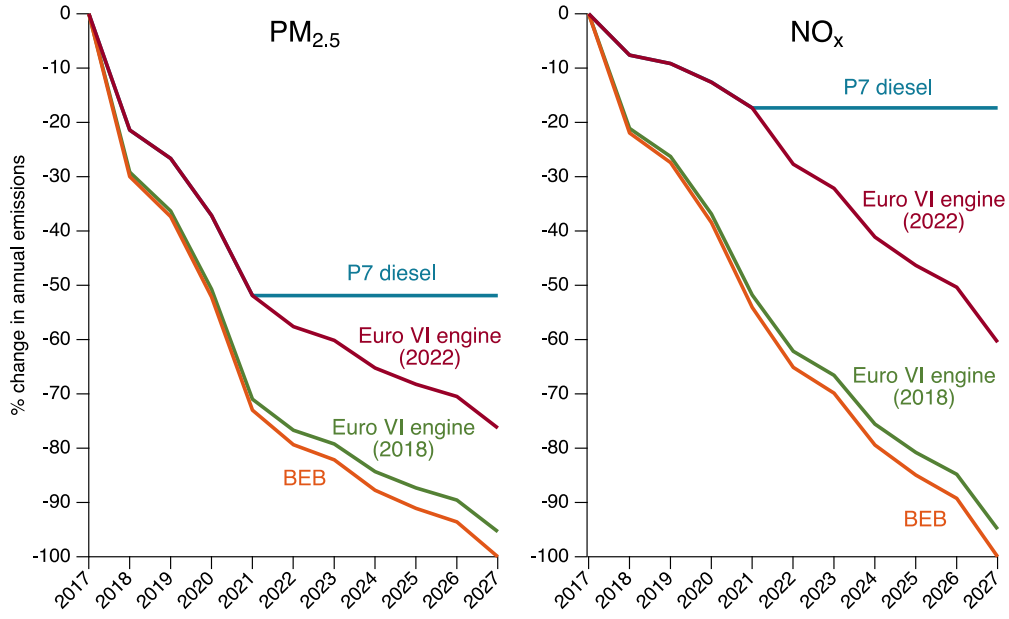

Figure 3. Annual change in PM2.5 and NOx emissions for soot-free engine technologies compared with baseline P-7 (Euro V) diesel technology. The difference between zero emission battery-electric and Euro VI diesel engines is comparatively small over the course of 10 years.

National Policy Milestones and Activities

National governments have played an important role in decision making around soot-free urban bus fleets at the city level. One example of this comes from Chile, where the national government regulates the public transit system and vehicle emissions of buses operating in the Metropolitan Region of Santiago. As part of a renewed air quality management plan called Santiago Respire, the Government of Chile adopted in 2016 a new regulation that will require all new buses operating in the TranSantiago public transit system to utilize minimum Euro VI emissions control technology from Sep 2017. By Sep 2019 all new buses operating in Santiago must meet these emission levels. The Centro Mario Molina-Chile with UN Environment led the engagement with the Government of Chile in support of these new requirements.

Between October 2013 and Nov 2017, the Chilean Ministry of Transport has certified eight soot-free engines that meet the Euro VI emission standard or better, including the following:

- BYD 12-meter K9 zero emission dedicated electric drive
- Scania 13.2-meter K280UB DC09 113 (EURO VI)
- M. Benz 13.2-meter OC 500 LE OM 936 LA.6-3 (Euro VI)
- Volvo 13.2-meter B8RLE D8K 280 (Euro VI)
- Volvo 13.2-meter B8R D8K 280 (Euro VI)
- Scania 13.2-meter K280UB DC09 113 (EURO VI)
- Yutong YTM280-CV9-H (dedicated battery electric)
- BYD BYD-2912TZ-XY-A (dedicated battery electric)

Seven out of eight of these engines were certified between June 2016 and Nov 2017 in preparation for a September 2017 tender of 2,000 Euro VI buses.

