BRIEFING

DECEMBER 2014

Opportunities to Reduce Vehicle Emissions in Jakarta

EXECUTIVE SUMMARY

Jakarta's expanding fleet of motor vehicles is a key target of urgently needed actions to curb the city's dangerous air pollution.[1,2] This briefing paper highlights technologies and policies to reduce direct emissions from new and in-use cars, trucks, and buses in the city. Such policies, coupled with the promotion of mass transit, non-motorized transport, and other smart growth measures aimed at reducing transport demand, can significantly diminish the adverse effects of transportation on local air quality and public health in Jakarta, and spur similar actions across Indonesia.

Several factors contribute to worsening pollution from motor vehicles in Jakarta. Emission standards for both cars and trucks are more lenient than in other Asian megacities, as are limits on gasoline and diesel sulfur content. Furthermore, even the lenient sulfur standards for diesel are not being met[3], and the supply of compressed natural gas (CNG) has not been reliable enough to provide a dependable alternative for heavy-duty vehicles.[4]

Ideally, strict fuel quality and vehicle emission standards would be implemented nationally. This would create regulatory certainty: a single set of laws and regulations

1 Santoso, M., Dwiana Lestiani, D., Hopke, P.K. (2013). Atmospheric Black Carbon in PM2.5 in Indonesian Cities. *Journal of the Air & Waste Management Association, vol. 63, no. 9.*

2 Santoso, M., Dwiana Lestiani, D., Mukhtar, R., Hamonangan, E., Syafrul, H., Markwitz, A. (2011). Preliminary study of the sources of ambient air pollution in Serpong, Indonesia. *Atmospheric Pollution Research, vol. 2.*

3 Safrudin, A., Krisnawati, L., and Mahalana A. (2011). *Indonesia Fuel Quality Report 2011: clean fuels for clean air.* Jakarta, Indonesia: Ministry of Environment, Deputy for Environment Pollution Control, Assistant Deputy for Mobile Source Emission Control.

4 Safrudin, A., Palguna, A., Adrison, V., Khoirunurrofik, Haryanto, B., Krisnawati, L., Zakaria, M., Hamonangan, E., Nurafiatin, L., Suhud, M., Reksowardojo, A.,and Huda, A. (2013). *Cost-Benefit Analysis for Fuel Quality and Fuel Economy Initiative in Indonesia.* Jakarta, Indonesia: Ministry of Environment, Assistant Deputy for Mobile Source Emission.

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enforced everywhere, so the oil and automobile industries could produce the same products for sale across the nation. But in the absence of national action, the Special Capital Region of Jakarta can take steps to mandate stricter standards and implement additional measures within its jurisdiction. Doing so would not only deliver local air-quality benefits for Jakarta, but could also spur the implementation of similar actions in other cities and regions, and eventually, across the country.

Metropolitan areas around the world have approached the challenge of controlling air pollution from motor vehicles with a range of technological and regulatory solutions. Jakarta can gain from this existing international experience, shaping its regulatory strategy around policies that have proven successful in similar circumstances. There is strong international precedent for cities taking aggressive action to lower vehicle emissions in anticipation of national policies. Most such local-level actions fall into three categories that complement each other in a comprehensive motor vehicle emission control program:

1. Cleaner burning fuels
2. Stringent emission standards for new vehicles sold or operated within a jurisdiction
3. Programs to clean up existing vehicles or remove them from service

Within the framework defined by these categories, cities adapt policy to local environmental concerns, availability of resources, and the composition of their specific vehicle fleet. In some cases, including several urban areas in India and China, cities have sought to reduce emissions from all vehicle types. Others (for example Santiago, New York, Bogota, and Tokyo) have set limits on specific classes of vehicles that typically account for a high share of on-road emissions, such as municipal bus fleets or heavy-duty diesel vehicles, and focused on reducing particulate matter (PM) emissions.

This briefing provides examples of city action in these three areas, and suggests policy options for Jakarta to consider.

Policy or program	Possible opportunity in Jakarta	International examples
Use of cleaner burning fuels		
Improve diesel fuel quality with mandatory standards, especially reduced sulfur content	Secure fuel with sulfur content <50 parts per million within the city to allow operation of Euro 4/IV vehicles in municipal fleets and to pave the way for Euro 6/VI standards. Fuel quality improvements—particularly lowering fuel sulfur content—are a necessary first step towards reducing air pollution from vehicles, because advanced vehicle emission control technologies such as diesel particulate filters require ultra-low fuel sulfur content to function optimally.*	Multiple cities in China, India, and Brazil
Improve fuel quality with financial incentives	Work with the Development Banks and other multilateral institutions to secure financing to upgrade refineries to supply low sulfur fuel to Jakarta.	Bogota, Colombia
Use Compressed Natural Gas (CNG) or other alternative fuels	Improve supply of CNG as an automotive fuel, in particular for new three-wheelers and buses.	Delhi, India
Improve emissions performance of new vehicles		
Establish stringent standards for vehicles sold in the city	Implementation of Euro 4/IV and beyond standards for vehicles sold in Jakarta. New buses to be Euro IV or better—either running on CNG or diesel with particulate filter fitted	Multiple cities in China and India, as well as Santiago, Chile**
Discourage purchase of diesel passenger cars through fiscal policies	Impose additional tax or annual fee based on conventional pollutant emissions rates of passenger cars, similar to fiscal policies to reduce CO_2 emissions.*** Set a higher sales tax rate for diesel fuel to disincentivize the purchase of diesel cars. Conversely, lower the sales tax rate for gasoline.	Vehicle pricing: CO_2-focused policy used in US, EU, China, India Fuel pricing: Delhi, India
Improve emissions performance of in-use vehicles and infrastructure		
Offer scrappage incentives	Create a vehicle scrappage program with financial incentives to replace Euro 1/I and older vehicles with new Euro 4/IV compliant vehicles	Beijing, China
Establish a low emissions zone (LEZ)	Establish a zone within Jakarta that only low-emission-compliant labeled vehicles can enter.	Multiple cities in Europe and China
Implement Stage I/II evaporative controls for gas stations	Mandate evaporative emission controls within Jakarta region to prevent VOC emissions during refueling	Beijing, China
Idle Reduction Programs	Local ordinances and driver training to reduce/eliminate idling	Multiple cities in U.S.
Improve compliance programs	Improve in-use vehicle emissions compliance programs	

* The International Council on Clean Transportation and The Energy and Resources Institute. (2011). Background Paper on Cleaner Liquid Fuels and Improved Vehicular Technologies. Retrieved from: http://theicct.org/sites/default/files/Background_India2011.pdf

** Santiago requires new diesel buses to have a particulate filter installed, even with a base Euro III engine, instead of mandating a stricter emission standard.

*** He, H. and Bandivadekar, A. (2011). *A Review and Comparative Analysis of Fiscal Policies Associated with New Passenger Vehicle CO_2 Emissions.* The International Council on Clean Transportation. Retrieved from http://www.theicct.org/sites/default/files/publications/ICCT_fiscalpolicies_feb2011.pdf

BACKGROUND AND PURPOSE

Indonesia has taken some important first steps towards controlling vehicular air pollution. The Ministry of Environment requires that all new vehicles meet Euro 2/II emission standards, and the Director General of Oil and Gas has set fuel quality standards necessary to achieve those emission levels. The Ministry of Environment has also established a protocol for in-use vehicle testing. These laws show important progress in national action to reduce emissions from mobile sources, although Euro 2/II emission standards are less stringent than those adopted by several other ASEAN nations[5]. The Ministry of Transportation has pursued a program to promote the use of compressed natural gas (CNG), distributing over 2,000 conversion kits for taxi and microbuses. The primary motivation for the CNG conversion program is energy security, but CNG can also provide air quality benefits. The government has reduced fuel subsidies, which encourage vehicle activity. The federal government raised the controlled price of fuels in 2008 and again in 2013, and President Joko Widodo (known as Jokowi) has committed to further increases.[6] Several ministries have examined other measures to reduce vehicle pollution in workshops and meetings with stakeholders such as oil and auto industry members, university experts, and NGOs. In one such effort, the Indonesian Ministry of Environment worked with partners including the US EPA and UNEP to conduct a cost-benefit analysis of various policies to improve fuel quality and fuel economy in Indonesia[7]. A representative of the Ministry of Environment has stated that the ministry intends to move to Euro 4 emission standards in the near future.[8]

This progress has not been sufficient to control pollution in Jakarta, and local officials confront a need to move beyond national efforts. Euro 2/II-equivalent standards are relatively lenient; many megacities require at least Euro 4/IV-equivalent standards and many are striving to implement Euro 6/VI, taking advantage of the dramatic reduction in vehicle emissions that can be achieved with advanced engine tuning and aftertreatment technology. Furthermore, much of the diesel fuel available around the country does not comply with the sulfur content limits imposed by the 2006 standards, and this has caused difficulties enforcing existing standards for new vehicles.[9] While CNG can serve as an intermediate or complementary measure to compensate for poor diesel quality, that potential has not yet been realized in Indonesia due to problems with pricing and supply as well as lax requirements for CNG vehicle emissions. Until national fuel subsidies are eliminated, they will continue to incentivize growth in sales and activity of private passenger vehicles even as Jakarta experiences notorious roadway congestion.[10] While officials have acknowledged the need to phase out fuel subsidies, address fuel quality problems, and pursue comprehensive policies to reduce vehicle emissions, national action has been delayed.

