2018 SOUTH AMERICA SUMMIT ON VEHICLE EMISSIONS CONTROL

SUMMARY REPORT AND REGIONAL WORKPLAN

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MEETING OBJECTIVES

The South American summit on vehicle emission control was set as a two-day event in Buenos Aires, Argentina, on September 26 and 27, 2018. It aimed to equip South American regulators with knowledge and tools to enhance vehicle emissions compliance and enforcement practices, and to provide guidance regarding the potential adoption of programs and regulations to accelerate a transition to efficient and soot-free transport. The summit fosters regional knowledge exchange and provides a practical demonstration of international cooperation in this area. Speakers from Europe, Canada, the United States, Brazil, Chile, Colombia, and Argentina covered a wide range of technical and regulatory issues. The audience was composed of a strong presence of Argentinian stakeholders from trucking and automotive associations, industry, government, and academia; regulators from South American countries such as Brazil, Uruguay, Ecuador, Colombia, and Peru; and an international audience. The summit was structured in the following way:

Day 1: Compliance. The discussion topics included updates to international best practices on mobile source emissions compliance and enforcement, technical and testing methods for in-use compliance, and strategies for contextualizing these practices to South America.

Day 2: Soot-free roadmap. This discussion focused on the motivation to start planning a move to soot-free (Euro VI/U.S. 2010) and zero-emissions heavy-duty vehicles, including current policies and practices, the experiences of early adopters, and the progress made in the region toward a cleaner heavy-duty fleet. Participants identified what is needed for South American countries to shift toward soot-free and zero-emission technologies, the set of policies for such a transition, and what is available in the market today.

Dr. Eduardo Behrentz of Universidad de los Andes Colombia, an expert on health issues from transport emissions, set the tone for the summit, highlighting the air-quality challenges of the region and potential solutions. Attendees were invited to reflect on the fact that most humans now live in cities, which offer a wide range of conveniences but present air quality challenges. Society desires economic growth and also needs clean air to live well. Clean air requires investing in clean technologies; these have a return of 8 to 1, meaning that for each U.S. dollar invested in clean technology, a societal benefit 8 times larger is achieved.[1] In addition, inaction has a cost in human health. He pointed out that focusing on particulate matter (PM) control, which is achieved via soot-free technologies, is the most cost-effective way to address the air-quality issue. Moreover, the recipe for addressing the issue is well-known: clean fuels, strong standards for emissions and efficiency, and clean technologies. These three pillars are strengthened with a strong compliance and enforcement program that ensures that benefits on paper are achieved in real life.

1 Benefits are generally higher for heavy-duty vehicle tailpipe emission standards because the health effects from reduction of diesel particles are substantial. For example, the U.S. Tier 2 rule affects mostly gasoline-powered passenger vehicles, and thus has a lower cost-benefit ratio (5:1) compared with the heavy-duty vehicle regulation (16:1). From Kodjak (2015) *Policies to reduce fuel consumption, air pollution, and carbon emissions from vehicles in G20 nations*. The International Council on Clean Transportation (ICCT). Washington DC.

COMPLIANCE AND ENFORCEMENT

INTERNATIONAL EXPERIENCE

Most South American countries lack a clear legislative basis to develop, implement, and enforce vehicle regulations on pollutant and greenhouse gas emissions. Only a handful of countries have government-owned laboratories to carry out vehicle and engine emissions testing. This results in vehicle and engine certification and homologation procedures being implemented without government or independent testing. In some cases, the manufacturer presents test data, while in other cases the manufacturer signs a sworn statement of compliance without presenting any numerical certification data. This lack of documentation leaves open the possibility that vehicles on the roads in South American countries are not compliant with their emission standards. Progress by countries around the globe serves as a benchmark for these South American countries to improve their compliance and enforcement programs.

UNITED STATES

The best global compliance and enforcement programs have clear legal authority and are built over time. The U.S. Clean Air Act, which was adopted more than 40 years ago, provides the legal authority and is the legal basis for the authority of the Environmental Protection Agency (EPA). EPA compliance and enforcement programs are designed to maximize air-quality benefits and to ensure that manufacturers can compete on a level playing field. The EPA estimates that, in 2030 alone, transportation-source air regulations will prevent more than 38,000 premature mortalities and realize more than $380 billion in health and welfare benefits. EPA environmental compliance measures ensure these benefits are delivered.

EPA compliance programs make sure manufacturers produce vehicle designs and products able to control emissions over the full lifetime of the vehicle. This goal requires testing along the product's life span: pre-production, product introduction, and in-use vehicles. Testing along each step of this path requires proper equipment and a professional, well-trained, and effective compliance team.

Enforcement actions apply once noncompliance is detected. The experience of the EPA points to the following key features for strong enforcement programs: robust compliance monitoring (e.g., vehicle testing), trained compliance inspectors, advanced tools and data analytics, and a predictable, strong, and fair government enforcement response. One example of robust compliance and enforcement presented was the Volkswagen "Dieselgate" case; once the determination of rule violation was detected via comprehensive vehicle testing, a series of legal and criminal proceedings were carried out. Monetary fines were paid to cover environmental damages (about U.S. $17 billion), and some VW engineers were prosecuted and found guilty on criminal charges.

CANADA

Environment and Climate Change Canada (ECCC) develops and implements air pollution and greenhouse gas emission regulations across a broad range of economic sectors, covering on-road and off-road vehicles and engines, which are authorized under the Canadian Environmental Protection Act, 1999.

