PROMOTING SUSTAINABLE TRANSPORT SOLUTIONS FOR EAST AFRICA

KENYA -NAIROBI AND UGANDA-KAMPALA

Cost and benefits of clean technologies for bus rapid transit (BRT)
Summary of results for Nairobi

December, 2012

Key findings

- Based on preliminary assumptions about the future BRT system, the ICCT's modeling of city-wide pollutant emissions, fuel consumption, health impacts, and time saved suggest that a BRT system in Nairobi will result in considerable overall benefits in the range of $42 to $51 million per year in 2035. Costs for vehicles and infrastructure range $23 to 29 million per year[1].
- Bus technology feasibility analysis identified multiple potential technologies for consideration in Nairobi's BRT system: diesel, hybrid diesel-electric, and LPG buses for Phase I (2013-2020); and clean diesel (with exhaust after-treatment devices), hybrid diesel-electric, LPG, and electric trolley buses for Phase II (2020-2030).
- Among the BRT bus technologies, the analysis revealed that the selection of any of the advanced technology choices – including the cleanest diesel conventional and hybrid-electric buses and trolley electric buses – will result in significant emissions reductions at modest additional cost over a Euro III diesel baseline bus. Several of these advanced technology choices result in significant fuel use and CO_2 emissions reductions (in the range of 600,000 cumulative tons by 2035)
- The specific choice of advanced technology should be based on more refined inputs for the planned future BRT system (i.e targeted capacity) in Nairobi as well as future fuel availability (i.e. excess electricity for transportation).

Introduction and project objectives

The UN Habitat GEF Sustran project aims at promoting sustainable mass transit solutions in East African cities. One of its objectives is to determine the feasibility of application of clean vehicles and fuel technology in the three project's focal cities: Nairobi (Kenya), Addis Ababa (Ethiopia) and Kampala (Uganda). The clean technology component of the project is overseen by United Nations Environment Program (UNEP). The International Council on Clean Transportation (ICCT) was selected to carry out a cost and benefit analysis of clean technology options for bus rapid transit (BRT) vehicle in the three cities, taking into account technology availability, fuel availability and quality, maintenance practices and capacity. The following summarizes the project scope, the analytical approach and the results obtained.

[1] Costs assessed in this study do not include the costs for building the BRT infrastructure

Project scope

The project scope was developed in collaboration with the GEF Sustran project partners interviewed during the project initial site visits. The analysis considers two phases: 2013-2020 and 2020-2030. Benefits and costs are assessed in 2035 when the BRT project is fully implemented. In addition to comparing the relative costs and benefits of clean bus technologies, project partners requested that results reflect the benefits of a BRT system compared to the current baseline ("no BRT"). The emission and health benefits are modeled over the entire metropolitan area in line with the resolution of needed data inputs such as background air pollutant concentrations.

Project approach overview

The ICCT's approach to selecting and evaluating the different vehicle technology and fuel options for each city is summarized as follows.

1. Determine feasible BRT bus technologies and fuels: A comprehensive set of selection criteria is applied to the full range of existing bus technologies. The highest ranked options are selected for further evaluation.
2. Model the cost of ownership for each feasible technology/fuel combination: Using the BestBus model[2], estimate the capital and operational costs at the bus depot level for each option. Output in $/km varies by fleet size.
3. Model the emissions under the baseline ("no BRT") and clean technology scenarios: Using the ICCT Country Emission Model template adapted to city level analysis, estimate the emissions and fuel use over the analysis period from buses and the rest of the vehicle fleet. Key inputs include assumptions about the size and operation of the BRT system such as the target modal shift.
4. Convert emissions reductions into health benefits expressed monetarily: Using the ICCT City Health Model Template, estimate the reductions in premature mortality from pollution exposure abatement and its monetary valuation using standardized methodologies.
5. Estimate the monetary value of fuel savings: Using the output of the emission model and assumption on fuel costs from project partners, estimate for each scenario savings from reduction in fleet-wide fuel use.
6. Estimate the monetary value of time savings: Using assumptions about the relative traffic speeds between BRT and no-BRT scenarios, estimate time saved from reduced congestion and apply valuation of time saved based on standardized methodologies.

Data inputs

As the literature provided few comprehensive sources of current, localized data required for the analysis, the project team relied on input from project partners and local experts, data from

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[2] Duke University, Life Cycle Cost & Emissions Model *Alternative Bus Technologies, Developed by M.J. Bradley & Associates, 2006.*

similar projects in other parts of the world (especially Asia and Latin America) and assumptions deemed reasonable by project partners. It is critical to note that the final benefits and costs analysis is very sensitive to certain input parameters and assumptions (for example, projected size and operation of the BRT system). Accordingly, future efforts to collect better data on the current and future transport system in the city will be instrumental to accurately evaluating the impacts. Key inputs and assumptions are listed in detail in the sections below.

Technology options for Nairobi

Virtually all bus technologies used internationally were initially considered for potential application in Nairobi. These include conventional diesel buses, biodiesel buses, hybrid-electric buses, buses fueled with gas (including LPG, CNG, and LNG), and buses fueled with electricity (including trolley, fuel cell, capacitor, and battery electric). Based on initial input from project partners on fuel availability as well as consideration of technology maturity, it was determined that only conventional diesel, hybrid electric, LPG, and trolley buses were feasible for Nairobi. Subsequently, a feasibility model was developed to determine scores for each technology according to certified tailpipe emission standard and other factors.

The technology scoring highlighted the following top technologies for consideration in Nairobi's BRT system:

Table 1. Ranking of top technologies for Nairobi

Rank	Phase I (2013-2020)	Phase II (2020-2030)
1	Hybrid diesel Euro IV	Electric bus
2	Diesel Euro IV	Hybrid diesel Euro VI
3	LPG Euro V or Euro VI	Clean diesel Euro VI

Based on the rankings in Nairobi and the two other cities, a set of 5 technology scenarios were developed combining Phase I and Phase II technologies. Scenarios 1,2,3,4, and 5 were all analyzed for Nairobi. Nairobi was the only city for which LPG was deemed a viable option.