Jakarta has an opportunity to lead the way toward better vehicle and fuel policies. As the capital and largest city in Indonesia, it exerts great influence on national policies. Actions in Jakarta also have an immediate impact on close to 10 million people, many of

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5 Thailand and Malaysia have both adopted Euro 4-equivalent standards beginning in 2012, and Veitnam and Laos may adopt Euro 4 in 2014.

6 Maulia E, Sihite E, and Sihaloho J. (2014, Nov 5).Jokowi Signals Imminent Subsidized Fuel Price Increase. *Jakarta Globe.*Retrieved from http://thejakartaglobe.beritasatu.com/news/jokowi-signals-imminent-fuel-hike/

7 Safrudin, A., Palguna, A., Adrison, V., Khoirunurrofik, Haryanto, B., Krisnawati, L., Zakaria, M., Hamonangan, E., Nurafiatin, L., Suhud, M., Reksowardojo, A.,and Huda, A. (2013). *Cost-Benefit Analysis for Fuel Quality and Fuel Economy Initiative in Indonesia.* Jakarta, Indonesia: Ministry of Environment, Assistant Deputy for Mobile Source Emission.

8 Asian Clean Fuels Association. (2009, November). Interview with Mr. Ade Palguna from Ministry of Environment, Indonesia. *ACFA News 7(7)*, 2-3.

9 Safrudin, A., Krisnawati, L., and Mahalana A. (2011). *Indonesia Fuel Quality Report 2011: clean fuels for clean air.* Jakarta, Indonesia: Ministry of Environment, Deputy for Environment Pollution Control, Assistant Deputy for Mobile Source Emission Control

10 (2012, May 26) Cars in Indonesia: Let them walk. *The Economist*. Retrieved from http://www.economist.com/node/21555970

whom live with poor air quality every day. Other cities around the world have shown that local action to reduce vehicle emissions can improve quality of life and result in better national policies.

This briefing presents examples of cities taking action to reduce vehicle emissions through clean fuels and emission control policies. Such policy measures are possibilities that Jakarta can consider as means to the end of cleaner air. Other measures, such as enhancing mass transit and non-motorized transport, that are also proven clean-air policies, are not addressed here.

AIR QUALITY AND HEALTH IN JAKARTA

Jakarta's poor air quality has been well documented. Monitoring data from the last decade show annual PM_{10} concentrations over twice the WHO guideline,[11] and annual concentrations of both sulfur dioxide and ozone that exceed national standards.[12] These pollutants are associated with a wide variety of health hazards, including heart disease, stroke, chronic bronchitis, asthma, and lung cancer.[13] From 2001 through 2010 the city saw a moderate reduction in PM_{10} and some other pollutants, such as nitrogen dioxide (NO_2) and carbon monoxide (CO), in part from successful programs like car-free days and bus rapid transit. But these air pollutants sharply increased again in 2011,[14] demonstrating that Jakarta still has a long road ahead to achieving healthy air. A 2012 Indonesian Ministry of Environment cost-benefit analysis (CBA) study reported the average cost of air pollution illnesses in Jakarta alone in 2010 was US $535 million.[15]

CURRENT STATUS OF VEHICLE EMISSIONS AND FUEL QUALITY IN INDONESIA AND JAKARTA

Vehicle sales in Indonesia have grown exponentially since the early 1990s, led primarily by motorcycle sales. Indonesia's vehicle market grew by 20% annually from 2007 through 2012 and continues to increase at double-digit rates, a growth rate that outstrips even that of China.[16] The Indonesian National Police reported over 86 million vehicles nationwide in 2011. At that time, the composition of Indonesia's fleet was 80% motorcycles, 11% passenger cars, 6% trucks, and 3% buses.[17] In Jakarta, an estimated 8 million vehicles were in use in 2011 within the city limits;[18] over 11 million vehicles were in use in the Greater Jakarta area.[19]

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11 Annual average PM10 has typically been around 50 μg m-3 compared to WHO limit of 20 μg m-3; annual average SO2 has been around 40 μg m-3 compared to WHO limit of 20 μg m-3 over a 24-hour period

12 DKI-Jakarta and PUSARBEDAL Observatory, quoted in Safrudin, A., Palguna, A., Adrison, V., Khoirunurrofik, Haryanto, B., Krisnawati, L., Zakaria, M., Hamonangan, E., Nurafiatin, L., Suhud, M., Reksowardojo, A.,and Huda, A. (2013). *Cost-Benefit Analysis for Fuel Quality and Fuel Economy Initiative in Indonesia.* Jakarta, Indonesia: Ministry of Environment, Assistant Deputy for Mobile Source Emission.

13 World Health Organization. 2006. Air Quality Guidelines: Global Update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide. http://www.euro.who.int/__data/assets/pdf_file/0005/78638/E90038.pdf?ua=1

14 Data from Jakarta Environmental Management Agency, as cited by the Wall Street Journal: http://online.wsj.com/article/SB10000872396390444897304578046713405298742.html

15 Safrudin, A., Palguna, A., Adrison, V., Khoirunurrofik, Haryanto, B., Krisnawati, L., Zakaria, M., Hamonangan, E., Nurafiatin, L., Suhud, M., Reksowardojo, A.,and Huda, A. (2013). *Cost-Benefit Analysis for Fuel Quality and Fuel Economy Initiative in Indonesia.* Jakarta, Indonesia: Ministry of Environment, Assistant Deputy for Mobile Source Emission.

16 Bandivadekar, A. (2013). Top vehicle markets, 2012. Retrieved from http://www.theicct.org/blogs/staff/top-vehicle-markets-2012.

17 Data from Indonesian National Police as cited by Statistics Indonesia. Retrieved from http://www.bps.go.id/eng/tab_sub/view.php?kat=2&tabel=1&daftar=1&id_subyek=17&notab=12

18 Saragih, S. (2012, June 29). Number of Vehicles Excessive. *Indonesia Infrastructure Initiative*. Retrieved from http://www.indii.co.id/news_daily_detail.php?id=4164

19 The Jakarta Post. (2010, September 27). Jakarta to embrace 12 million vehicles by 2011. Retrieved from http://www.thejakartapost.com/news/2010/09/27/jakarta-embrace-12-million-vehicles-2011.html

Indonesia has acted to regulate emissions from motor vehicles for the last two decades. When the Ministry of Population and the Environment (the predecessor to the current Ministry of Environment) published air quality guidelines in 1988, they set initial limit values for mobile source HC and CO emission rates.[20] The mandate to perform emissions tests and the delegation of testing responsibility to provincial governments were issued in 1992[21] and 1993[22], although testing was only required for freight or public transport vehicles. In 2003, the Ministry of the Environment issued a new decree requiring Euro 2/II-equivalent emission standards for new motorcycles, cars, and heavy-duty vehicles to be met in 2005 for new vehicle types and 2007 for all new vehicles. In 2006 the Directorate General of Oil and Gas required fuel to meet the standards necessary for Euro 2/II emission levels, including the provision of unleaded gasoline and a limit of 500 parts per million (ppm) sulfur content in both gasoline and diesel.[23] The governor of the Jakarta Special Capital Region (DKI Jakarta) has the authority to decree more stringent vehicle emission standards within the city in advance of new national standards in order to meet city air quality standards; such decrees have been issued in 1990 and 2000.[24]