In the wake of the global Dieselgate scandal, ECCC is developing and exploring new approaches to enhance its compliance verification program including : better data

sources and management, broadened testing diversification, increased scrutiny of information submitted by vehicle manufacturers, expanded collaboration with strategic partners, and a strengthened legislative and regulatory framework. Specific actions that ECCC is implementing or exploring include conducting comprehensive on-road vehicle testing with portable emissions measurement systems (PEMS) and non-standard test cycles, monitoring fleet performance with remote sensing emissions measurement, and undertaking coastdown testing to verify manufacturer-submitted data on road-load coefficients.

Canada's emission regulations for vehicle and engines are aligned with those of the United States. ECCC and the U.S. EPA collaborate closely in the implementation of compliance-related activities to maximize efficiencies in the administration of their respective programs and deliver the intended health and environmental benefits of the regulations.

ARGENTINA

More than 90% of the population of Argentina lives in cities, and primarily in Buenos Aires. In 2017, there were 14.4 million automobiles and 7 million motorcycles in Argentina: 51% were gasoline, 35% diesel and 14% compressed natural gas (CNG), according to **Julio Vassallo, vehicle homologation director from the Secretary of Environment of Argentina.** Ultra-Low Sulfur Diesel (ULSD) is already available throughout the country but in the order of 25% of the total volume of diesel fuel marketed in Argentina, and is expected to increase strongly in the coming years due to the incorporation of the Euro 5 standard for the heavy duty vehicles from 2016 and in agreement with the declarations of Yacimientos Petrolíferos Fiscales, the national oil company.

Argentina is in the process of developing laws and regulations that will strengthen the compliance framework. Some of these are being developed under the government's plan to meet the country's Nationally Determined Contributions (NDC) under the United Nations Framework Convention on Climate Change (UNFCCC). **Juan Trebino, undersecretary of environmental monitoring and control, Secretary of Environment and Sustainable Development of Argentina**, briefed the meeting participants on the development of the National Law of Energy Efficiency of Argentina. This law covers all sectors and will provide the basis to move from voluntary programs in the transport sector, such as *Transporte Inteligente* (SmartWay), to fuel efficiency regulations. The SmartWay program (Resolucion Min. Transporte CNTR 1075/2016) , was launched in 2019, was developed among the Secretaries of Energy and Mines, the secretary of Environment and Sustainable Development, and the Ministry of Transport of Argentina and has been set up with the support of the private-sector freight operators federation (FADEEAC). The stakeholders involved in the development of this program acknowledge the need for data-driven policy designs.

A second key regulation presented by Trebino was a Conformity of Production (COP)[2] proposal that would provide the framework to run COP tests for new light-duty vehicles (LDVs) and motorcycles in Argentina. Argentina has two vehicle chassis laboratories: one owned by Toyota, and another by the Secretary of Environment.

2 Conformity of Production (COP) is a regulatory framework established to generate the evidence, via vehicle testing, that the vehicle being sold in the market today meets exactly match the specification, performance and marking requirements outlined in the type approval documentation.

The latter was built in 1998, through a loan by the World Bank, and incorporated international emission homologation technology in accordance to European Directives the U.S. Code of federal regulations. The laboratory has been used to control the entry of automotive technologies under Euro 2 standards since 2004 to Euro 5 currently in force in the country.

Argentinian regulators want to update their laboratory and acquire PEMS equipment to carry out Euro 6 tests, to conduct real driving emissions tests (RDE) in the future. In recent times, the staff has committed to carrying out fuel efficiency tests for heavy vehicles on the road to support compliance with the Smartway program. In this sense, they also see the possibility of expanding their technical capacity with PEMS equipment and measurement technology with motor and chassis dynamometers to develop a Fuel Efficiency Verification framework for heavy vehicles and evaluate the alternative technologies offered in the national market.

The Argentinian government is also working on passenger car fuel efficiency labeling. Since 2016 Argentina has incorporated regulations (Resolutions SAyDS 797/2017 and 85/2018) for the incorporation of energy efficiency labeling of light vehicles that is effectively implemented as of June 2019 and has a website[3] where the values of emissions and fuel consumption certified by the models of vehicles marketed in the Argentine market.

CHILE

In South America, most countries have no access to vehicle testing laboratories for COP tests, according to **Gianni Lopez, director of Centro Mario Molina-Chile (CMMch).** Only Brazil, Chile, and Argentina have such laboratories. Among these countries, Chile is the only one with the authority to make direct vehicle measurements; in Brazil the tests are performed in the manufacturer laboratory or third-party laboratory and are witnessed by the type approval authority. The authorities in Chile have more than 16 years of experience with COP implementation. Tests have shown noncompliance in more than 15 models intended for sale in the country since 2010.

According to **Alfonso Cádiz, Technical Secretary of the Vehicle Control and Certification Center (3CV) of the Ministry of Transport and Telecommunications (MTT)**, the regulatory framework for vehicle emission compliance in Chile was developed in the late 1990s and granted MTT the authority to verify compliance with vehicle emission regulations through the homologation testing process. In this way, the regulatory framework was established, and a vehicular laboratory was built for emissions testing and verification of safety components. Since 2014, the applicable standards are Tier 2- Bin 5, or Euro 5, for light and medium duty vehicles. Chile has also adopted the energy efficiency label for light vehicles, and the Ministry is in charge of carrying out the emission tests. The data on carbon dioxide (CO_2) and nitrogen oxides (NO_x) are used as inputs to define the "ecological tax" [green tax]. This ecological tax encourages the acquisition of efficient and clean vehicles.