Table 2. Technology scenarios for Phase I and II

Scenario	Phase I (2013-2020)	Phase II (2020-2030)
No BRT: Baseline	No BRT	No BRT
BRT 1: Diesel BRT	Euro III	Euro III
BRT 2: Clean diesel BRT	Euro IV	Euro VI
BRT 3: Hybrid diesel BRT	Hybrid Euro IV	Hybrid Euro VI
BRT 4: LPG BRT	LPG Euro V/VI	LPG Euro V/VI
BRT 5: Diesel + Electric trolley BRT	Diesel Euro IV	Electric Trolley

Cost of ownership for Nairobi

Cost model inputs

The BestBus cost model requires inputs for capital costs (buses, fueling station/electric infrastructure and depot upgrades) and operating costs (fuel, bus and infrastructure maintenance) for each of the technologies/fuel anticipated by city. The inputs were derived from data obtained during the initial site visit supplemented by desk research.

Table 3. Summary of cost model inputs

Depot and Local Data	Assumptions	Source/Comments
Conversion rates, $1 USD	84 KES	(1)
Number of Buses	10-400	(2)
BRT System Length, km	29	(2)
Annual Travel, km	50,000	(2) See emissions model
Labor Rates	168 KES/hr	(3)
Inflation	6.6%	(1)
Capital discount rates	6%	(2)
Diesel price per liter	98 KES/L = $USD 4.4 /gal	(1)
LPG price per liter	$USD 4.4/gal	(4)
Electricity price per kWh	12.8KES/kWh~0.15 $USD/kWh	(5)

(1) *World Data Bank (2012). World Development Indicators (WDI) and Global Development Finance. http://data.worldbank.org/data-catalog*
(2) ICCT assumption, buses fleet and system size depends on year of program
(3) Average value from newspaper job postings for drivers in Nairobi, Kenya, and the report by the World Bank and the Economic Commission for Africa*, Scoping Study, Urban Mobility in Three cities Addis Ababa, Dar es Salaam and Nairobi. Working Paper No 70.*
(4) ICCT data
(5) Kenyan Ministry of Energy. http://www.energy.go.ke/

Cost results

The total cost of ownership was evaluated for the vehicle lifetime. Internal combustion engine (ICE) buses were assumed to have a 15-year useful life; trolley buses were assumed to have 20-year useful life. Capital costs were distributed along the vehicle useful life; bus overhaul costs were assumed following expected overhaul periods, which vary for each bus technology. Operating costs were linked to vehicle kilometers traveled and/or time.

Cost of ownership results, in $USD per km, assuming 100 buses and 29-km of BRT corridor are presented below. Increasing the number of buses only marginally reduces the cost per mile of ICE (diesels and hybrid), but has a very significant effect on trolleys, as the infrastructure cost are spread among the fleet. LPG was included in cost calculations. Among all three cities, the lowest cost per km is observed in Addis Ababa given the relatively low cost of diesel.

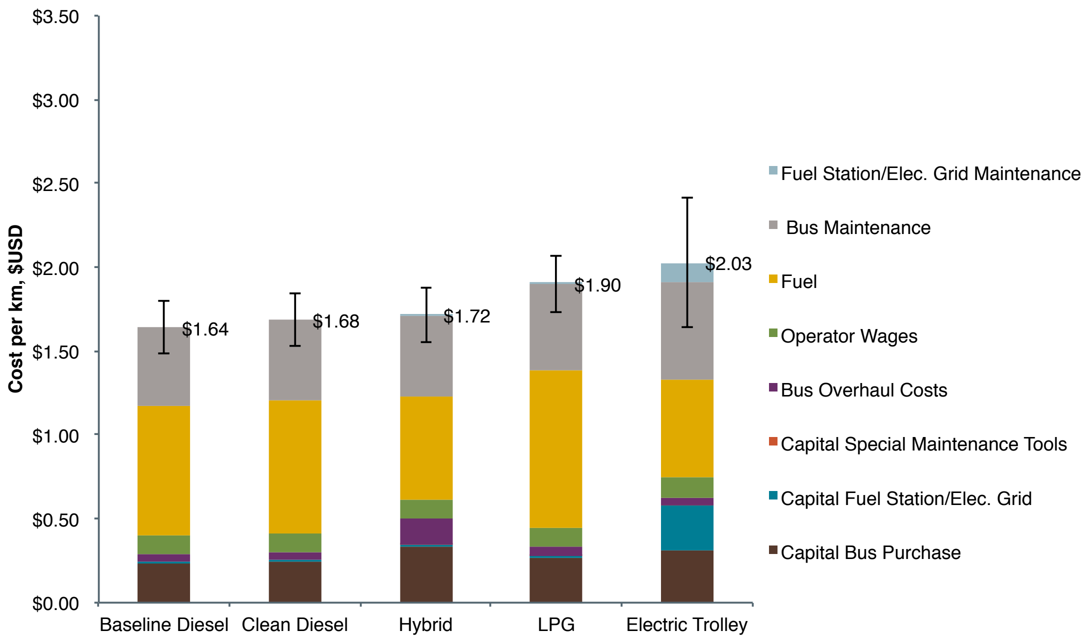

Figure 1. Nairobi cost of ownership in $USD per km. Assumes 100 buses and 29 km of BRT corridor

Total annual cost, including capital and operating costs, are calculated by multiplying expected annual VKT (~50,000 km/year) by the number of BRT buses and the cost per kilometer. Differences with respect to the standard diesel option, Diesel Euro III, are presented below.

The benefits from trolley implementation during Phase II arise from energy cost reductions due to electricity use, which is very competitive compared to diesel prices in Nairobi. In addition, increased number of trolley buses reduces the impact of high capital costs for trolley implementation. LPG costs are higher than diesel due to the LPG bus lower fuel economy and similar price per liter between fuels.