An evaluation of fuel quality in selected Indonesian cities revealed that by the year 2011 neither the diesel nor the gasoline available at the pump was fully in compliance with 2006 standards: gasoline met the new standards for octane number, lead content, and sulfur content, but exceeded the Reid Vapor Pressure limit in many samples; diesel in some cities did not meet the minimum cetane number and in almost all cases exceeded the maximum sulfur content.[25] The uncertainty in fuel quality, specifically diesel sulfur content, has hindered the government's ability to enforce vehicle emission standards. Fuel sulfur content depends on availability of low-sulfur products from both domestic and international refineries. As of 2012, domestic refineries met only 64% of national demand for petroleum products, with the remaining demand met by imports.[26] The six domestic refineries produce diesel with sulfur content ranging between 300 ppm and 4,500 ppm, and diesel sulfur content varies even between batches of fuel produced by the same refinery. Imported diesel contains between 2,500 ppm and 5,000 ppm sulfur.[18] Diesel in Jakarta is primarily supplied by the Balongan and Plaju refineries, which produce an average of 300 ppm and 900 ppm sulfur diesel, respectively, and supplemented with higher-sulfur imports.[19] The sulfur content of diesel samples in Jakarta ranges from 270 to 2,600 ppm.[27]

Fuel is heavily subsidized by the government of Indonesia. Large amounts of gasoline and diesel are sold at rates far below their market value.[27] These subsidies have made up between 7 and 25 percent of total annual public government expenditures from 2005 through 2013;[28] in 2013, subsidies amounted to 246.5 trillion rupiah, or over $21 billion USD.[29] Furthermore, diesel is more heavily subsidized than gasoline, which may

20 Decree of the Ministry of Population and Environment :KEP-02/MENKLH/I/1988, appendix IV
21 Act number 14 of 1992 on Traffic and Land Transportation
22 Decree of the Ministry of Transportation: KM-71/1993
23 Directorate General of Oil and Gas Decision Numbers 3674K/24/DJM/2006 and 3675K/24/DJM/2006
24 Governor of the Jakarta Special Capital Region Decree No, 1041/2000, retrieved from http://bplhd.jakarta.go.id/peraturan/pergub/KEPGUB_NO_1041_TH_2000.pdf
25 Safrudin, A., Krisnawati, L., and Mahalana A. (2011). *Indonesia Fuel Quality Report 2011: clean fuels for clean air.* Jakarta, Indonesia: Ministry of Environment, Deputy for Environment Pollution Control, Assistant Deputy for Mobile Source Emission Control.
26 U.S. Energy Information Administration. (2014, March 5). Indonesia: Analysis. U.S. Energy Information Administration, Independent Statistics & Analysis. Retrieved from http://www.eia.gov/countries/cab.cfm?fips=id
27 Braithwaite, D., Chandra, A., Prasetyaning D.R.L., Indriyanto, A., Lang, K., Lontoh, L., Siahaan, N., Vis-Dunbar, D., Wattimena, B., Widhiantoro, U., and Wooders, P. (2012, March). Indonesia's Fuel Subsidies: Action plan for reform. *The International Institute for Sustainable Development.* Retrieved from http://www.iisd.org/gsi/sites/default/files/ffs_actionplan_indonesia.pdf
28 U.S. Energy Information Administration. (2014, March 5). Indonesia: Analysis. U.S. Energy Information Administration, Independent Statistics & Analysis. Retrieved from http://www.eia.gov/countries/cab.cfm?fips=id
29 Manurung, N. and Anstey C. (2014, Aug 12). Indonesia Officials Look to Jokowi to Cap Fuel Subsidy in 2015. *Jakarta Globe.* Retrieved from http://www.thejakartaglobe.com/news/indonesia-officials-look-jokowi-cap-fuel-subsidy-2015/

incentivize the purchase of higher polluting diesel vehicles. Recently-elected President Jokowi and his administration have committed to fuel subsidy reform, and have raised the price of gasoline and diesel by 30% and 36%, respectively.[30]

In reaction to the growing cost of fuel subsidy and rising air pollution, Indonesia has taken steps to promote the use of CNG as an alternative fuel, guaranteeing a supply of natural gas for domestic needs[31] and regulating and pricing CNG for motor vehicles.[32,33] In Jakarta, a pilot project began in the late 1980s to install CNG converter kits on 200 local taxis, but the project failed after two years. Numerous reasons are given for the project's failure, including the inconvenience of refilling the kit's small tank at one of the few CNG stations, inconsistent supply and quality of CNG, and the expense of conversion kits.[34,35] The price of CNG was capped at 55% of gasoline to make it an attractive alternative for motor vehicles, but this low pricing also reduces the profitability of privately operated CNG stations, and has been blamed for the poor quality and limited availability.[35] In 2007, Jakarta saw a renewed effort to adopt CNG with governor's regulation No. 141, which required a transition to CNG fuel for local government operational vehicles and public transportation vehicles. The head of the Jakarta Transportation Agency has committed to a full conversion of three-wheeled taxis in Jakarta to CNG by the end of 2016.[36] The TransJakarta BRT system operates 600 CNG buses with plans to introduce 1,000 more, and DKI Jakarta will procure an additional 3,000 CNG-powered mini buses. As of 2012, the city had eight CNG fueling stations and planned to build 35 more,[35] although it was reported in spring of 2014 that only six of ten total stations were in operation.[37] In the fall of 2014, the Jakarta Department of Industry and Energy announced its intention to build an additional 50 stations throughout the province,[38] and a recent memorandum of understanding between TransJakarta and PT Jakarta Propertindo calls for construction of 20 new stations by the end of 2015.[39]

STRATEGIES TO CONSIDER

There are three types of policies which complement each other in a comprehensive motor vehicle emission control program: clean fuels, new vehicle emission standards, and programs to clean up existing vehicles and infrastructure. Together, these three types of policies provide a comprehensive menu of options from which Jakarta can choose tactics that are suitable for local conditions.

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30 Bland, B. (2014, Nov. 17) Joko Widodo raises Indonesia's subsidized petrol price. Financial Times. Retrieved from http://www.ft.com/intl/cms/s/0/f8b84820-6e73-11e4-afe5-00144feabdc0.html#axzz3LKRkpGz7

31 Law No. 22/2001 concerning Petroleum and Natural Gas

32 Minister of Energy and Mineral Resources Regulation No. 19/2010 concerning natural gas utilization for fuel gas used for transportation

33 Minister of Energy and Mineral Resources Decision No. 2932K/12/MEM/2010, concerning the selling price of the fuel gas used for transportation in Jakarta.

34 Safrudin, A., Palguna, A., Adrison, V., Khoirunurrofik, Haryanto, B., Krisnawati, L., Siahaan, N., Vis-Dunbar, D., Wattimena, B., Widhiantoro, U., and Huda, A. (2013). *Cost-Benefit Analysis for Fuel Quality and Fuel Economy Initiative in Indonesia.* Jakarta, Indonesia: Ministry of Environment, Assistant Deputy for Mobile Source Emission.

35 Braithwaite, D., Chandra, A., Prasetyaning D.R.L., Indriyanto, A., Lang, K., Lontoh, L., Siahaan, N., Vis-Dunbar, D., Wattimena, B., Widhiantoro, U., and Wooders, P. (2012, March). Indonesia's Fuel Subsidies: Action plan for reform. *The International Institute for Sustainable Development.* Retrieved from http://www.iisd.org/gsi/sites/default/files/ffs_actionplan_indonesia.pdf

36 Elyda C. (2014, November 4) Iconic orange 'bajaj' to be phased out by 2016. *The Jakarta Post*. Retrieved from http://www.thejakartapost.com/news/2014/11/04/iconic-orange-bajaj-be-phased-out-2016.html

37 (2014, March 3). Pertamina to open new CNG station. *The Jakarta Post.* Retrieved from http://www.thejakartapost.com/news/2014/03/03/pertamina-open-new-cng-station.html.