In August 2018, Chile developed the first test cycle for urban bus operation in the city of Santiago. The methodology could be applied in other cities in Latin America to

3 Argentina's passenger car fuel efficiency and CO_2 emissions website: https://datos.gob.ar/dataset/ambiente-certificaciones-emisiones-gases-efecto-invernadero-consumo-vehiculos-livianos

evaluate the energy efficiency of buses powered by internal combustion engines or for battery electric buses, using a representative test cycle. The Santiago bus cycle was developed with activity data from Santiago bus operation. With the adoption of this drive cycle, bus manufacturers must certify that emission limits are met under the Santiago bus cycles, besides the traditional engine certification cycles (Euro o EPA).

A key contribution of the Chilean experience was the importance of transparency: all the results of the tests of light and medium vehicles were made public, since the data is used to tax taxes on this type of vehicle.

BRAZIL

The Companhia Ambiental do Estado de São Paulo (CETESB) is the lead technical agency for vehicle emissions regulations and management in Brazil. CETESB's in-use vehicle control unit is responsible for opacity tests and ensuring effective operation of selective catalytic reduction (SCR) systems, including urea quality and application, according to **Andre Kuniyoshi, engineer from CETESB**. The CETESB has recently been developing procedures to check HDV in-use emissions performance, including the development of procedures to check HDVs for the use of defeat devices called emulators. Those emulators disable the operation of SCR systems by simulating the injection of urea to the HDV engine control unit and avoiding triggering of the warnings and torque losses associated with improper urea quality, quantity, and consumption. By using an emulator, a driver attempts to save money by reducing urea consumption costs. The detection method developed by CETESB includes a visual inspection of the vehicle and a urea test. The urea test involves extracting a sample from the urea tank and dropping some droplets on a handheld refractometer to evaluate whether the urea concentration is within the test limits (30% to 35% by volume). The test can also detect the presence of ionized water (i.e., addition of tap water). As part of the methodology development process, it was identified that urea concentrations above 35% indicated vehicle operation without urea consumption. As water evaporates, urea concentration increases over time. Fines for defeat devices and improper urea filling are around U.S. $240 to U.S. $370. One key takeaway from this presentation is that enforcement is very necessary and random vehicle pullovers combined with hefty fines are strong deterrents against tampering.

OTHERS

In all other South American countries, the certification and homologation process does not include any laboratory-based test and verification. In Colombia and Uruguay there is no COP, and test result information is submitted to the authority—usually from tests carried out in Europe. In Peru and Ecuador, only a letter is presented and no test information is shown.

INNOVATIVE TOOLS

REMOTE SENSING

Remote sensing of vehicle emissions differs from chassis dynamometer and PEMS testing in that the testing equipment does not physically interact with the vehicle undergoing testing, according to **Oscar Delgado, senior researcher at the ICCT**. Rather, a light source and detector, placed either at the side of or above a roadway, are used to measure exhaust emissions via spectroscopy as vehicles pass by the measurement location. In this way, remote sensing measurements yield snapshots

of emission rates from thousands of individual vehicles as they are driven on actual roadways. A camera captures an image of the vehicle's plate, allowing investigators to link each emissions measurement to essential vehicle information, including vehicle make, model, model year, and certified emission standard. Thus, the ensemble of remote sensing measurements provides air pollutant emission rates for the fleet across a wide range of driving conditions.

The Real Urban Emissions (TRUE) initiative, presented by Delgado, seeks to supply cities with the real-world emissions of vehicle fleets and equip them with technical information that can be used for strategic decision-making. TRUE aims to raise awareness of the magnitude and scope of excessive real-world vehicle emissions. The initiative recently completed a data-collection campaign in London and Paris. This yielded a database of more than 200,000 vehicle records that are added to the 700,000 vehicle records across Europe. Data collection continues as the TRUE initiative expands to other cities and regions. The TRUE initiative has developed a ratings system that classifies vehicles within a city as good (green), moderate (yellow), or poor (red) emissions performance linked to vehicle families and emission standards. Results from the initiative show that from Euro 3 to Euro 5, all diesel families in Europe are rated red (high emissions). For Euro 6 vehicles, approximately 10% of diesel families are rated yellow, and the remainder are rated red. In contrast to diesel vehicles, the TRUE ratings for petrol vehicles in Europe improve with each successive emission standard. Only 3% of Euro 3 petrol vehicle families have received a green rating, but almost two-thirds of Euro 6 petrol vehicle families are rated as green and none are rated as red.

PORTABLE EMISSIONS MEASUREMENT SYSTEMS (PEMS)

PEMS are mobile emission laboratories that sample directly from the vehicle exhaust, allowing direct emission measurements under real-world driving conditions. These systems are now used to certify real-driving emissions for both light-duty and heavy-duty vehicles in Europe to demonstrate compliance with Euro 6/VI vehicle emission standards. **Leo Breton, director of technology development for Horiba, and one of the original developers of PEMS**, gave a presentation on the potential of PEMS for compliance and enforcement actions and the evolution of RDE testing in Europe. The European Union adopted its first two pieces of legislation to implement RDE in 2015. The RDE test began taking effect in September 2017. It will apply to all new cars by the beginning of 2021 and all new vans by the beginning of 2022. The new procedure will complement the current laboratory certification of vehicles with on-road testing under more realistic real-world conditions. For HDVs, PEMS testing has been part of the European In Service Conformity (ISC) regulation that verifies RDE performance from trucks and buses. ISC has been enforced in Europe since 2012, for NO_x emissions, and the next update to the regulation will include particulate number (PN) emission testing.