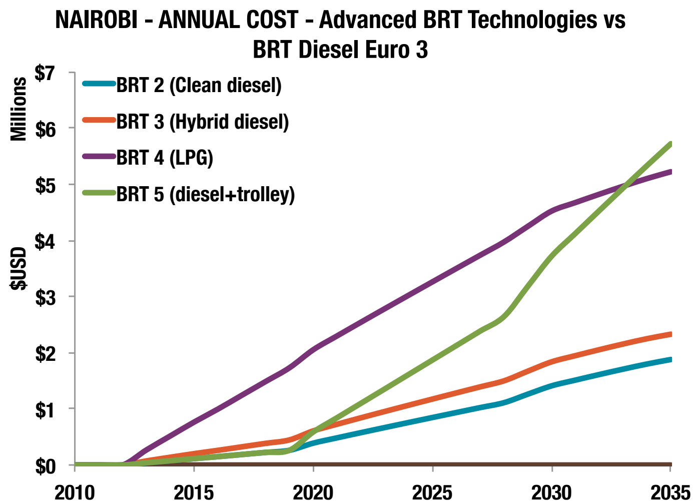

Figure 2. Incremental annual cost compared to diesel BRT (Euro III)

City-wide emissions reductions for Nairobi

Emissions and fuel use from on-road transport modes under the baseline ("no BRT") and the various identified BRT technology scenarios were modeled using the modified ICCT Country Emission Model. As mentioned previously, little input data were available for several key parameters, most importantly future BRT system size and operation. Therefore, the results presented here should be considered preliminary results highlighting the important distinctions between the different bus technology options, though the specific magnitude of some results may change as more input data are identified.

Emission model inputs

Key data inputs and sources for Nairobi are summarized in the following tabled.

Table 4. Summary of inputs to emission model

Parameter	Value(s)	Source
Passenger cars (2010 stock)	491,000	(1)
Passenger cars (2010 VKT, km)	8,133	(1)
Passenger cars (load factor)	1.8	(4)
Taxis (2010 stock)	2,000	(2)
Taxis (2010 VKT, km)	50,000	(4)
Taxis (load factor)	1.5	(4)
Minibuses (2010 stock)	23,000	(1)
Minibuses (2010 VKT, km)	18,000	(1)
Minibuses (load factor)	7	(4)
Light-duty trucks (2010 stock)	30,000	(2)
Light-duty trucks (2010 VKT, km)	30,000	(3)
Urban buses (non-BRT) (2010 stock)	790	(1)
Urban buses (non-BRT) (2010 VKT, km)	15,000	(1)
Urban buses (non-BRT) (2010 load factor)	75	(4)
Heavy-duty trucks (2010 stock)	10,000	(2)
Heavy-duty trucks (2010 VKT, km)	60,000	(3)
Motorcycles (2010 stock)	8,000	(2)
Motorcycles (2010 VKT, km)	7,000	(3)
Motorcycles (load factor)	1	(4)
BRT system assumptions		
Number of BRT buses, 2030	263	(5)
VKT of BRT buses, km	50,000	(4)
Load factor of BRT buses	75	(4)
Modes from which BRT buses pull	Minibuses (100%)	(4)

(1) *UITP, UATP, TransAfrica, 2010. Report on Statistical Indicators of Public Transport Performance in Africa*.
(2) Estimated based on data from Nairobi on fractions of vehicle operating on the road, as documented in *ISSRC, 2002. Nairobi, Kenya Vehicle Activity Study.*
(3) Estimated based on comparable numbers for China, from *Huo, H., et al., 2012. Vehicle-use intensity in China: Current status and future trend. Energy Policy, Volume 43, April 2012, Pages 6–16*.
(4) ICCT assumption.
(5) ICCT estimate based on combination of total urban passenger-km demand in 2030 and modal shift assumption.

Table 5: Typical fuel economy values for bus technologies considered

Bus type	Baseline Diesel, km/L	Clean Diesel, km/L	Hybrid Diesel, km/L	LPG, km/LDE	Electric Bus –Trolley, km/kW-h	Electric Bus –Trolley, km/LDE
12 m Bus	1.6	1.6	2.0	1.4	0.27	2.7
Articulated Bus	1.1	1.1	1.4	1.0	0.19	1.9

LDE: Liter of diesel equivalent.

No BRT vs. BRT modal share

The BRT system in Nairobi, when fully implemented in 2030, was assumed to pull completely from minibuses passenger-km. This change is highlighted in the graphs below. The modal share shift assumptions made by the ICCT are important parameters that will need to be updated as more data about the future planned BRT system become available.

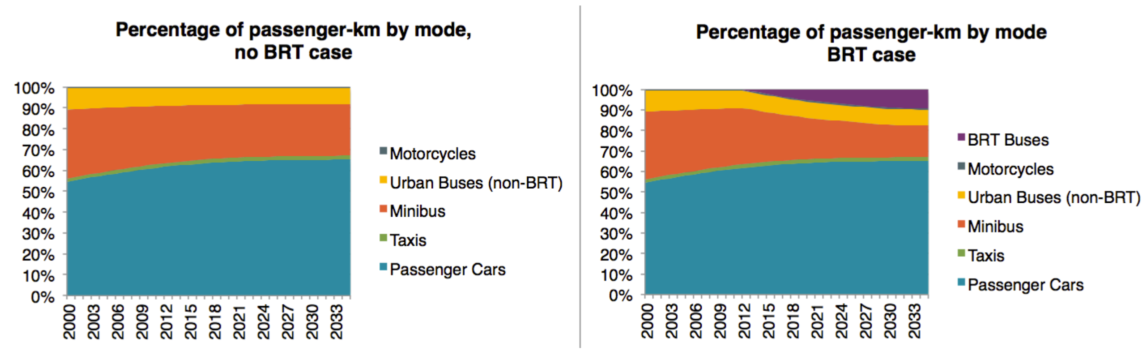

Figure 3. Modal share under no-BRT and BRT scenarios

Under the current modal shift assumption, the BRT system will result in considerably reduced minibus demand. The analysis suggests that over 11,000 minibuses will be no longer necessary in Nairobi due to the BRT system.