38 (2014, October 8). Akan Ada 50 SPBG Lagi di Jakarta. *Kompas.com*. Retrieved from http://megapolitan.kompas.com/read/2014/10/08/20132851/Akan.Ada.50.SPBG.Lagi.di.Jakarta

39 (2014, October 16). Jakpro dan Transjakarta Kerja Sama Bangun 20 SPBG. *Kompas.com*. Retrieved from http://megapolitan.kompas.com/read/2014/10/16/16072691/Jakpro.dan.Transjakarta.Kerja.Sama.Bangun.20.SPBG

1) USE CLEANER FUELS

Indonesia has already taken an important step in cleaning up petroleum fuels by eliminating the use of leaded gasoline. The next critical step to facilitate the use of advanced vehicle emission control technologies is the reduction of sulfur. Ensuring that current standards are met is an immediate need, but regulators should also look ahead towards more dramatic reductions in order to facilitate more stringent emission standards. In particular, sulfur levels below 50 parts per million (ppm) are required for proper functioning of most advanced diesel emission control technologies, and levels below 15 ppm are necessary for those technologies to perform optimally. The government of Jakarta could urge the national government to tighten fuel sulfur limits and specify early implementation of those limits within DKI Jakarta. Providing low-sulfur fuel throughout the city would reduce particulate emissions from the entire fleet and allow local vehicles to meet more stringent emission standards.

Guaranteeing less than 50 ppm sulfur fuel within Jakarta would enable the implementation of Euro 4/IV emission standards for captive city vehicle fleets and private vehicles registered and operating within the city. This would put Jakarta on par with other Asian national capitals such as Bangkok and New Delhi. China's capital, Beijing, has already reduced sulfur levels to 10 ppm and implemented Euro 5/V-equivalent standards. Other major cities in China, including Shanghai and Guangzhou, are at 50 ppm and Euro 5/IV levels. A survey of costs of producing low sulfur fuels globally shows that the incremental cost of providing 10 ppm sulfur fuel is in the range of 1–2.5 US cents per liter (~ 100–300 IDR per liter).[40,41]

In addition to securing low-sulfur fuel, Jakarta can continue to support the use of compressed natural gas (CNG). The development of fueling infrastructure for municipal vehicles and buses provides an opportunity to promote the use of CNG for private vehicles. The government can support uptake of CNG use in the private sector by regulating the quality of conversion kits and offering low-rate loans to purchase these kits.[42] Three-wheeled taxis have already been identified as a target for replacement with CNG vehicles, and goods vehicles which operate within the city boundaries would also be candidates for conversion. For the program to be successful, policies must also ensure a steady, high-quality supply of CNG within the city. To take full advantage of the potential air quality benefits of CNG, new CNG vehicles procured for the city should conform to Euro IV or more stringent standards. Because CNG-powered vehicles can use a three-way catalyst rather than the more expensive aftertreatment required for diesel engines, there is a much lower additional cost to purchase heavy-duty CNG vehicles that meet strict emission standards.

EXAMPLES OF CITIES PURSUING CLEAN FUEL STRATEGIES

BEIJING'S AGGRESSIVE LOW SULFUR FUEL TIMELINE

Beijing has consistently led Chinese megacities and the national government in implementing progressive motor vehicle emission control policies. Prior to the Olympic Games in 2008, the government of Beijing successfully secured mainland China's first supply of 50 ppm sulfur gasoline and diesel. This enabled the city to implement Euro 4/IV-equivalent standards for locally-registered vehicles years before the rest of the

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40 Enstrat International Limited. (2003). Cost of diesel fuel desulphurization for different refinery structures typical of the Asian Refining Industry. Asian Development Bank. Retrieved from http://www.unep.org/transport/pcfv/PDF/PubADBSulphurReport.pdf

41 Hart Energy and MathPro Inc. (2012). Technical and Economic Analysis of the Transition to Ultra-Low Sulfur Fuels in Brazil, China, India and Mexico. Washington DC, US: International Council on Clean Transportation. Retrieved from http://www.theicct.org/technical-and-economic-analysis-transition-ultra-low-sulfur-fuels-brazil-china-india-and-mexico

42 Braithwaite, D., Chandra, A., Prasetyaning D.R.L., Indriyanto, A., Lang, K., Lontoh, L., Siahaan, N., Vis-Dunbar, D., Wattimena, B., Widhiantoro, U., and Wooders, P. (2012, March). Indonesia's Fuel Subsidies: Action plan for reform. *The International Institute for Sustainable Development.* Retrieved from http://www.iisd.org/gsi/sites/default/files/ffs_actionplan_indonesia.pdf

nation. In 2012, Beijing again led in becoming the first region in China to secure 10 ppm sulfur fuel and subsequently implementing Euro 5/V-equivalent standards. Beijing's consistent push for aggressive standards has not only delivered important emissions reduction for the city, but also driven China's automakers and fuel refiners to improve their environmental performance and encouraged other major cities like Shanghai and Guangzhou to follow suit.

LOW SULFUR FUEL AND PUBLIC TRANSIT IN BOGOTA, COLOMBIA

Colombia requires that all diesel fuel within the country contain a maximum of 50 ppm sulfur, and all gasoline contain at most 300 ppm.[43] Bogota spearheaded the adoption of 50 ppm sulfur fuel for the city's diesel bus fleet with Euro IV standards in 2010.[44] This movement was done in parallel with major advances in promoting public transit such as the TransMilenio BRT system. Starting January 2013, the 50 ppm diesel and Euro IV emission standards for heavy-duty vehicles have been applicable countrywide.[45] It must be noted that the requirement to supply 50 ppm diesel for the new Euro IV BRT buses has been the key factor in Colombia's eventual transition to Euro IV standards.

FISCAL POLICY TO SUPPORT TRANSITION TO LOW-SULFUR FUELS IN HONG KONG

Hong Kong transitioned from diesel with 5,000 ppm to 500 ppm between 1995 and 1997,[46] and introduced 50 ppm diesel in 2000. The government temporarily reduced the taxes on cleaner imported diesel when it was first introduced, facilitating its uptake by local filling stations. The import tax was gradually raised again but the tax on higher-sulfur diesel was also increased to maintain the same price gap between the two fuel grades. It was estimated that the total cost of the three-year tax concession to the Hong Kong government was $1.8 billion.[47] To begin the transition to 10 ppm diesel in 2007, the government again lowered the import tax and eventually waived all tax on ultra-low sulfur diesel.[48] These fiscal policies helped to ease the price shocks associated with the move to low-sulfur fuel and ensure a smooth, quick transition to cleaner fuel.

CNG IN NEW DELHI, INDIA

At the turn of the century, the Supreme Court of India mandated that New Delhi convert its entire fleet of buses, three-wheelers and taxis to run on compressed natural gas (CNG). New CNG vehicles were also required to meet Euro III emission standards. This represented a leap forward in terms of both PM and NO_x emissions compared to the contemporary Euro I buses and three-wheelers with no emissions control; PM emissions per bus were reduced by a factor of nearly 40. The dramatic reduction in emissions had an immediate impact on air quality, although some of these have been subsequently eroded since policy action has stalled in the recent years.[49] Delhi has also instituted a small diesel fuel levy (0.25 Indian rupee per liter, or about 40 Indonesian rupiah per liter) that is used for the purpose of an environmental fund used to mitigate air pollution impacts in Delhi.