PEMS testing equipment is also cheaper than full vehicle chassis emissions laboratories. CMMch is now advising the government of Peru to transition to a COP model based on PEMS testing. In this case, the authority would review the chassis tests results submitted by manufacturers, and then perform PEMS testing before issuing a certificate of conformity. Vehicles would still be subject to testing by PEMS along their useful life—following international best practices.

SOOT-FREE ENGINES

Soot-free transport refers to the use of fuels and technologies that achieve a 99% reduction in diesel black carbon and fine particulate matter emission compared with conventional engine technology. These technologies include engines compliant with Euro VI or U.S. 2010 emission standards; or diesel engines with a wall-flow diesel particulate filter, gas engines, or zero emission electric drive engines.

By 2021, an estimated 80% of the world's diesel fuel supply will be of sufficient quality for vehicles certified to Euro VI or EPA 2010 equivalent standards, according to **Joshua Miller, senior researcher at the ICCT**. This means that fuel-importing countries are not expected to encounter supply constraints when purchasing ULSD. At the same time, two-thirds of all new HDVs will be soot-free. The regional perspective for South America is that on-road diesel fuel consumption would be higher than gasoline consumption. The projections show a growing trend as economic growth increases the demand for goods movement. The number of ambient air pollution-related premature deaths (from all sources of $PM_{2.5}$ and ozone) in South America has risen by nearly one-third since 1990—from 91,600 to 118,300 in 2015. An evaluation by CETESB of Sao Paulo shows that more than 50% of NO_X, PM and SO_X from vehicles comes from HDVs. Requiring Euro VI in Brazil would avoid 5,500 premature deaths annually via reductions in tailpipe $PM_{2.5}$ emissions, with a benefit-to-cost ratio of 11 to 1.[4]

INTERNATIONAL EXPERIENCE

Soot-free heavy-duty engines with diesel particulate filters (DPFs) first entered the U.S. market in 2007 with the introduction of the EPA 2007 emission standards. Europe introduced soot-free Euro VI HDV standards in 2013. Note that Euro IV and Euro V are not soot-free standards as particle emissions management is achieved via fuel system calibration and oxidation catalysts only. Only the Euro VI standards are sufficiently stringent to require DPFs, which reduce PM emissions 90% below Euro V and 99% below older technologies. Most countries in South America follow the European regulatory framework for HDV emission standards.

EUROPEAN UNION

All new HDVs sold today in Europe must meet the soot-free Euro VI emission standard, according to **Meinrad Signer, an independent consultant with MSCO GmBH** and former general manager at FPT Powertrain. The Euro VI standard was developed as a global regulation, ECE R49.6. The standard is a great improvement over the Euro IV and V regulatory frameworks as it covers all stages of vehicle design and useful life: type approval, conformity of production, and in-service conformity. The standard includes tests for each of these stages. The most relevant changes for type approval are more stringent engine emission limits tested under more representative engine cycles—the World Harmonized Stationary Cycle (WHSC) and the World Harmonized Transient Cycle (WHTC). Euro VI includes a limit on PN, which is critical to require the use and effective performance of DPFs. The on-board diagnostic (OBD) system coverage is more comprehensive than with Euro IV and Euro V. Euro VI includes a more detailed protocol of actions for ensuring that the urea used in the vehicle is the right quality and quantity and that the usage rate is within expected bounds. For conformity

4 Miller. J., & Façanha C., (2016) Cost-benefit analysis of Brazil's heavy-duty emission standards (P-8). The International Council on Clean Transportation. San Francisco.

of production, a chassis vehicle test cycle was developed, the Word Harmonized Vehicle Cycle (WHVC). For in-service conformity, the use of PEMS testing is defined. This regulatory component has been critical to achieve the real-world benefits of the NO_X limits as required in the regulation; the limits are 1.5 times the WHTC standard. In the wake of Dieselgate, PEMS tests show that a Euro VI diesel truck emits 70% less NO_X per distance driven than a diesel passenger car produced by the same manufacturer. The technologies required to reach Euro VI standards include exhaust gas recirculation (EGR), SCR, and a DPF. The first two have a strong influence on fuel consumption as the engines can be designed under a tradeoff for higher engine efficiency and higher engine-out NO_X, or lower engine efficiency and lower engine-out NO_X. Higher efficiency and engine-out NO_X lowers fuel consumption but increases urea consumption (close to 7% to 8% of fuel consumption), whereas lower efficiency and engine-out NO_X results in the opposite, lowering urea consumption to 4% to 5%. EGR is used as a lever in that tradeoff.

UNITED STATES

On-road diesel vehicles in the United States make up more than one-third of NO_X emissions from mobile sources, according to **James Sanchez Engineer specialist from U.S. EPA.** Between 1970 and 2017, the combined emissions of the six common pollutants ($PM_{2.5}$ and PM_{10}, SO_2, NO_x, VOCs, CO and Pb) dropped by 73%. This progress occurred while the U.S. economy continued to grow, Americans drove more miles, and population and energy use increased. This achievement was thanks to a strong set of emission standards, especially for HDVs. The EPA 2007 standards were the first standards for HDVs to require DPFs for PM control. This regulation was accompanied with a shift in fuel quality from sulfur in diesel concentration of 500 parts per million (ppm) to S<15 ppm, and was phased in over several years. The key to transition to maximum 15 ppm was a federal program, since neither consumers nor refiners have an innate economic incentive to consume or produce ULSD. This explains why a national-level decision to require refinery upgrades is needed, along with a plan for distribution and a pricing strategy that does not penalize the cleaner fuel. Three years later a new set of standards required the adoption of SCR systems for EPA 2010 standards. The trucks sold after model year (MY) 2010 are among the cleanest trucks sold globally, along with Euro VI HDVs. HD aftertreatment technology has been in production for over 10 years. Catalyzed DPFs are more than 99% efficient at removing PM and Poly-Aromatic hydrocarbons PAHs from diesel exhaust. DPF durability has improved substantially since the introduction of EPA 2007. A robust compliance program is necessary to ensure that the right technology is installed and continues to function as designed.