The Government of the Philippines provides another example of national regulation of city-level public transit service. The national government has undertaken a comprehensive reform of public transit service operating in Manila, called the Public Utility Vehicle (PUV) Modernization Programme. As part of a wholesale revitalization, consolidation, and re-organization of public transit service operating in Manila, the government will include new minimum emission control requirements requiring all new jeepney[3] franchises to meet minimum Euro IV emission levels. These are an important step towards soot-free engines in a country that only requires 50ppm sulfur diesel fuels. In late 2015 and early 2016 the ICCT engaged in direct dialogue with both Quezon City, a C40 city, and the national government through the Department of Transportation and Commerce (DOTC). Further momentum is needed in the Philippines through dialogue with the national government to take a final step towards requiring soot-free emissions in all new public vehicle procurements. The example in

[3] The jeepney is a public transport vehicle unique to the Philippines and originally made from United States military jeeps. The jeepney is the most popular form of public transit vehicle in Manila.

the Philippines along with Chile shows how national governments are integrating emission control efforts into public transit and air quality management in their major capital cities.

Following its transition to low-sulfur fuels in January 2015, Kenya began considering Euro 4/IV vehicle emissions standards for all vehicles. The Kenya Bureau of Standards was already working on Bus Standards as part of Nairobi's improved public transport systems. The main focus of this program was to ensure that new bus standards for high capacity buses in Nairobi met world-class standards and capitalized on new fuel quality standards, with at least Euro IV running on 50 ppm diesel and a longer-term vision for Euro V and above. With UN Environment support, draft Kenya Standards DKS1515:2015 were revised to include Euro 4/IV equivalent emissions from January 2018; the standard is now being updated to specifically encourage electric buses.

National policies to shift to soot-free emissions were not an explicit aim of this work, but in the course of implementation we experienced multiple opportunities for national-level engagement. Considering the scale-up opportunities from national action, we highlight below those developments before and during the implementation of this project to require soot-free emissions performance for vehicles outside of the 20 targeted cities.

- INDIA adopted in September 2016 national Euro VI emission standards for all light- and heavy-duty vehicles to be implemented in 2020.
- CHINA proposed in October 2016 to implement Euro VI standards nationwide by 2020.
- IRAN implemented Euro IV+DPF requirements on all urban buses beginning in September 2015 and extended these to all urban heavy-duty vehicles beginning in March 2016. Discussions are ongoing to shift to Euro VI emission standards nationwide in future years.

At the start of this project, two countries had already taken important actions to shift to soot-free emission standards for all heavy-duty vehicles nationwide.

- MEXICO proposed in December 2015 to adopt Euro VI or US 2010 emission standards for all heavy-duty vehicles beginning in 2018. The Government has not formally adopted this proposal and is considering a delay of the implementation timeline.

- TURKEY implemented Euro VI standards for heavy-duty vehicles nationwide beginning in January 2015

Over the course of this project, the national governments of cities we targeted have taken new national actions.

- ARGENTINA in late 2017 through its Ministry of Energy and Ministry of Environment will host an international seminar on heavy-duty vehicle energy efficiency and emissions controls, including a focus on Euro V and Euro VI emission standards. In 2016 the Ministry of Environment undertook a public procurement process to purchase zero emission dedicated electric drive buses for the city of Buenos Aires and surrounding cities.

- AUSTRALIA released in December 2016 a cost-benefit analysis of emission control roadmaps to implement Euro VI emission norms nationwide under a variety of scenarios. The government is in the process of finalizing its proposal based, which by law must reflect the pathway with the greatest benefit-to-cost ratio. With the support of the CCAC, the ICCT submitted technical comments in support of the Australian proposal.

- BRAZIL in early 2017 launched through its Environment Ministry a public dialogue and proposed to transition from Euro V to Euro VI emission norms nationwide by 2019. Discussions are ongoing between the government, civil society, and the private sector over the ultimate timeline and scope of the emission standard proposal. The ICCT has engaged in technical dialogue with the Environment Ministry and made presentations to it on Euro VI standard adoption in 2016 and 2017.

- INDONESIA adopted in March 2017 a national Euro IV emission standard, leapfrogging Euro III emission norms and enabling a transition towards Euro VI emission norms nationwide. With the support of the CCAC, the ICCT undertook a public consultation on soot-free urban bus fleets in Jakarta, including three public workshops.