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43 United Nations Environment Programme. (2012). Status of Fuel Quality and Vehicle Emission Standards: Latin America and the Caribbean. United Nations Environmental Programme, Partnership for Clean Fuels and Vehicles. Retrieved from http://www.unep.org/transport/pcfv/PDF/Maps_Matrices/LAC/matrix/LAC_FuelsVeh_Feb2014.pdf

44 Joint Resolution 2604, 2009 Ministry of Environment, Housing and Territorial Dvelopment (December 24, 2009). Retrieved from http://www.alcaldiabogota.gov.co/sisjur/normas/Norma1.jsp?i=38491

45 Ministerio de Ambiente, Vivienda y Desarrollo Territorial. (2010) Minambiente anuncia moderna y eficiente tecnologia de motores que reducira emisiones vehiculares. Ministherio de Ambiente, Vivienda y Desarrollo Territorial. Retrieved from http://www.minambiente.gov.co/contenido/contenido.aspx?conID=4749&catID=1042

46 Hung W. (2004). Taxation on Vehicle Fuels: its impacts on switching to cleaner fuels. Energy Policy 34 (2006) 2566-2571

47 Ibid.

48 He, H. (2013, June 14). Policy measures to finance the transition to lower sulfur motor fuels. *The International Council on Clean Transportation.* Retrieved from http://www.theicct.org/sites/default/files/publications/ICCT_LSF-fiscalpolicy_June2013.pdf

49 Roychowdhury A. (2010) CNG programme in India: The future challenges; Center for Science and Environment (CSE) Fact Sheet Series

2) IMPROVE EMISSIONS PERFORMANCE OF NEW VEHICLES

Modern vehicle emission control technologies deliver dramatic emissions reductions at modest cost. Table 1 below shows the percent reduction in per-vehicle emissions that would be achieved by strengthening standards from Euro 2/II, currently in place in Indonesia, to Euro 4/IV for light-duty vehicles (LDV) and heavy-duty vehicles (HDV), respectively. Key technologies used to reduce emissions are also listed.

Table 1: Percent reductions in per-vehicle emissions of various pollutants in moving from Euro 2/II to Euro 4/IV standards, and key technologies used.[50]

Vehicle Type	Percent Reduction in Emissions					Technologies Used
	CO	HC	HC+NO_X	NO_X	PM	
Gasoline LDV	55%	64%	-	64%	-	Exhaust gas recirculation (EGR), improved fuel injection
Diesel LDV	50%	-	67%	70%	75%	Diesel oxidation catalyst (DOC), improved fuel injection
HDV	63%	58%	-	50%	87%	EGR, DOC, selective catalytic reduction (SCR)

Requiring that Indonesia's vehicles be equipped with the emission control technologies necessary to move from the current standard of Euro II to Euro IV would add a cost of approximately USD $125 per gasoline passenger car,[51] and USD $2,700 for a heavy-duty bus or truck.[52] The switch to more stringent standards does involve a significant up-front investment, especially given rapidly growing vehicles in Indonesia, but studies have shown that these costs are quickly repaid in benefits to worker productivity, health, and increased lifespan.[53]

The implementation of Euro 4/IV-equivalent standards for new vehicles in Jakarta would be an important milestone in mitigating the air pollution impacts of motor vehicles in the city. Compared to Euro 2/II standards, Euro 4 standards reduce NO_X and hydrocarbon (HC) emission rates from light-duty gasoline vehicles by 70% and 80%, and Euro IV standards reduce NO_X and PM emission rates from heavy-duty trucks by 45% and 80%. The control of hydrocarbons must extend beyond reductions in vehicle exhaust, as hydrocarbons are also released as evaporative emissions from unburned fuel. High rates of evaporative emissions occur during refueling unless controls are put in place.[54] Evaporative emissions of hydrocarbons, including volatile organic compounds, can be reduced by requiring new vehicles to include onboard refueling vapor recovery (ORVR) systems. ORVR systems are low cost and offer savings over the lifetime of the vehicle due to fuel recovery, but require an effective certification testing and approval system to ensure the potential emission reductions and savings are realized.

Although Euro 4/IV standards deliver dramatic emissions reductions for many pollutants, one technology not required to meet Euro 4/IV standards is the diesel particulate filter (DPF). DPFs capture >99% of diesel particulate emissions by mass and >90% by number.[55] They are the only technology effective at reducing emissions of ultrafine

50 Data from http://www.transportpolicy.net/index.php?title=EU:_Heavy-duty:_Emissions
51 The cost of upgrading a diesel passenger car is estimated to be significantly higher at USD $450–500 per car.
52 International Council on Clean Transportation: India Emissions Model
53 See similar ICCT analysis for India at http://theicct.org/case-early-implementation-stricter-fuel-quality-and-vehicle-emission-standards-india
54 Fung F. and Maxwell B. (2011, Nov) Onboard Refieling Vapor Recovery: Evaluation of the ORVR Program in the United States. *The International Council on Clean Transportation.* Retrieved from http://www.theicct.org/sites/default/files/publications/ORVR_v4_0.pdf
55 Khalek, I.A., Bougher, T.L., Merritt, P.M., Zielinska (2012). Regulated and Unregulated Emissions from highway Heavy-Duty Diesel Engines Complying with U.S. Environmental Protection Agency 2007 Emissions Standards. *Journal of the Air & Waste Management Association, 61:4, 427-442.*

particles, which are hypothesized to be more toxic than larger particles.[56] DPFs also efficiently capture the black carbon component of diesel particulate emissions, a potent short-lived climate forcer.[57] DPFs do not usually become a primary compliance strategy until light-duty Euro 5 and heavy-duty Euro VI standards are in place. Even before Euro 5/VI standards are in place, some regions have specifically mandated the use of DPFs on certain vehicles for PM control. For example, Santiago, Chile, required Euro III buses to be outfitted with DPFs once 50 ppm sulfur diesel was available. Beijing, China just announced that all new diesel vehicles in the city would be equipped with DPFs by the end of 2014.

Significant benefits could also come from reducing emissions from motorcycles, which overwhelmingly dominate the vehicle fleet in Jakarta and throughout Indonesia. Emissions from two-wheeled vehicles are already improving, as cleaner 4-stroke motorcycles have largely replaced 2-stroke motorcycles.[58] The Indonesian Motorcycle Industry Association (AISI) had signaled in early 2012 that Indonesia's motorcycle industry is ready for Euro 3,[59] and Indonesia issued a new regulation several months later requiring that motorcycles meet Euro 3 standards and equivalent limits on the World Harmonized Motorcycle Emissions Certification/Test Procedure (WMTC).[60] Both the reduction in emissions limits and move to the WMTC are notable steps forward. These standards do not apply to three-wheeled vehicles, however. Many three-wheelers are still powered by higher-emitting 2-stroke engines, increasing the importance of extending standards. These limits can be met cost effectively, even with the lower-cost 2-stroke engines.[61]

Jakarta could move beyond national standards by adopting an additional control level for motorcycles, either continuing to follow equivalent standards to those adopted in the EU or following the path recently laid out by India with Bharat IV.[62] Bharat IV offers more stringent CO and HC+NO_x limits, provides a flexiblility in HC limits to incentivize improved evaporative emission control, and relaxes NO_x standards. It provides an easier step than moving to Euro 4, and could be implemented sooner; Bharat IV might be required in 2018, while it would be more reasonable to move to Euro 4 in 2020. Table 2 shows percent reductions in emissions of various pollutants from motorcycles between Euro 3 and Euro 4 or Bharat IV, as well as technology options available to manufacturers to meet these standards at a low cost.

56 Health Effects Institute. (2013). *Understanding the Health Effects of Ambient Ultrafine Particles*. HEI Perspectives 3. Retrieved from http://pubs.healtheffects.org/getfile.php?u=893
57 Bond et al. 2013. Bounding the role of black carbon in the climate system: A scientific assessment. Journal of Geophysical Research—Atmospheres.
58 Asosiasi Industri Sepeda Motor Indonesia (Indonesian Motorcycle Industry Association). (2008, Feb. 14) Motorcycle & Exhaust Emission in Indonesia. JARI Indonesia Round Table Meeting. Retrieved from http://www.jari.or.jp/Portals/0/resource/pdf/indonesia_2008/Session3-3_E.pdf
59 Bogamitra. (2012, Feb. 24) Indonesia Ready to Go Euro 3. *Bizcovering.* Retrieved from http://bizcovering.com/business/indonesia-ready-to-go-euro3/
60 Minister of the Environment Regulation No. 10/2012 concerning the quality standard for motor vehicle exhaust emissions for new types of L3-category vehicles
61 Iyer (2012). A Technical Assessment of Emissions and Fuel Consumption Reduction Potential from Two and Three Wheelers in India. *International Council on Clean Transportation.* Retrieved from http://www.theicct.org/sites/default/files/publications/Iyer_two-three-wheelers_India_August2012.pdf
62 International Council on Clean Transportation (ICCT). (2014). Bharat Stage IV Emission Standards for Two-Wheelers in India. ICCT. Retrieved from http://www.theicct.org/sites/default/files/publications/ICCTupdate_BSIV-motorcycles_aug2014.pdf