BRAZIL

Brazil is the only South American country that has adopted Euro VI equivalent standards (called PROCONVE P8) at the national level. PROCONVE P7 is the current standard implemented in 2012 and equivalent to Euro V, according to **Rui de Abrantes, manager of vehicle type approval sector.** Vehicle emissions regulations leapfrogged from P5 (Euro III) to P7. Leading up to the transition to P7, there were issues with fuel availability and pre-buy of P5 vehicles. Diesel fuel containing no more than 10 ppm sulfur reached most areas of Brazil in 2013. During the transition years, Brazil had a price differential of 4% in favor of the S500 (500ppm sulfur) fuel that led to improper fueling. The most troublesome finding is that air quality benefits were not observed. This may be linked to the fact that Euro V never delivered the emission levels promised by the standards, as PEMS data has shown before. High in-use NO_x

emissions from Euro V trucks and buses are the result of emission control systems that were designed under the unrepresentative European Transient Cycle (ETC) and were never required to undergo PEMS testing for certification. The good news is that a move to PROCONVE P8 (Euro VI equivalent) has just been approved. The current proposal from the government calls for P8 implementation by 2023, with all new models meeting P8 one year earlier (in 2022). The critical regulatory provisions of Euro VI are expected to be required, such as higher durability, better OBD, and in-service conformity testing with PEMS.

ARGENTINA

On the second day, Julio Vassallo presented the monitoring of Nitrogen Dioxide (NO_2) in the Autonomous City of Buenos Aires (CABA) and the impact of the transport sector. In this presentation it is highlighted that the air quality standards of the CABA from 2006 and the current air quality standards for NO_2 and PM_{10} are approximately twice those specified by the 2005 WHO Guidelines. It shows that air quality standards are outdated, even in places as critical as the densely urbanized cities of Latin America, Current AQ standards were updated in 2013 by the WHO with the identification of the diesel particulate within the compounds of Group 1 as carcinogenic for humans. NO_2 risks were made more evident in 2015 by the US EPA dieselgate findings that showed excess NO_x emissions from transport, and subsequent sanctions.

In this sense, an analysis of the NO_2 monitoring was data carried out between 2009 and 2013 for an air quality monitoring station operated by the Environmental Protection Agency (APRA). The station covers a area of high vehicular traffic, and reveals numerous episodes of contamination for NO_2, when NO_2 measurements were analyzed for 1 hour against the standards of the 2005 WHO Guidelines. There it was observed that these episodes were increasing since 2010 (9 episodes of NO_2- 1h), until reaching 142 episodes for the NO_2 -1 h in the first semester of 2013.

In order to evaluate the situation, a bottom-Up emissions inventory in peak transit time was developed for that station. It was detected that the largest contribution of NO_2 came from diesel buses, mostly EURO II and III (42.5% of the load of NO_2 emitted), as well as, to a lesser extent, diesel commercial vehicles (8.8%), and diesel taxis (7.7%). However, when total emissions are divided by the number of passengers or equivalent cargo in units of 70 Kg transported, it is observed that light vehicles and new diesel taxis (EURO 2 to EURO5), both contributing approximately 21% of NO_2 by weight equivalent, they become the main contributors to NO_2 emitted by the circulating fleet in Avenida Córdoba in 2013, revealing not only the highest NO_x emissions in the actual use of pre-Euro 6 vehicle models (dieselgate), but also the high component of NO_2 on the total NO_x emitted, which these vehicles have due to the presence of the oxidation catalysts.

This presentation emphasizes the importance of air quality monitoring in relation to the contribution of transportation to clarify the impact of emission technologies including programs as well as the incorporation of remote sensing or PEMS technologies that allow verifying the emissions in real use, improving bottom-up inventories and the disengagement on the contribution of pollutants by the different emission sources

CHILE

In the late 1990s, Santiago faced a large air-quality challenge; the region at that time was in non-attainment for ozone, with an estimated 2,000 early deaths annually due

to poor air quality at a cost between U.S. $670 million and $1,9 billion due to health costs and lost productivity. The government shifted into action with a plan for better fuel quality and emission standards, as well as develop public transport and renew the urban fleet. As a result, emissions fell by almost 70% while GDP doubled, according to **Gianni Lopez**. At the national level, Chile shifted to diesel fuel containing less than 50 ppm sulfur in 2004 and less than 15 ppm sulfur in 2009. The national government adopted an air quality management plan that today requires all new buses to comply with Euro VI emission standards from September 2017 with a shift expected in all LDVs to Euro 6 emissions beginning in 2020. There are no plans to shift to Euro VI standards for the rest of the HDV fleet (i.e., trucks). The Euro VI bus market is important in Chile, therefore manufacturers reacted to it; Mercedes, Volvo, Scania, Yutong developed and certified Euro VI buses (both 12 m and articulated) in Chile. The cost of a Euro V bus is U.S. $190,000 to $200,000 compared with $U.S. $210,000 to $215,000 for Euro VI. The government's forward-thinking strategy on addressing air pollution from the public transport sector is now materializing with a move to 25% electric drive buses by 2025. Today Santiago is deploying 200 battery-electric buses made available by Chinese vehicle manufacturer BYD, and an additional 500 are in the procurement phase. The operating cost of electric buses on some routes can be 20% lower than diesel. But the transition to electric buses requires proper planning, including bus and route selection, duty cycle determination, and vehicle simulation. Technology selection should include a study of depot versus opportunity charging. An operating range of 200 to 220 km is the sweet spot for battery-electric buses. Air conditioning and heating use should also be considered, as AC takes 20% of power.