Fuel consumption and emissions differences

The shifting of passenger-km from minibuses to BRT buses results in considerable fuel savings and emissions reductions. The graphs below present the reductions in fuel consumption and emissions of particulate matter ($PM_{2.5}$) and oxides of nitrogen (NOx) between the no BRT and BRT scenarios.

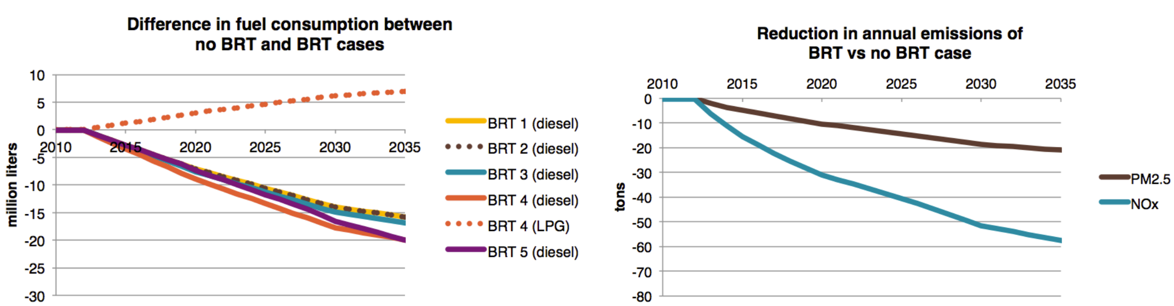

Figure 4. Reduction in fuel use and pollutant emissions compared to no-BRT scenario (emissions compare no- BRT to BRT1)

The following figures feature the differences between the all the BRT scenarios and the no-BRT scenarios.

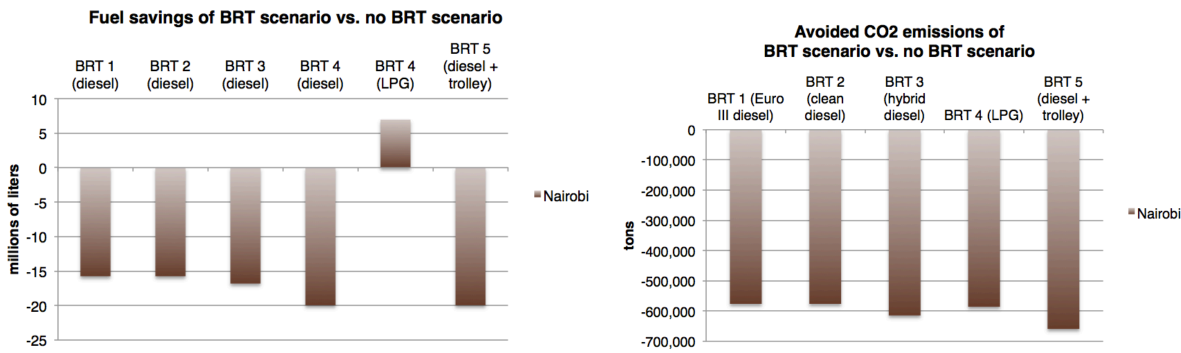

Figure 5. Fuel savings and CO_2 reduction by technology compared to no BRT

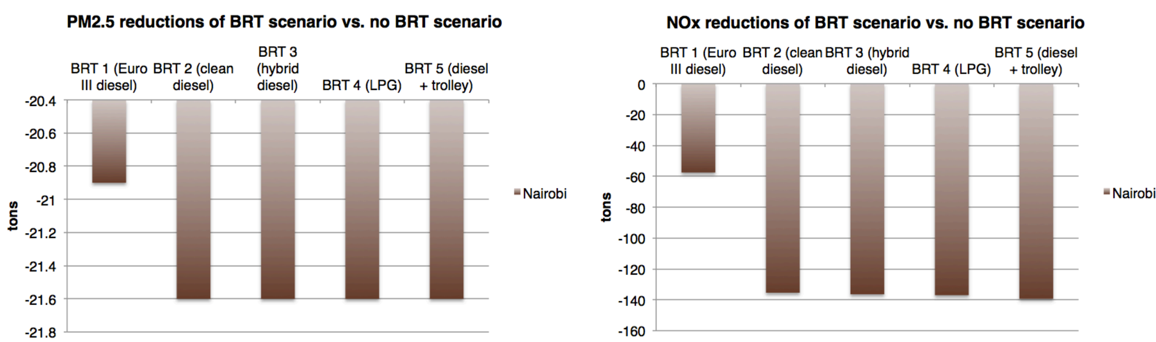

Figure 6. Pollutant emission reduction by technology compared to no BRT

Annual $PM_{2.5}$ emissions reductions from different BRT bus technologies are especially dramatic. Exposure to $PM_{2.5}$ is associated with a host of health impact including premature death. Note that all of the advanced technologies result in significant emissions savings as compared with the baseline Euro III diesel technology as shown in Figure 7 below.