Table 2: Percent reductions in per-vehicle emissions of various pollutants in moving from Euro 3 to Euro 4 or Bharat IV motorcycle emission standards and key technologies used.[62]

Standard (Vehicle Type)	Percent Reduction in Emissions			Technologies Used
	CO	HC+NO_x	NO_x	
Euro 4 (Motorcycles)	56%	51%	59%	• Further engine optimization—wider use of variable ignition timing + improved catalytic converter—Close-coupled catalyst / start-up Catalyst / quick warm-up xatalyst, exhaust insulation (double exhaust pipes)—all on selected models, • A few models with port fuel injection • A few models with electronic carburetor
Bharat IV (Motorcycles)	46%	36% (27% if evap. controls met)	Increase of 130%	• Electronic fuel injection • Three-way catalyst systems • Some models may require oxygen sensors

Indonesia grants the governor of DKI Jakarta the authority to require that vehicles operating within the city meet tighter standards than those required at a national level. Without the accompanying authority to require low sulfur fuels, however, this authority cannot be effectively exercised; vehicles are only guaranteed to meet their certified emissions level if they are operated with the appropriate fuel, and the use of high sulfur fuel can damage advanced-technology systems. To enable implementation of new emissions standards in DKI Jakarta, the city must advocate for tighter national fuel standards , and recommend that these standards be implemented early within the city. This strategy would reduce vehicle emissions in Jakarta and put the city in a leading role in setting the tone for the country.

EXAMPLES OF CITIES IMPROVING EMISSIONS PERFORMANCE OF NEW VEHICLES

AGGRESSIVE NEW VEHICLE EMISSION STANDARDS IN BEIJING, CHINA

As mentioned in the previous section, Beijing has led China in supplying low sulfur fuels. These fuels have enabled the introduction of advanced vehicle emission standards. In 2008 and 2013, Beijing became the first region in China to implement Euro 4/IV and 5/V-equivalent tailpipe emission standards, respectively. This leadership encouraged many other cities to follow: Shanghai and Guangdong Province, which contains Guangzhou and Shenzhen, followed Beijing in implementing Euro 4/IV ahead of the national schedule, and Shanghai has also adopted Euro 5/V standards on an accelerated timeline. In September 2013, Beijing's government announced targets to implement even more aggressive vehicle emission standards, planning the introduction of Euro 6/VI-equivalent standards in 2016.[63]

FUEL QUALITY AND EMISSION CONTROL IN MULTIPLE CITIES IN INDIA

For over a decade, cities in India with larger vehicle populations and poorer air quality than the rest of the country have required new vehicles to meet emission standards at one Euro level above the rest of the nation; currently, they follow Euro 4/IV-equivalent standards while the rest of the country follows Euro 3/III-equivalent. To enable this, these

63 Office of the Beijing Municipal People's Government. (2013, Sept. 2) Beijing Municipal People's Government Office action plan focused on the task decomposition on the issuance of Beijing 2013-2017 Clean Air. Retrieved from http://zhengwu.beijing.gov.cn/gzdt/gggs/t1322955.htm

cities have been supplied with lower sulfur fuel (50 ppm gasoline and diesel compared to 150 ppm gasoline and 350 ppm diesel in the rest of the country).

Initially, only Delhi and three other megacities implemented stricter Euro standards. From 2005 onwards 13 cities moved to Euro 3/III standards, while the rest of the country progressed to Euro 2/II. Currently, 30 cities require Euro 4 vehicles and are supplied with 50 ppm sulfur fuel. The number of cities receiving <50 ppm sulfur fuel and mandating Euro 4 standards will expand to 63 by 2015.[64] Meanwhile, India is in the process of establishing a long-term roadmap for vehicular emissions that will improve fuel quality (first to 50 ppm nationwide followed by 10 ppm) along with a move to tighter emission standards (Euro 5/6 as well as Euro V/VI).

ACCELERATED STANDARDS IN SANTIAGO, CHILE AND BOGOTA, COLOMBIA

In order to combat degrading air quality, the Metropolitan Region of Santiago, Chile has introduced stringent vehicle standards ahead of the rest of the country. The metro region led the nation in adopting its first emission standards, and strengthened its standards to Euro 2/II-equivalent in 1998, eight years before the national schedule.[65,66] The city has since progressed to Euro IV/5 standards, leading national implementation by a year. A similar practice was applied in Bogota, Colombia, where public transport vehicles operating within the city, including buses used in the BRT system, were required to meet Euro IV-equivalent emission standards in January 2010, nearly three years in advance of national implementation.[67]

3) IMPROVE EMISSIONS PERFORMANCE OF IN-USE VEHICLES AND INFRASTRUCTURE

New vehicle emission standards are a foundational part of a long-term emissions reduction strategy. However, new vehicle standards do nothing to clean up existing vehicles on the roads. Older vehicles, some of which may have useful lifetimes of a decade or more, may emit many times as much pollution as a single new vehicle. Programs targeting the cleaning up or scrappage of these vehicles are an important part of achieving short-term air quality improvements to complement the long-term impact of new standards.

There are a diverse array of in-use vehicle emission control programs, including scrappage programs, retrofit programs, low emission zones, and more. Many of these programs are ideally suited for implementation (and customization) at the local level. A combination of many programs targeting in-use vehicles will be more effective, for example: using inspection, remote sensing or spotter programs to identify high-emitting vehicles; providing financial incentive to repair, retrofit, or retire these high-emitters; and establishing a low-emission zone in which activity of older vehicles or known high-emitters is restricted.[68] The following examples of cities demonstrate the variety of programs that Jakarta may consider.

Aside from reducing emissions from vehicles themselves, Jakarta can take steps to reduce evaporative emissions during refueling. Stage I and Stage II controls, which are

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64 Central Pollution Control Board, Ministry of Environment & Forests, Govt. of India. (2010). Status of the Vehicular Pollution Control Programme in India. http://www.cpcb.nic.in/upload/NewItems/NewItem_157_VPC_REPORT.pdf

65 TransportPolicy.net. “Chile: Light-duty:Emissions” Last modified 18 September 2013, http://transportpolicy.net/index.php?title=Chile:_Light-duty:_Emissions

66 TransportPolicy.net. “Chile: Heavy-duty:Emissions” Last modified 18 March 2014, http://transportpolicy.net/index.php?title=Chile:_Heavy-duty:_Emissions

67 Joint Resolution 2604, 2009 Ministry of Environment, Housing and Territorial Dvelopment (December 24, 2009). Retrieved from http://www.alcaldiabogota.gov.co/sisjur/normas/Norma1.jsp?i=38491

68 Wagner V. and D. Rutherford (2013). Survey of Best Practices in Emission Control of In-Use Heavy-Duty Diesel Vehicles. *The International Council on Clean Transportation (ICCT)*. Retrieved from http://www.theicct.org/sites/default/files/publications/ICCT_HDV_in-use_20130802.pdf

installed at fuel pumps and designed to prevent emissions from vehicles that do not have an onboard refueling vapor recovery (ORVR) system, can reduce hydrocarbon emissions by at least 60% when refueling retail fuel stations and vehicles.[69] These can be put in place while ORVR systems are still rare and have an immediate and positive impact on the health of those in the vicinity of fuel stations.

EXAMPLES OF CITIES IMPROVING EMISSIONS PERFORMANCE OF IN-USE VEHICLES

BEIJING'S IN-USE EMISSION CONTROL PROGRAMS

To complement its efforts to improve fuel quality and upgrade new vehicle emission standards, Beijing has moved aggressively to control existing vehicles. The Beijing city government has administered China's longest running scrappage program, providing subsidies to drivers of older vehicles to eliminate them from the fleet. Older, high-emitting vehicles—gasoline vehicles not meeting Euro 1 and diesel vehicles not meeting Euro III—are marked with a yellow label. In 2008, the Beijing government offered subsidies ranging from 800 to 25,000 RMB (USD $131 to $4,086) to replace yellow-label vehicles,[70] and reduced subsidies in later years to encourage early action. From 2009 to 2010, over 150,000 yellow-label vehicles were eliminated from the city, with an average subsidy of 7,347 RMB (USD $1,225).[71] Even after such success, the Beijing government continues to set even more ambitious goals and plans to eliminate another million vehicles between 2013-2017.[72] This program targets both light-duty and heavy-duty vehicles.