- THAILAND Pollution Control Board initiated a public dialogue to develop a roadmap that would transition from Euro III heavy-duty vehicle emission standards nationwide to Euro VI standards nationwide. With the support of the CCAC and the Swiss government, the

ICCT participated in a public dialogue organized by the Pollution Control Department and presented on the costs and benefits of Euro VI standards adoption.

Technical Milestones

This project undertook a variety of cross-cutting technical activities in support of its engagement at the city and national level. These included the development of a soot-free urban bus fleet technology procurement, planning and cost model to advise and support cities on multi-year technology transition and procurement strategies. The following additional milestones are highlighted:

Urban Bus Fleets Database

This project built a picture of the global bus fleet by undertaking a series of activities designed to collect, analyze and communicate new information about the activity and emissions of bus fleets in the 20 targeted cities. A survey and accompanying fleet database summarize this information. Public access to the database is available at http://theicct.knack.com/bus-database and https://theicct.knack.com/bus-cost-database.

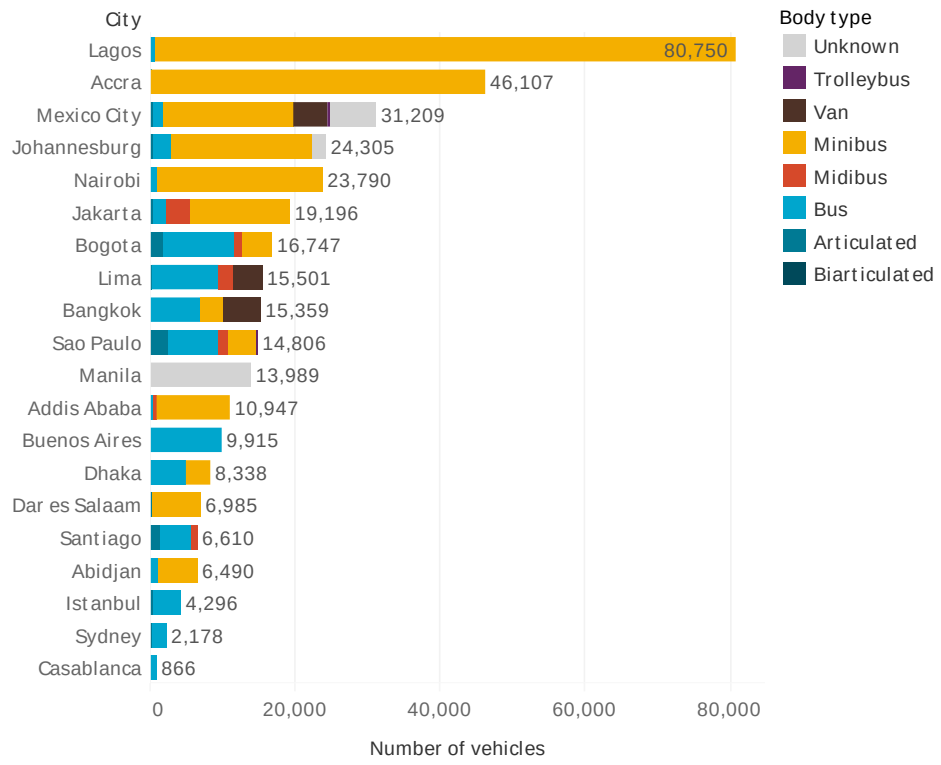

Figure 2. Fleet size and composition in each of the 20 targeted cities based on the most recent data.

Low-Carbon Technology Pathways for Soot-Free Urban Bus Fleets in 20 Megacities

This study set out to determine what the preferred low-carbon soot-free technology is in each of the 20 targeted cities. The final results show that in almost all cases, a switch away from dedicated CNG and diesel buses can be justified not only to achieve soot-free emissions but also to generate the greatest climate benefits from a future technology transition. Certain non-fossil fuels should be avoided entirely, such as palm oil biodiesel. And in at least two megacities—Johannesburg and Morocco—dedicated CNG or Euro VI diesel hybrid engines may provide a narrow climate benefit over some of the non-fossil alternatives due to the high carbon intensity of the electric grid today. The introduction of some low-carbon fuels can take advantage of existing refueling infrastructure and deliver meaningful climate bene ts, such as bio-CNG from land fill or digester gas and biodiesel from plant oils or animal fats. But, on the whole, zero-emission electric drive buses appear to provide the greatest magnitude of climate benefits for the greatest number of routes in the largest number of cities.