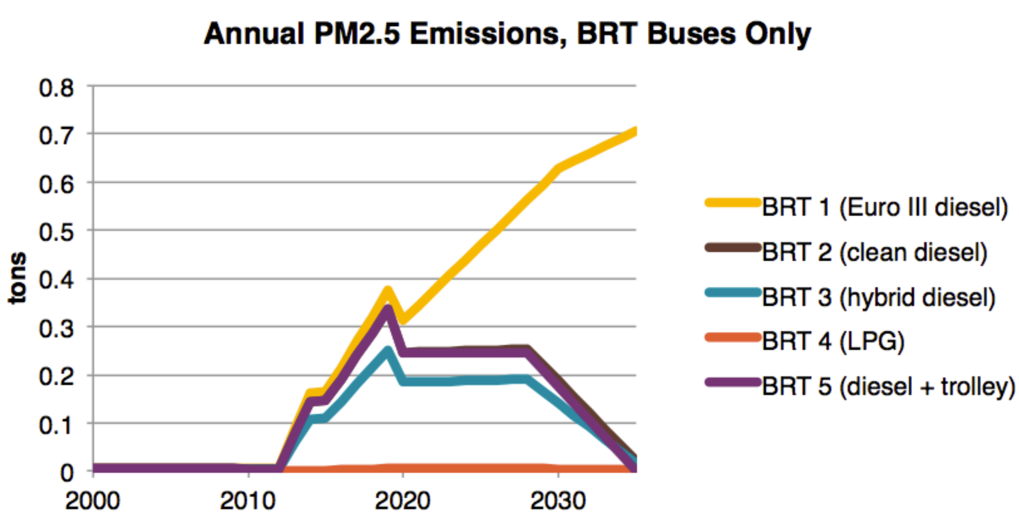

Figure 7. Comparative annual emission by technology

Health benefits for Nairobi

The health benefits from the BRT scenarios stem from reductions in exposure to harmful pollutants. For this study, the focus is on reduction of exposure to $PM_{2.5}$, which is translated into a reduced incidence of premature mortality. The reduction in mortality is assigned a value given by the Value of Statistical Life (VSL) based on willingness to pay studies. In this case, the ICCT applied the same methodology as was used by ICF in their recent assessment of the cost and benefits of lower sulfur fuels in Sub-Saharan Africa[3]. Figure 8 and 9 illustrate the health benefits over time.

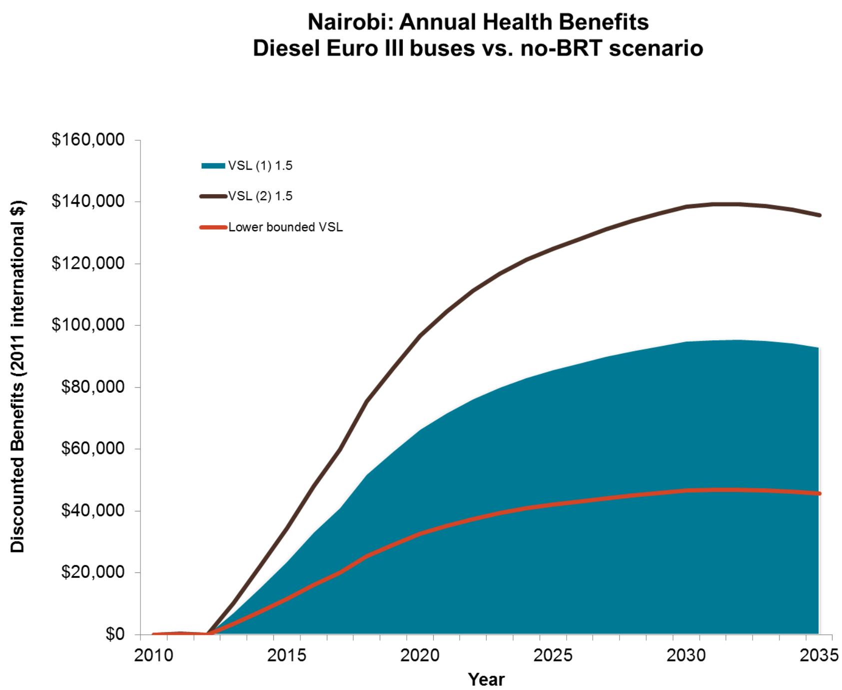

Figure 8. Health benefits of diesel BRT (Euro III) compared to no-BRT

[3] ICF International. 2009. Final Report: Sub-Saharan Africa Fuel Refinery Project. World Bank and Africa Refiners Association.

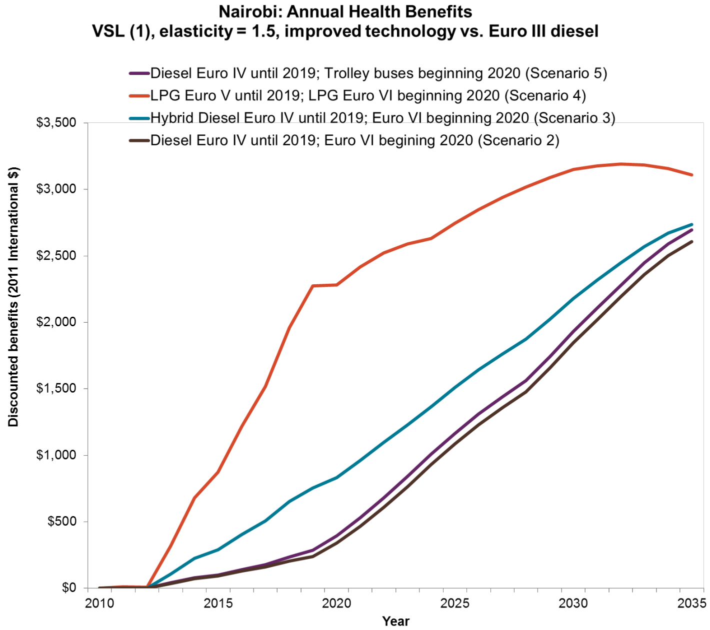

Figure 9. Health benefits of clean technologies compared to diesel BRT (Euro III)

Time saving benefits for Nairobi

The benefits of reduced congestion were estimating by assigning the value of the prevailing wage ($0.84/hour) to the estimated travel time saved. Absent data specific to the Nairobi BRT system, traffic speeds from the Chinese city of Guangzhou with and without BRT were used to approximate travel time savings in Nairobi. The average traffic speed without BRT are based on estimates for Kampala (10 km/hour). It is important to note that the time saving benefits are technology independent so they apply equally to all the BRT scenarios considered.