To further incentivize owners of these older vehicles to take advantage of the subsidies and prevent the dirtiest vehicles from polluting in high-exposure areas, Beijing has established a Low Emission Zone into which yellow-label vehicles are prohibited from driving. Beginning in 2008, Beijing began restricting yellow-label vehicles from entering inside the 5th Ring Road encircling the city. Later, the prohibition was extended to the 6th Ring Road.[73] This has proved an effective complement to the city's scrappage program: by prohibiting activity of high-polluting vehicles, the government reported that over 500,000 vehicles were eliminated from the city during 2011 and 2012 while subsidies were issued to only 254,000 vehicle owners.[74]

For vehicles currently on the road in Beijing, the environmental protection bureau (BEPB) requires periodic emission inspections: annual inspections for all trucks and commercial passenger vehicles increasing to twice a year for older vehicles, and annual inspections for private passenger cars over six years of age.[75] The city periodically revises the test procedures and issues manuals to standardize test procedures across inspection stations. BEPB has also deployed 9 remote sensing vehicles that act as temporary monitoring stations, identifying high-emitting vehicles among passing traffic. BEPB then sends notices to owners of high-emitting vehicles.

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69 Fung F. and Maxwell B. (2011, Nov) Onboard Refieling Vapor Recovery: Evaluation of the ORVR Program in the United States. *The International Council on Clean Transportation.* Retrieved from http://www.theicct.org/sites/default/files/publications/ORVR_v4_0.pdf

70 Beijing Motor Vehicle Department. (2008, Dec 30). Strengthen high emission vehicles to promote pollution prevention and control air quality continues to improve capital. *Beijing Municipal Environmental Protection Bureau* Retrieved from http://www.bjepb.gov.cn/bjepb/323474/331443/331834/331850/445964/index.html

71 Beijing Municipal Environmental Protection Bureau. (2011, Jan 18). In 2010 the city out of high pollution emissions yellow cars break through 50,000. Retrieved from http://zhengwu.beijing.gov.cn/zfjd/qtjg/t1151253.htm

72 Office of the Beijing Municipal People's Government. (2013, Sept 2). Beijing Municipal People's Government Office action plan focused on the task decomposition on the issuance of Beijing 2013-2017 Cean Air. Retrieved from http://zhengwu.beijing.gov.cn/gzdt/gggs/t1322955.htm

73 Pinghui, Z. (2008, Oct 3) 'Yellow-label' cars face ban from city in green drive. *South China Morning Post* Retrieved from http://www.scmp.com/article/654871/yellow-label-cars-face-ban-city-green-drive

74 Chu X. (2012, Dec 25). Continue to implement policies to encourage the city to further promote the elimination of old vehicles update. Retrieved from http://www.bjepb.gov.cn/bjepb/323474/331443/331834/331850/451670/index.html

75 Application for motor vehicle inspection marks. Retrieved from http://www.bjjtgl.gov.cn/publish/portal0/tab90/info5653.htm

Beijing has also worked to reduce VOC emissions from refueling. Prior to the Olympics, the city completed a full Stage I/II retrofitting of all gas stations. Stage I refers to controls on VOC emissions during refueling of underground storage tanks by tanker trucks; Stage II refers to controls on gas dispending nozzles used when consumer refuel their cars.[76]

LOW-EMISSION ZONES IN GERMAN CITIES

Just as Beijing has established a low-emission zone within the 6th Ring Road, many cities in Germany use a similar technique. Germany has created a national vehicle labeling program based on emission levels, and most major cities use the labeling system to restrict entrance to gasoline vehicles with a catalytic converter and diesel vehicles meeting Euro 4 or Euro 3 with a DPF. In Berlin, this has resulted in over 60,000 vehicles being retrofitted with a DPF and an observed reduction of diesel soot emissions.[77]

DPF ROLLOUT IN SANTIAGO, CHILE

According to the Ministry of Environment in 2004, 22% of all particulate matter (PM) emissions in the city of Santiago could be attributed to city buses.[78] Starting in 2004, the city began a program to install diesel particulate filters (DPF) on buses. For long-lived, high-value vehicles like buses, incentives for aftertreatment retrofits may be a more cost-effective measure than subsidized scrappage. After an initial pilot program identified the aftertreatment options that offered sufficient PM control (filtration efficiency of <70%), the city offered incentives to bus owners to retrofit their fleet in 2005. Response to these incentives was initially weak, but increased when the city announced that Euro III+DPF would become the mandatory standard in 2010 and revised its incentive scheme. The city supported compliance through an education and awareness campaign about vehicle emissions, identifying approved technology options.

Diesel fuel with a maximum sulfur content of 50 ppm is a prerequisite of a DPF retrofit program. Santiago also worked with Chile's state-owned oil company to reduce sulfur in fuel supplied to Santiago from 3000 ppm in 1997 to 50 ppm in 2004. Now, <50 ppm sulfur fuel is required throughout Chile, and Santiago has a limit of 15 ppm sulfur in both diesel and gasoline.

EMISSION REDUCTION TECHNOLOGIES AND ENFORCEMENT OF FUEL QUALITY IN TOKYO, JAPAN

Tokyo's air pollution has improved greatly since the 1990s, in part because of higher quality fuel and emission control technologies. In 2003, the Tokyo Metropolitan Government set stringent local PM emission standards and banned the operation of heavy-duty diesel vehicles that failed to meet those standards. Operators were forced to either purchase new vehicles or retrofit their vehicles with DPFs or diesel oxidation catalysts (DOC),[79] or to shift to gasoline or alternative fuels such as natural gas. About 75% of these vehicles were replaced, exported, or registered in other parts of Japan, and the remaining 25% were retrofitted with DPFs or DOCs. Ultimately, the majority of retrofits were manufactured by domestic companies, because Japanese vehicles produced a unique NO_x/PM balance that required new technologies.[80]

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76 China Ministry of Environmental Protection (2013, Jan 22) MEP answers questions raised by journalists on the second draft of limits and measurement methods for emissions from light-duty vehicles for comments (national Stage V). Retrieved from http://english.mep.gov.cn/Policies_Regulations/interpretation/201301/t20130122_2453809.htm

77 Friedrich, A. EU- Air Quality Directive and the Implementation in Cities. Retrieved from http://sustainabletransport.org/?wpdmact=process&did=MjYuaG90bGluaw==

78 Swiss Agency for Development and Cooperation/Ministerio del Medio Ambiente (2011). "The Santiago de Chile Diesel Particle Filter Program for Buses of Public Urban Transport.

79 DOCs can be used with higher sulfur diesel (<500 ppm vs. <50 ppm for DPF) and reduce CO and unburned fuel as well as PM, but are not as effective as DPFs in reducing PM (20-25% reduction for heavy duty vs. 70%–95% reduction for DPF).

80 Rutherford, D. (2006). *Policy change in Japan: The Tokyo Metropolitan Government's regulation of diesel emissions*. Dissertation, Stanford University.

In the early years of Tokyo's emission standards, the city faced high rates of non-compliance and fuel adulteration. The city government found that fuel suppliers were mixing heavy oil into diesel fuel, which increases pollution. Local authorities cracked down on violators, reducing illicit fuel use from 14% to less than 1%. Now, Japan's compliance program is run by suppliers who cross check each other's fuel quality. Competitors take on some of the analytical burden and call policymakers' attention to potential violations. Additionally, the Ministry of Economy, Trade, and Industry (METI), inspects every fuel retail outlet in the country annually and at random.[81]

Since the implementation of the compliance program, air quality in Tokyo has improved greatly, with a drop in annual PM_{10} concentration from around 50 μg/m³ in the early 1990s to 23 μg/m³ in 2009.[82] Furthermore, Tokyo's program was instrumental in prompting the Japanese government to tighten its nationwide heavy-duty standards.[83]

CLEANER HEAVY-DUTY VEHICLES IN NEW YORK CITY, USA

New York City is leading the way for more efficient vehicles with the city-owned vehicle fleet and school buses. Starting in 2005, a large percentage of city vehicles have been replaced with fuel-efficient hybrid vehicles and alternative fuel vehicles (e.g., natural gas). The Department of Sanitation is working with truck manufacturers to introduce gas-electric hybrid garbage trucks, and the Department of Education is taking older and dirtier school buses off the road. The city government has also equipped public and private ferries with cleaner engines and pollution control equipment; these ferries now operate on ultra-low sulfur diesel (<15 ppm).