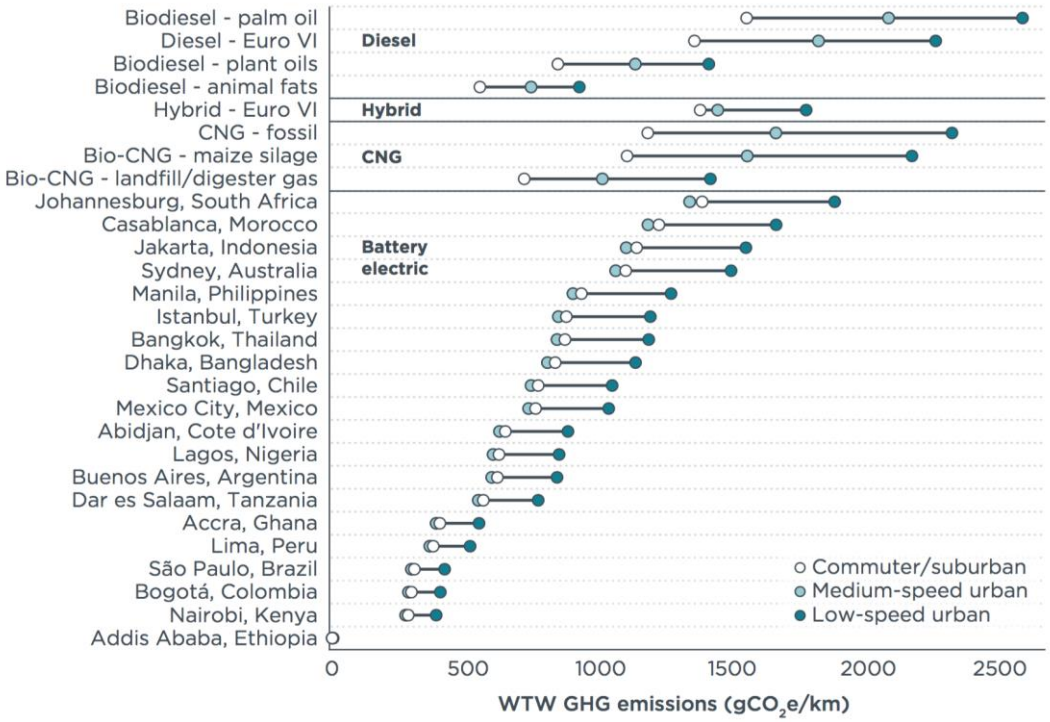

Figure 3. Well-to-wheel greenhouse gas emissions of soot-free engines in 20 targeted cities. Battery –electric arranged in order of highest to lowest carbon intensity by city and compared against diesel, diesel-hybrid, and gas engines. Effect of commuter, medium-speed, and low-speed driving conditions included.

Financing the Transition to Soot-Free Urban Bus Fleets in 20 Megacities

This paper set out to inform city officials and financing institutions on the investment opportunities and constraints around a soot-free technology transition in all 20 targeted cities. The main conclusion is that soot-free technologies can pay for themselves, with negative net outlays of approximately $14 Billion USD across all 20 cities. The additional value of avoided black carbon and CO2 reductions brings the net savings to $43 Billion USD. In 17 out of 20 cities a soot-free transition is justified today based purely on operational cost savings, and not included societal benefits. These results are the product of taking a 'total cost of ownership' perspective to vehicle procurement and operation. In this way, the operational cost savings of cleaner and more efficient vehicles pay for the higher up-front cost of technology and deliver additional CO2 reductions. Cities should enact soot-free environmental performance standards for new buses and evaluate competitive bids with a preference for least total cost of ownership. Finance institutions likewise should assess how

cities pay for bus procurement today, develop total cost of ownership finance models, and deploy these models in finance schemes.