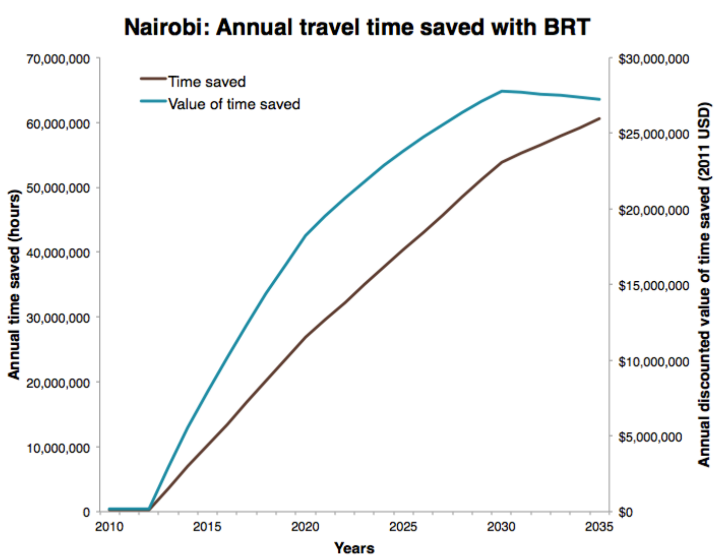

Figure 10. Time saving benefits over time

Costs and benefits in 2035 for Nairobi

The following table summarizes the technology costs and health, fuel, and time savings benefits assessed for the four technology scenarios considered for Nairobi. The quantifiable benefits from a BRT system are substantial and in line with the estimate annual costs of purchasing and maintaining a bus fleet. When considering the benefits that are beyond the scope of this project (i.e. occupational exposure, fuel foreign exchange fees, mobility, access), it is clearly a valuable mass transit investment. Incorporating clean technology alternatives provides additional health and fuel savings benefits at a relatively modest incremental cost. Ultimately the choice of technology for the Nairobi BRT should be based on more refined and project-specific input data. Ongoing projects to compile and maintain a basic transportation information database (i.e. fleet size, vkt, modal shares) will be valuable resources for similar future efforts.

Table 6. Summary of cost and benefits of technology scenarios in 2035

Scenarios	Annual technology cost	Annual health benefits	Annual fuel savings benefit	Annual time savings benefit
BRT 1: Diesel BRT	$23	$0.09 to $0.95	$18	$27
BRT 2: Clean diesel BRT	$25	$0.10 to $0.98	$18	$27
BRT 3: Hybrid diesel BRT	$26	$0.10 to $0.98	$19	$27
BRT 4: LPG BRT	$29	$0.10 to $0.98	$15	$27
BRT 5: Diesel + Electric trolley BRT	$29	$0.10 to $0.98	$23	$27

About ICCT

The International Council on Clean Transportation is an independent non- profit organization founded to provide first-rate objective research and technical and scientific analysis to environmental regulators. Our mission is to improve the environmental performance and energy efficiency of road, marine, and air transportation, in order to benefit public health and mitigate climate change.

Cost and benefits of clean technologies for bus rapid transit (BRT)

Summary of results for Kampala

December, 2012

Key findings

- Based on preliminary assumptions about the future BRT system, the ICCT's modeling of city-wide pollutant emissions, fuel consumption, health impacts, and time saved suggest that a BRT system in Kampala will result in considerable overall benefits in the range of $80 to $86 million per year in 2035. Costs for vehicles and infrastructure range $21 to 26 million per year[1].
- Bus technology feasibility analysis identified multiple potential technologies for consideration in Kampala's BRT system: diesel, and hybrid diesel-electric for Phase I (2013-2020); and clean diesel (with exhaust after-treatment devices), hybrid diesel-electric, and electric trolley buses for Phase II (2020-2030).
- Among the BRT bus technologies, the analysis revealed that the selection of any of the advanced technology choices – including the cleanest diesel conventional and hybrid-electric buses and trolley electric buses – will result in significant emissions reductions at modest additional cost over a Euro III diesel baseline bus. Several of these advanced technology choices result in significant fuel use and CO_2 emissions reductions (in the range of 750 to 850,000 cumulative tons by 2035)
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Based on the rankings in Kampala and the two other cities, a set of 5 technology scenarios were developed combining Phase I and Phase II technologies. Scenarios 1,2,3, and 5 were all analyzed for Kampala.

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BRT 5: Diesel + Electric trolley BRT	Diesel Euro IV	Electric Trolley

Cost of ownership for Kampala

Cost model inputs

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Electricity price per kWh	487 UGX/kWh~0.20 $USD/kWh	(5)

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(4) ICCT data
(5) Local commercial tariff

Cost results

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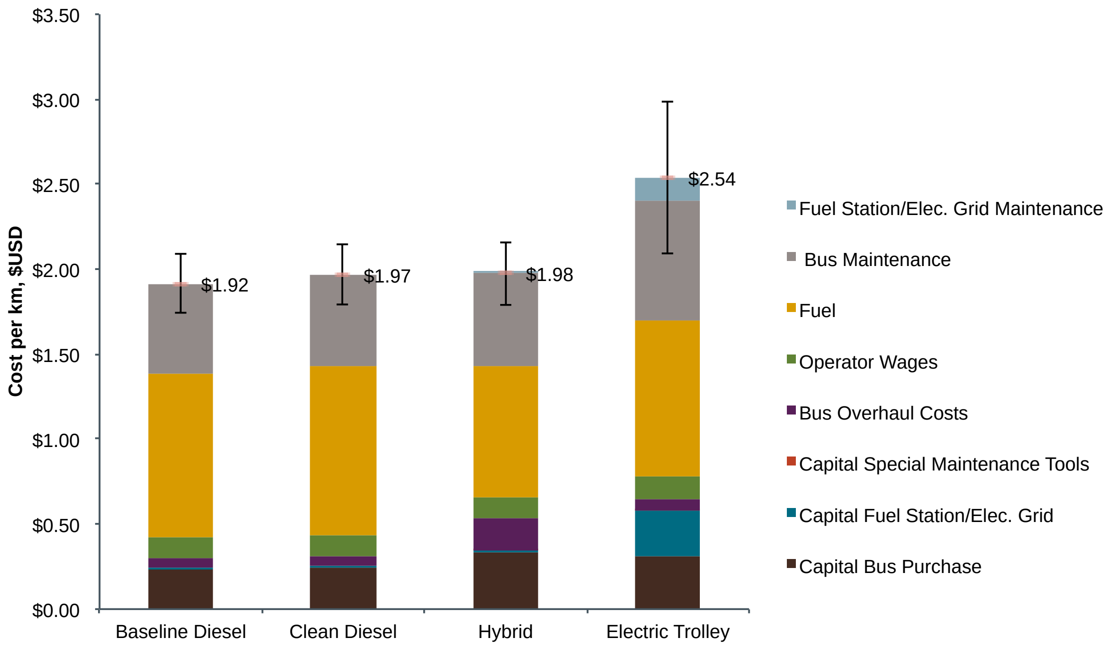

Figure 1. Kampala cost of ownership in $USD per km. Assumes 100 buses and 29 km of BRT corridor

Total annual cost, including capital and operating costs, are calculated by multiplying expected annual VKT (~50,000 km/year) by the number of BRT buses and the cost per kilometer. Differences with respect to the standard diesel option, Diesel Euro III, are presented below.