ANTI-IDLING REGULATIONS IN THE UNITED STATES

Anti-idling regulations may be an effective way to improve local air quality and to reduce fuel consumption and CO_2 emissions in urban environments. In the United States, where drivers idle climate-controlled trucks overnight to sleep, the EPA estimates that truck and locomotive engine idling is responsible for 200,000 tons of NO_x, 5,000 tons of particulate matter, and 11 million tons of CO_2 per year, in addition to other harmful pollutants.[84,85] Although the United States has no national anti-idling laws, numerous states and counties have implemented restrictions on the amount of time that diesel truck drivers can idle their engines.[86] Stringent anti-idling laws are commonly adopted under State Implementation Plans (SIPs) for meeting U.S. federal ambient air quality targets. For example, New York City prohibit idling for more than three minutes (one minute if near a school), and California restricts the idling of HD diesel commercial vehicles to less than five minutes throughout the entire state. Tokyo, Hong Kong, Canadian cities, and cities in Sweden and other European countries have adopted similar requirements.

81 Fung, F. (2011, Nov) Best Practices for Fuel Quality Inspection Programs. The International Council on Clean Transportation (ICCT). Retrieved from http://www.theicct.org/sites/default/files/publications/ICCT_fuelqualityBP_nov2011.pdf

82 Data is annual averages. Data from early 1990s from Hutchinson et al. (2010), Universidad Madero de Puebla; data from 2009 from World Health Organization (http://www.who.int/phe/health_topics/outdoorair/databases/en/index.html)

83 As of 2009: max of 0.63 g km^{-1} CO, 0.24 g km^{-1} HC (unburned fuel), 0.08 g km^{-1} NO_x, 0.005 g km^{-1} PM (NO_x limit 0.15 g km^{-1} for vehicles over 1700 kg). This is a substantial improvement from 1997, when the standards were: 2.1 g km^{-1} CO, 0.4 g km^{-1} HC, 0.5 g km^{-1} NO_x, and 0.08 g km^{-1} PM for mean emissions.

84 US EPA. Idle Reduction: A Glance at Clean Freight Strategies. *US EPA EPA-420-F09-038*. Retrieved from http://www.epa.gov/smartway/forpartners/documents/trucks/techsheets-truck/EPA420F09-038.pdf

85 US Environmental Protection Agency. (2012, Oct 22) National Clean Diesel Campaign: Idle Reduction Campaign. *US EPA*. Retrieved from http://www.epa.gov/cleanschoolbus/antiidling.htm

86 American Transportation Research Institute. (2013, Nov). Compendium of Idling Regulations. Retrieved from http://www.atri-online.org/research/idling/ATRI_Idling_Compendium.pdf

POLICY OPTIONS FOR JAKARTA

By taking steps now to reduce harmful vehicle emissions, Jakarta can improve its own air quality while leading the way for Indonesia to adopt nationwide standards in the future. Other cities' experiences suggest that the most effective control programs combine programs for fuel quality improvement with new and in-use vehicle emission controls.

Based on the case studies from other cities worldwide and from Jakarta's current air quality status, the following are some policy steps and options Jakarta can consider to promote vehicle emissions reductions. We split regulatory options into short-term opportunities without major changes to refineries, and longer-term options that do require cleaner fuels.

Near-term opportunities

» **Tighter Emission Standards for the City Bus Fleet.** The current program to convert city buses and other government-operated vehicles to CNG will reduce particulate emissions compared with the former diesel fleet, and it can be extended to achieve greater reductions of other pollutants. Any new CNG vehicles procured by the city could be required to meet Euro VI standards at a cost far below that for diesel: requiring Euro VI rather than Euro II would likely cost over $6,000 for a diesel bus, but less than $200 for a CNG bus.[87] In addition, the use of CNG avoids the major hurdle of securing low-sulfur diesel. In consideration of the problems from which CNG-based programs have suffered in the past, city officials should consult with CNG providers and work to adjust pricing so that stations can provide consistent, high-quality fuel. The development of CNG infrastructure for city vehicles can provide the foundation for a greater uptake of CNG technology by private vehicle operators.

» **Higher sales tax for diesel fuel.** Jakarta could implement a scheduled tax rate increase for diesel fuels. Although politically challenging, lowering the fuel price gap between diesel and gasoline will disincentive the purchase of high-polluting diesel cars in the short term. At the same time, the additional fee on diesel fuel could be used to defray the costs of implementation of other programs, and to ease the transition to imported low-sulfur diesel.

» **Mandate Stage I and Stage II controls.** Mandate these within city limits for evaporative emission controls. Ideally, ORVR systems should be mandated on all new vehicles sold in Indonesia. These are generally more cost effective than Stage II controls, which means that Stage II controls can be lifted after a decade or so, when ORVR fitted vehicles penetrate the on-road fleet in substantial numbers.

» **Driver training programs.** Mandate that heavy-duty vehicle operators participate in periodic training programs that teach and reinforce environmentally friendly driving. This can include practices to save fuel and to reduce pollutant emissions, including anti-idling practices and proper vehicle maintenance. Once established, these programs can be expanded to include operation and maintenance of advanced after-treatment technology like DPFs or SCR systems once such technology is mandated by emission standards. The programs could also include drivers of passenger vehicles.

Mid-term and longer-term measures

» **Advocate for stronger national fuel standards and early adoption of low sulfur fuel.** The transition to <350 ppm fuel could be accomplished more quickly and rely on domestic refinery capacity, and would allow the move to Euro 3/III standards. A tighter mandate for <50 ppm sulfur fuel would allow greater emissions reductions, as fuel with lower sulfur content results in lower emissions regardless

87 Emission costs are assumed to be comparable to heavy-duty gasoline vehicles

of vehicle technology. This would also allow the city to mandate Euro 5 standards for light-duty vehicles—and additionally mandate DPFs if necessary to minimize PM emissions—in the coming years. Standards for fuel quality should be enforced with strong penalties for non-compliant fuel suppliers.

» **Fiscal policies to support low sulfur fuel.** If Jakarta is able to secure a supply of low sulfur fuel within its jurisdiction, it can ease the transition by adjusting sales tax rates of both low and higher sulfur fuel. Furthermore, it can work with the national government to adjust the prices of low sulfur fuels at the refinery and import level.

» **Vehicle scrappage or retrofit financing program.** Once low-sulfur fuel is available, Jakarta can offer subsidies to replace Euro 1 and older vehicles with those meeting Euro 4/IV standards. A scrappage program should be designed with strong cost-effectiveness criteria: it should ensure that scrapped vehicles are replaced with substantially cleaner ones, and should not offer fiscal incentives to scrap vehicles that were already slated to be scrapped. It is equally important the scrapped vehicles are truly removed from the nation's fleet, rather than transferred to an area outside Jakarta for use. For heavy-duty vehicles, it may be more effective to offer financial assistance for DPF retrofits.

» **Low emissions zone.** Explore the feasibility of establishing such a zone where vehicles are labeled based on their emissions compliance and cannot enter the city or zone if they do not meet the compliance (for example based on a Euro standard). This may be implemented in conjunction with a vehicle scrappage program.

» **Enforce in-use emission standards.** Create an effective compliance program that includes regular testing through independent inspections and strong penalties for non-compliance. Vehicle owner can be required to annually test emissions from their vehicles at one of these centers. Conduct road-side apprehensions to further check compliance.

» **Financial Incentives for low sulfur fuel.** Provide financial incentives to suppliers of low sulfur fuel and financing to oil refineries for capital investments in technology required to refine low sulfur fuel. Jakarta could work with the Asian Development Bank (ADB), World Bank, and other multilateral institutions to develop a program to do this.

CONCLUSION

Jakarta has the opportunity to take the lead in vehicle emission and fuel quality regulations in Indonesia. By reducing sulfur levels in fuels, tightening emission standards, disincentivizing the purchase of diesel cars over gasoline cars, and working towards implementing alternative fuels for transportation, emissions from transportation can be significantly reduced. This would undoubtedly be a positive step for Jakarta's 10 million residents. It could also jumpstart similar regulatory action in other parts of Indonesia.