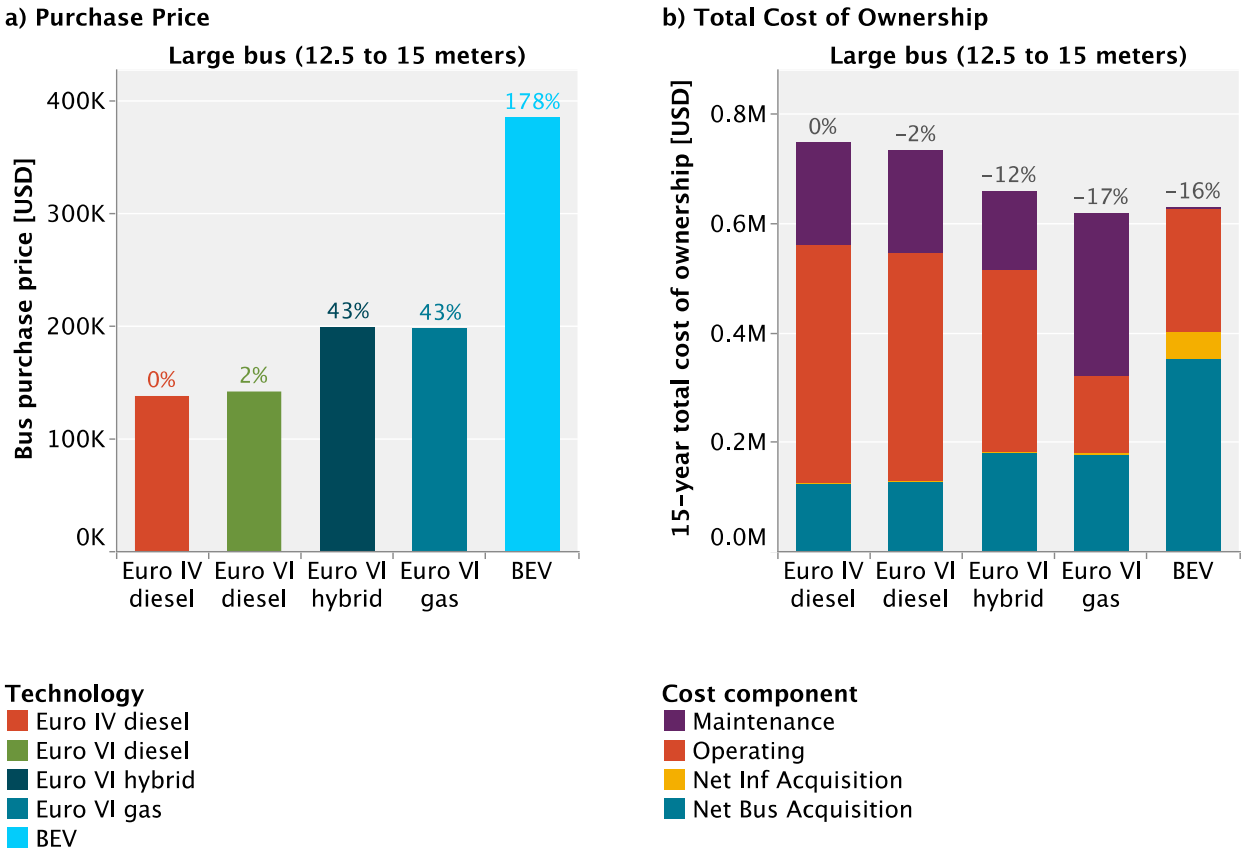

Figure 4. The effect of cost perspective on affordability of soot-free urban buses. (A) Decisions based on purchase price alone put cleaner and more efficient technology further out of reach. (B) Total cost of ownership flips the cost calculus, suggesting the most efficient soot-free technologies are the least expensive to acquire and operate since they provide fuel savings that pay for higher up-front costs. Euro VI gas includes compressed natural gas only.