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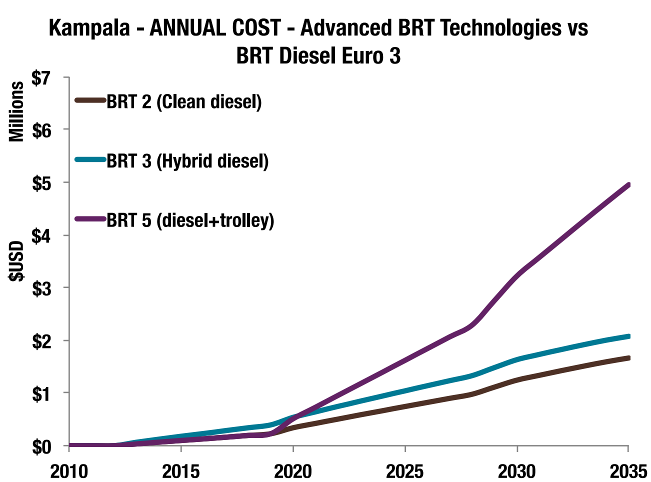

Figure 2. Incremental annual cost compared to diesel BRT (Euro III)

City-wide emissions reductions for Kampala

Emissions and fuel use from on-road transport modes under the baseline ("no BRT") and the various identified BRT technology scenarios were modeled using the modified ICCT Country Emission Model. As mentioned previously, little input data were available for several key parameters, most importantly future BRT system size and operation. Therefore, the results presented here should be considered preliminary results highlighting the important distinctions between the different bus technology options, though the specific magnitude of some results may change as more input data are identified.

Emission model inputs

Key data inputs and sources for Kampala are summarized in the following table.

Table 4. Summary of inputs to emission model

Parameter	Value(s)	Source
Passenger cars (2010 stock)	42,000	(1)
Passenger cars (2010 VKT, km)	16,745	(1)
Passenger cars (load factor)	1.8	(4)
Taxis (2010 stock)	170	(2)
Taxis (2010 VKT, km)	50,000	(4)
Taxis (load factor)	1.5	(4)
Minibuses (2010 stock)	8,000	(1)
Minibuses (2010 VKT, km)	40,000	(1)
Minibuses (load factor)	7	(4)
Light-duty trucks (2010 stock)	2,500	(2)
Light-duty trucks (2010 VKT, km)	30,000	(3)
Urban buses (non-BRT) (2010 stock)	43	(1)
Urban buses (non-BRT) (2010 VKT, km)	100,000	(1)
Urban buses (non-BRT) (2010 load factor)	75	(4)
Heavy-duty trucks (2010 stock)	800	(2)
Heavy-duty trucks (2010 VKT, km)	60,000	(3)
Motorcycles (2010 stock)	700	(2)
Motorcycles (2010 VKT, km)	7,000	(3)
Motorcycles (load factor)	1	(4)
BRT system assumptions		
Number of BRT buses, 2030	228	(5)
VKT of BRT buses, km	50,000	(4)
Load factor of BRT buses	75	(4)
Modes from which BRT buses pull	Minibuses (100%)	(4)

(1) *UITP, UATP, TransAfrica, 2010. Report on Statistical Indicators of Public Transport Performance in Africa*.
(2) Estimated based on data from Nairobi on fractions of vehicle operating on the road, as documented in *ISSRC, 2002. Nairobi, Kenya Vehicle Activity Study.*
(3) Estimated based on comparable numbers for China, from *Huo, H., et al., 2012. Vehicle-use intensity in China: Current status and future trend. Energy Policy, Volume 43, April 2012, Pages 6–16*.
(4) ICCT assumption.
(5) ICCT estimate based on combination of total urban passenger-km demand in 2030 and modal shift assumption.

Table 5: Typical fuel economy values for bus technologies considered

Bus type	Baseline Diesel, km/L	Clean Diesel, km/L	Hybrid Diesel, km/L	LPG, km/LDE	Electric Bus –Trolley, km/kW-h	Electric Bus –Trolley, km/LDE
12 m Bus	1.6	1.6	2.0	1.4	0.27	2.7
Articulated Bus	1.1	1.1	1.4	1.0	0.19	1.9

LDE: Liter of diesel equivalent.

No BRT vs. BRT modal share

The BRT system in Kampala, when fully implemented in 2030, was assumed to pull completely from minibuses passenger-km. This change is highlighted in the graphs below. The modal share shift assumptions made by the ICCT are important parameters that will need to be updated as more data about the future planned BRT system become available. In the Kampala case, the large estimated size of the BRT system as compared to the baseline vehicle population results in larger modal shift from to the BRT system than the other two cities evaluated.