COLOMBIA

The courts are asking the Ministry of Environment to take actions to achieve World Health Organization (WHO) air-quality guidelines, which Bogotá and Medellín are currently failing, according to **Mayra Lancheros, representative of the Ministry of Environment of Colombia.** Transport contributes 70% of the national emissions inventory for PM. This results in more than 8,000 early deaths and to a 1.5% rate of lost GDP. The main challenges in the country include a large fleet of Euro 2 motorcycles representing 53% of the vehicles, while 42% are light-duty passenger vehicles and 5% are HDVs. Among the fleet of LDVs, 25% are pre-Euro while 60% are Euro 2 and 15% are Euro 4. One critical example for Medellin was presented, where 400 dump trucks emit 30% to 40% of total PM pollution in the city. According to the latest government plan for economic development, the country would move to diesel Euro VI by 2025, but gasoline would only reach that level by 2028. The ministry is planning on environmental labels to create low emission zones. On vehicle efficiency, Colombia is following the Chilean example, starting with LDV labeling to be followed by standards.

URUGUAY

Uruguay is currently at Euro III emission standards and plans a move to Euro V, according to **Magdalena Hill of the Ministry of Environment**. The main limitation is fuel quality. In Uruguay, gas oil (gasoline) of S <10 ppm is available throughout the country. The challenge is to match the price with S 50 ppm diesel. On an annual basis, Uruguay is meeting annual average WHO air quality guidelines, but hourly guidelines are not performing as well. PM emissions are generated in large part by the transport sector and wood burning; NO_x emissions come almost exclusively form the transport sector.

ECUADOR

Officials from Ecuador announced the development of the first LDV COP homologation laboratory to be installed in Quito. The building housing the equipment has been constructed. They are currently in the process of developing the certification steps for laboratory traceability.

INDUSTRY PERSPECTIVE

Industry representatives provided an overview of key considerations on technologies for a roadmap to soot-free technologies, Euro VI diesel, CNG and battery electric vehicles (BEVs).

AFEEVAS

The association of emissions control manufacturers for South America, represented by **Stephan Blumrich,** provided an overview of the technology evolution required to meet soot-free emission standards on HDVs. Euro III requires no aftertreatment; Euro IV standards are met with SCR or EGR systems; Euro V requires the same Euro IV technologies plus ammonia slip catalysts; and Euro VI requires the addition of a DPF.

On fuel consumption Euro VI has shown improvements in fuel consumption in contrast to the experience in the United States; the downside is that this lower fuel consumption is achieved with 4% to 8% higher urea consumption. In Europe, where urea is cheaper per gallon than diesel, Euro VI is profitable to adopt. But if urea is more expensive per gallon, a high consumption becomes an operating cost issue.

In the US, the adoption of EPA 2004 emission standards requiring the use of EGR resulted in a sudden increase in fuel use. The move to EPA 2010 standards allowed the use of SCR, which was key to tune the engine for high efficiency and low emissions.

One big takeaway from the description of these technology pathways is that these have been in the market for many years now: DPF since 2007 and SCR since 2006. Given this, South American countries can benefit from more than 15 years of manufacturer experience on design and production of emission control technologies. South America can benefit from reduced production costs and failure rates as manufacturers scale up their technology across the globe.

SCANIA

CNG or biogas engines provide another technology path toward soot-free emissions. **Scania engineer Guillermo Hughes** explained the challenges ahead for wide-scale gas engine deployment in the region. Argentina recently discovered large reservoirs of shale natural gas in Vaca Muerta, opening up new opportunities. However, the regulatory framework on vehicle fuels is outdated and does not consider CNG for new vehicles, only retrofits; liquefied natural gas (LNG), the preferred option of natural gas for long-haul applications, is also not mentioned at all in the regulations. ENERGAS, the national gas company, is working on developing the missing regulatory elements. CNG and LNG have not advanced more rapidly because of competition on fuel price with diesel, which receives subsidies. The market for advanced CNG designs is limited and tanks deployed today use older, heavier designs. The benefits of gas engines are focused mainly around air quality given their low PM emissions, but the benefits are about even with diesel engines with respect to

greenhouse gas emissions. In Colombia, Transmilenio will receive Scania gas engines with a range of 250 km, including air conditioning.

BYD

BYD Brazil Director of Marketing and Sustainability Adalberto Maluf presented an update on battery electric bus technology. Cities like Shenzhen in China are shifting to 100% electric bus purchases. Currently, 16,500 electric buses are in Shenzhen, with more than 40,000 sold globally. Unlike China, Brazil does not have air quality limits that can push zero-emission technology. Sao Paulo operates 200 electric garbage trucks from BYD. BYD buses operate up to 250 km and require 3 to 4 hours of charge. The batteries are designed for 30 years of useful life. A vehicle's battery is used for 15 years on the vehicle itself, after which its remaining life is spent as stationary storage. Total cost of ownership (TCO) can be better than diesel in some routes, but this is sensitive to electricity price and fuel price differentials. BYD is opening a bus production plant in Brazil, with an expected production of 300 buses per year. The key for expanding electric vehicle manufacture in Brazil is the production of batteries in MERCOSUR—there is lithium in Manaus, an area of Brazil in the state of Amazonas opening the possibility to that option.