Global Industry Partnership on Soot-Free Urban Bus Fleets

The principal aim of this project was to secure commitments in each of the targeted cities to shift to soot-free urban bus fleets, which creates new demand for these cleaner engines. But in many cases, the demand is not met by supply from the manufacturers since these cities are located in countries where national standards do not yet require these cleaner engines. For this reason we undertook to establish a Partnership with global manufacturers of buses and engines and requested them to voluntarily commit to make soot-free engine technology available in all 20 targeted cities.

On 27 September 2017 at OECD Headquarters in Paris, representatives of the Soot-Free Urban Bus Fleets Project including the ICCT, C40 Cities, UN Environment and the Climate and Clean Air Coalition and the World Health Organization joined four global bus and engine manufacturers to announce the Global Industry Partnership on Soot-Free Clean Bus Fleets. In a signing ceremony on 27 September at OECD Headquarters in Paris, the four manufacturers - Scania, BYD, Volvo Buses, and Cummins - publicly committed to the following:

- We commit to make soot-free engine technology available in all 20 targeted cities; where clean fuels are available today, this technology will be available no later than 2018; cities without clean fuels must first make these available.

- We commit to provide to all 20 cities a list of soot-free bus and engine technology that is available to purchase in each city, including all relevant and publicly available product specifications.
- We commit to provide to all 20 cities the name and point of contact we designate to advise and consult on product specifications, demonstration, and procurement.
- We commit to publicly report the number of soot-free buses and engines we have sold in the most recent year.
- We commit to update this information on an annual basis.

Through this Partnership we expect cities will gain access to new information around product details and points of contact that were not previously available to the public. And furthermore, we expect that the heavy-duty diesel initiative of the CCAC will create new opportunities to directly engage the private sector to further deploy soot-free engine technology. This includes a discussion of market barriers and attempts to overcome them, as well as a broadening of the Partnership to include other bus and engine manufacturers and even to include certain fuel providers.

Key Successes and Lessons Learned

Progress is moving towards soot-free urban bus fleets. Based on the policies currently implemented, adopted, and proposed, we estimate that 55 percent of the global bus market will be soot-free by 2020.

To a significant degree the Soot-Free Urban Bus Fleets Project has established the technical underpinning for a shift in procurement practices at the city level. This includes the identification of critical data needs for cities to assess the current cost and performance of its fleet. And it includes new cost and emissions performance modeling approaches to estimate the benefits and investment needs for cities to make a shift to soot-free technology. The Heavy-Duty Diesel Initiative of the CCAC is now well positioned to advise with these tools any city on its long-term procurement strategy. All cities should have a long-term perspective and should prepare for a technology transition needed to achieve clean air and low-carbon sustainable transport.

One lesson of this work is the extent to which cities are reliant on national actions to shift procurement practices at the local level. Admittedly many of the cities targeted in this project are national capitols or important political centers of their countries. Nevertheless, we found that in many cases the national government and not the city government was the appropriate actor for choosing to shift to cleaner urban bus fleets because the national government is the de facto operator of the city fleet or is responsible for setting air quality or fuel quality policy for the city. This was true in Bangkok, Dhaka, Manila, Santiago, and many other cities. And even in cases where the city has jurisdiction over its own fleet management, we found that involvement by the national government was still necessary to ensure access to ultra low-sulfur diesel fuels (10ppm S) or other cleaner burning fuels needed to support soot-free engine technology.

Clean fuel is often a barrier to soot-free engine deployment, but in this project we found that 17 out of 20 cities currently have access to at least one clean-burning fossil fuel (either 10ppm S or gas) that enables soot-free engine technology. The cities without enabling fuel - Abidjan, Addis Ababa, and Nairobi - can still gain access to this fuel through imports. And zero emission electric drive technology is still an option in all cities where electricity is available. But for those manufacturers who dominate the global bus market today with the sale of combustion engines, availability of fuel is not a legitimate reason to deny access to soot-free engine technology.