JOINT REGIONAL WORKPLAN

The presentations by country representatives share a common thread: South American countries wish to address outdoor air pollution from motor vehicles, reducing health impacts and fuel consumption. At the same time, there is a need to ensure that the environmental and social benefits provided by more stringent regulations on paper, translate to real world gains, with the adoption of robust compliance and enforcement programs. This joint regional workplan summarizes strategies and specific actions that south American regulators can study, develop, and implement to achieve their air-quality and social goals. The workplan serves as a guideline to strategize resources and prioritize the work ahead.

The most effective way to reduce emission in the long term is by adopting more stringent vehicle emission standards, adopting Euro VI or its US equivalent EPA 2010. Fuel quality is a technical barrier, but as soon as S10 is available for new diesel trucks there is no reason to delay the adoption of Euro VI (diesel and CNG) and zero emission technologies for HDVs in the region. Because Euro V and Euro VI diesel HDVs use the same fuel, any countries considering a move to Euro V could just as easily leapfrog to Euro VI, with far greater net benefits. The benefits of such a transition are confirmed over and over again by independent studies in many regions. Each dollar invested in Euro VI equivalent vehicles and fuels yields between 8 and 16 dollars in health and welfare benefits.

The cost of inaction has been partially evaluated, and results show the negative impact of not addressing this issue. Poor air quality in South American countries is connected to thousands of early deaths per year: Argentina currently experiences between 14,000 and 16,000 early deaths per year due to poor air quality; the numbers in Brazil are above 55,000 early deaths; Peru and Colombia are around 10,000 early deaths per year. It was also pointed out in several presentations that soot-free standards would reduce the costs for governments due to illnesses and early deaths related to air pollution.

Countries far behind the timeline to transition to soot-free engines should continue nevertheless, pursuing those fuel and technology pathways that provide the most cost-effective solutions. This includes zero-emission electric drive engines, a potential leapfrog technology with dramatically lower energy consumption than today's internal combustion engines. Such engines provide a dual climate co-benefit in most cases. China achieved the transition to electric buses in key cities with strong national and local government support. In South America, the transition does not have the same scale of financial support, but even today some fleets will find that much lower operational costs in some cases can pay for the higher upfront cost over the full life of the vehicle. TCO analysis could provide clarity on which cities and transportation modes could benefit from this transition.

Actions must be taken to overcome key technical and political obstacles to establishing emission control regulations. And not all countries in the region can act equally—joint, harmonized actions can ensure that all countries equally benefit from investments in clean technology, provide mutual aid to those countries with the fewest resources, and minimize the compliance burden on manufacturers.

A proposed draft regional workplan on soot-free transport was presented by **Francisco Posada**, followed by discussion and comment from the audience. The following summarizes the workplan, which will form the basis for future coordinated action in the region.

SOOT-FREE NEW ENGINE STANDARDS

The presentations by representatives from South American countries demonstrate that current Euro IV and V diesel standards are not sufficient to control the contribution of the transport sector to ambient particulate matter and ozone exposure. Euro IV and V diesel have failed to deliver on the promise to control NO_x in urban driving. PM can only be properly controlled in diesel vehicles with a DPF, which is only required with Euro VI standards. The market of soot-free vehicles is growing at a fast rate. By 2021, the ICCT estimates that 70% of all new HDVs sold will meet Euro VI equivalent standards.

As an alternative to diesel, CNG and battery electric HDVs are strong options for Euro VI and zero tailpipe emissions. CNG applications are preferred when originally designed to meet the Euro VI CNG standard because CNG retrofits come with significant tradeoffs (higher NO_x emissions and CH_4 leaks and emissions). Battery electric buses are prominent in China and this growing market is reducing manufacturing costs and opening the global market to new alternatives; some cities in China have completely moved to electric buses with strong state support. Battery electric buses are increasingly cost effective and may show lower TCO in some circumstances.[5]

COMPLIANCE AND ENFORCEMENT

Taking a lesson from the discussions of the first day of the summit, a solid compliance and enforcement program is required to ensure that the expected benefits of emission standard regulations, and in particular of adopting Euro VI or EPA 2010, are achieved.

5 http://theicct.org/sites/default/files/publications/Soot-Free-Bus-Financing_ICCT-Report_11102017_vF.pdf

This covers not only type approval or homologation, but also conformity of production and in-use testing.

The level of maturity of the U.S. and Canadian programs is the result of decades of work by regulators. The lack of clear legal authority for setting and enforcing standards, recall, and fines in the South American region leads to chronic inaction. Nonexistent or antiquated laboratories and limited resources reduce the impact of the authority.

FUEL QUALITY

For several countries in South America, the sulfur content of diesel fuel must be brought down to 10 ppm (S10) to enable the transition to Euro VI equivalent standards. In some countries that refine crude, the shift to S10 implies investments in refineries. However, the cost of those upgrades can be recovered through fuel sales at an incremental cost of around U.S. $0.02 per liter; note that this added cost is an order of magnitude lower than the normal variation in fuel prices due to global oil market dynamics. For countries where the fuel is imported, the transition can be more rapid by updating the fuel quality standard sheet. One slightly different type of challenge is found in Argentina, where S10 is currently available but is sold at a 15% to 20% higher price than the dirtier S500 diesel. The price differential is not necessarily reflective of the price differential found on the international market. Such a large price difference provides an incentive to use higher sulfur fuels.

STARTING A TRANSITION IN CITIES

Santiago is also studying the best options for shifting its Bus Rapid Transit fleet to BEVs, and is preparing all the technical studies to apply such technology to the most cost-effective routes for BEV operation. On these routes, the TCO of BEVs is expected to be lower than diesel. The example from Santiago shows that a procurement volume in the order of thousands of buses would incentivize manufacturers to change their production lines to accommodate the request for buses meeting local design specifications, effectively meeting Euro VI emission standards requirements for new buses in Santiago. One of the most powerful tools to accelerate that transition by local bus fleets is changing procurement practices to require Euro VI and battery electric buses. The example by Santiago suggests that the incorporation of tailored emissions test cycles is possible and highly encouraged as this would ensure proper emission control under target city driving conditions. This would need proper data collection and analysis.

LEGACY VEHICLES

A major challenge in South America is the significant pollution contributed by current in-use vehicles. The fleet tends to be old, mostly between pre-Euro and Euro II emission levels. Most of the older vehicles are owned, operated, and even repaired by their owners, and many are faced with scarce resources to maintain the vehicle properly. Fleet renewal can replace the oldest and dirtiest vehicles in the fleet with new ones, but any such program will need to take into consideration the economic challenges of the low-income population. Such fleet renewal programs would be most cost-effective if combined with the introduction of Euro VI equivalent standards and fuel efficiency measures for the new vehicles. A high emitter identification campaign combined with analysis of a fleet renewal or retrofit strategy is needed.

Complementary measures such as low emissions zones could be explored as part of a regulatory package for in-use fleet emissions control.

COST-BENEFIT ASSESSMENT

One common request by national authorities is an assessment of the societal impact of inaction, especially as urbanization and fleet activity are projected to grow quickly in the region. Authorities and the public in general have limited access to the information that shows the impact of the current vehicle fleet and the projections compared against future actions to control the emissions of the fleet. Limited public awareness exists on the cost of inaction, and limited public debate exists around the benefit of a shift to cleaner transportation. An under-informed public will not have the information it needs to judge the benefits or costs of public actions. Politicians and regulators would be more effective if information on the cost of inaction was available and compared against the cost of adopting soot-free technologies.

SOUTH AMERICAN WORKPLAN- ACTION ITEMS

These action items are building blocks for policy and program development focused on accelerating a transition to zero emission transport. They provide guidance into key research products (analysis), and simple policies/programs (e.g., fiscal programs) that can have significant impact in a very short time at very low development and implementation cost. National regulators are encouraged to use these action items as guidelines to develop their national regulatory agenda for soot free and efficient transport in the region.

- **Cost and benefit assessments**: Define technical cooperation activities that support the transition to soot-free transport. As an example, the ICCT is preparing an emissions baseline assessment and cost and benefit analysis to illustrate the benefits achievable with a move in Argentina to Euro VI in the future, compared with the costs of that transition.
- **Improve procurement practices for government and public fleets**: Implement complementary programs such as lead-by-example programs. These programs focus on changing new vehicle procurement practices for the fleet of government and local officials. Lead-by-example programs can be set within a framework of fuel saving, focusing on fuel-efficient and electric vehicle purchases.
- **Fiscal measures**: Develop fiscal measures, such as those proposed in Santiago favoring lower taxes for cleaner and efficient vehicles, that incentivize the demand of clean vehicles and can be added to increase the overall impact of emission or fuel efficiency standards.
- **Total cost of ownership analysis for buses**: The transition can be accelerated via city-level efforts focusing on public transit systems. Action items can focus on identifying leader cities that enjoy available fuel quality (S10 or CNG) and that are also willing to invest in electrification programs. For those cities, a TCO program would provide the grounds for in-depth analysis for application in specific bus routes.
- **Strengthen compliance and enforcement programs**: A key issue was lack of regulatory authority and equipment to conduct compliance and enforcement activities. This is low-hanging fruit to correct some of the issues facing national systems in South American countries. Some of the solutions in this area include:

- The proposed solution is to promote the development of technical capacity for regulators in terms of knowledge, training, and equipment acquisition.
- The financing could come from international development or multilateral banks. It can be set up under a test-based revenue scheme that makes it partially or totally self-sustained, similar to the example presented by the Ministry of Transport of Chile.
- International agreements with leading regulatory bodies in the United States, Europe, and China (e.g., EPA, Joint Research Center JRC, China Automotive Technology and Research Center CATARC) can be arranged for staff training. Training can proceed in parallel to the development of testing labs. The regulators can be trained in best regulatory practices around the world and develop or strengthen national programs based on available resources.

- **Fuel upgrading**: A transition to soot-free transport would require national government support, not just with respect to legal and regulatory framework, but with funding of programs such as refinery upgrades or fleet renewal programs. Specific action items are:
  - Developing the analytical framework to support refinery upgrades, focusing on the health benefits and monetized positive impact of that shift.
  - Coordinating pricing schemes for cleaner fuels with the national ministry of economy in such a way that its use is incentivized.
  - Fleet renewal programs would require significant resources. This type of program would focus on high emitters (PM and NO_x) and financing a HDV replacement for each retired unit. A complementary high emitter labeling campaign and potential low emission zone in selected cities would be required to maximize consumer participation.