We learned that cities that must make investments in cleaner fuels can and should consider the climate implications of these investments. They can do this by considering the lifecycle climate impacts of soot-free urban bus fleets, whose impacts vary based on the carbon intensity, route plan, and efficiency of the engines they utilize. Battery-electric buses provide the greatest potential for the lowest carbon emissions from soot-free buses. The lifecycle climate impacts of these buses can vary by a factor of 3-4 according to the carbon intensity of the national electric grid. But in 16 out of 20 cities analyzed, these battery-electric buses can provide lower lifecycle carbon emissions than a diesel Euro VI bus, therefore justifying for climate reasons a transition away from combustion engines. Many African cities including Addis Ababa, Nairobi, Accra, Dar es Salaam, Lagos and Abidjan can benefit, as well as Latin American cities including Bogotá, Sao Paulo, Lima, Buenos Aires, Mexico City, and Santiago. Certain cities powered by high carbon electric grids will still benefit from the zero emissions

tailpipe of electric buses, and a transition to an electric fleet can take place over time as the energy grid in that country decarbonizes, as is needed to meet global climate change goals. In the immediate term cities may also consider low-carbon biogas from landfill methane, including Sydney, Jakarta, Casablanca, and Morocco. But fossil gas and diesel fuel in general provide very similar climate impacts. And certain biofuels including palm oil biodiesel can generate even worse climate impacts than fossil diesel and should be avoided (largely due to indirect land use change and deforestation).

Challenges and Remaining Barriers

Despite the growing trend towards soot-free urban bus fleets, more than 40 percent of the global population will not benefit from their lower emissions. The problem will be particularly acute in the world's largest megacities where national actions on emission controls are not being taken and where suffering from urban air pollution will grow as population and economic growth rates increase over the coming years. More forceful actions are still needed in nearly all of the cities targeted in this project, particularly all of those that have not made a commitment to soot-free urban bus fleets and where national actions are not proposed, such as: Abidjan, Accra, Addis Ababa, Bogotá, Buenos Aires, Casablanca, Dar es Salaam, Dhaka, Jakarta, Johannesburg, Lagos, and Lima. These and the other cities will be the engines for future growth in the global bus market, and they will define the future technology pathway.

In many of these cities, the current technical capacity available in the local workforce) simply is not able to support the latest generation of soot-free engine technology until public and private investments in training are made. Furthermore, certain capital investments including urea supply to support diesels or battery electric charging to support dedicated battery-electric are often non-existent. Cities therefore face the dual challenge of investing in its people and investing in its capital infrastructure. These investments take time, they take political will, and they take planning. International institutions can serve cities by providing technical assistance and coordinated trainings in partnership with local government agencies and academic institutions.

What is the Future?

The future is soot-free low carbon urban bus fleets. Massive investments are needed in public transit to avoid the further increase in health and environmental impacts of private vehicle ownership as economic growth accelerates in the most populated regions of the world. Investments at the city level in soot-free urban bus fleets will mitigate diesel black carbon emissions and improve public health through cleaner air. It will also enable a transition to cleaner technology in the broader transportation fleet, introducing cleaner fuels that other vehicle types can utilize and technical capacity and experience needed to deploy the latest generation of vehicle technology.

Where Bus Rapid Transit (BRT) systems are deployed, near-term opportunities exist to shift new bus purchases to soot-free technology. These BRT systems are centrally planned and organized, and they tend to receive international financing. Investors in BRT systems should consider procuring Euro VI engines and purchasing the service packages offered by bus and engine manufacturers to reduce risk and guarantee performance in regions without the existing local technical capacity. These service packages can serve as a bridge to train and develop local staff to maintain these vehicles over the long-term

Financing presents interesting opportunities to make new investments in soot-free engines. As our work has shown, soot-free engines can pay for themselves in cases where investments are based on total cost of ownership and not on purchase price of the vehicle. Financing institutions should undertake investigations into the different ways that cities pay for public procurement today and recommend changes to procurement decisions that will favor technologies that save money by saving fuel over the life of the vehicle. These investments will favor vehicles that are more efficient and provide greater benefits to the climate.

National actions are still critical to shifting the global marketplace to soot-free engines. Cities can and should take the lead where national leadership is not present. But cities can also support and encourage national efforts that will lead to broad and systemic fleet-wide transitions to inherently cleaner burning and environmentally friendly transportation.