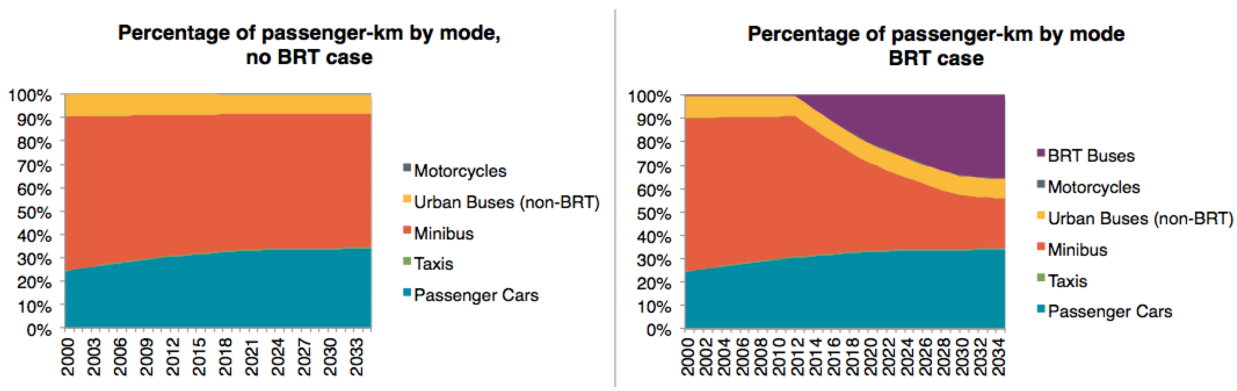

Figure 3. Modal share under no-BRT and BRT scenarios

Under the current modal shift assumption, the BRT system will result in considerably reduced minibus demand. The analysis suggests that over 6,500 minibuses will be no longer necessary in Kampala due to the BRT system.

Fuel consumption and emissions differences

The shifting of passenger-km from minibuses to BRT buses results in considerable fuel savings and emissions reductions. The graphs below present the reductions in fuel consumption and emissions of particulate matter ($PM_{2.5}$) and oxides of nitrogen (NOx) between the no BRT and BRT scenarios.

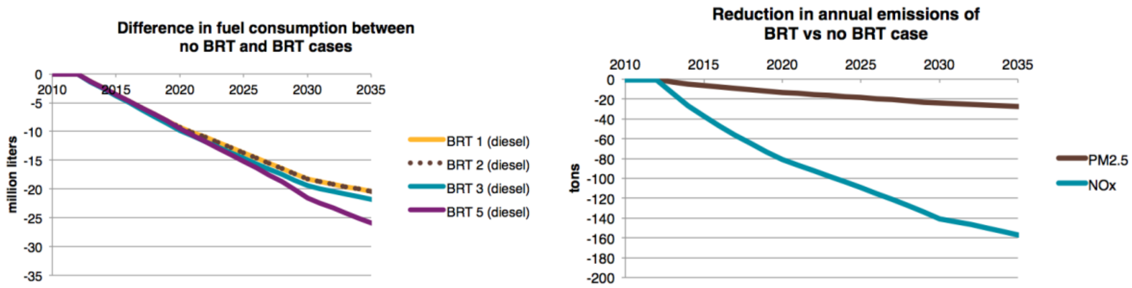

Figure 4. Reduction in fuel use and pollutant emissions compared to no-BRT scenario (emissions compare no- BRT to BRT1)

The following figures feature the differences between the all the BRT scenarios and the no-BRT scenarios.

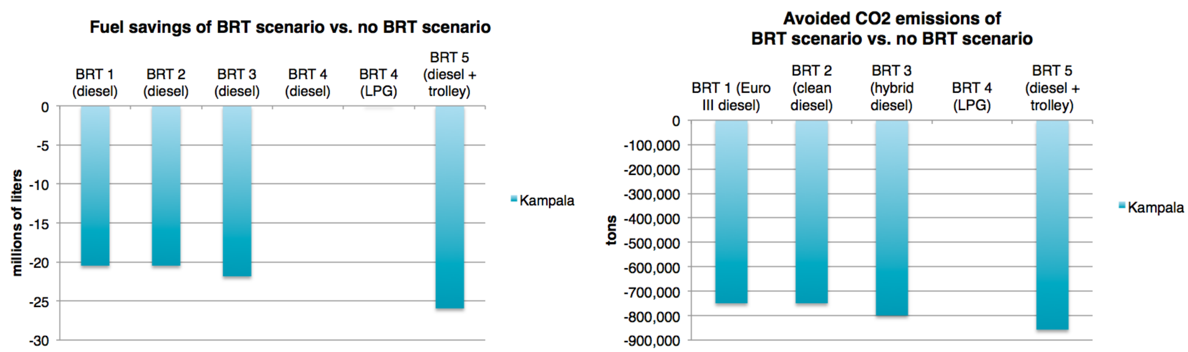

Figure 5. Fuel savings and CO_2 reduction by technology compared to no BRT

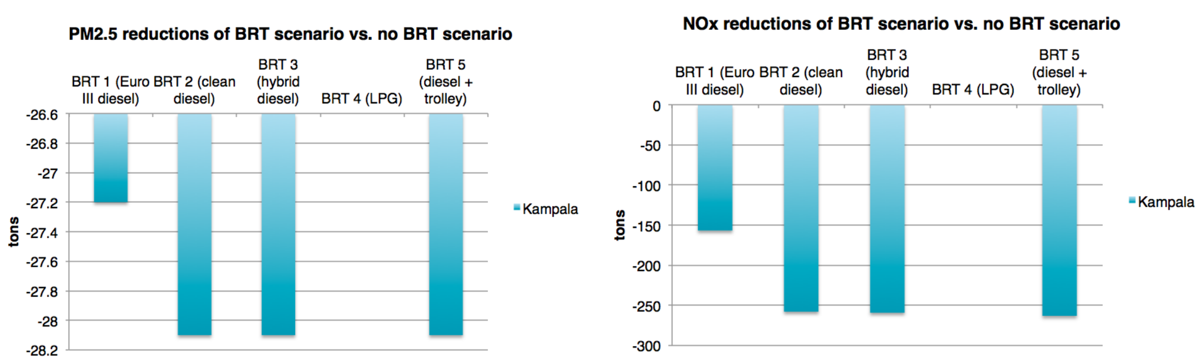

Figure 6. Pollutant emission reduction by technology compared to no BRT

Annual $PM_{2.5}$ emissions reductions from different BRT bus technologies are especially dramatic. Exposure to $PM_{2.5}$ is associated with a host of health impact including premature death. Note that all of the advanced technologies result in significant emissions savings as compared with the baseline Euro III diesel technology as shown in Figure 7 below.

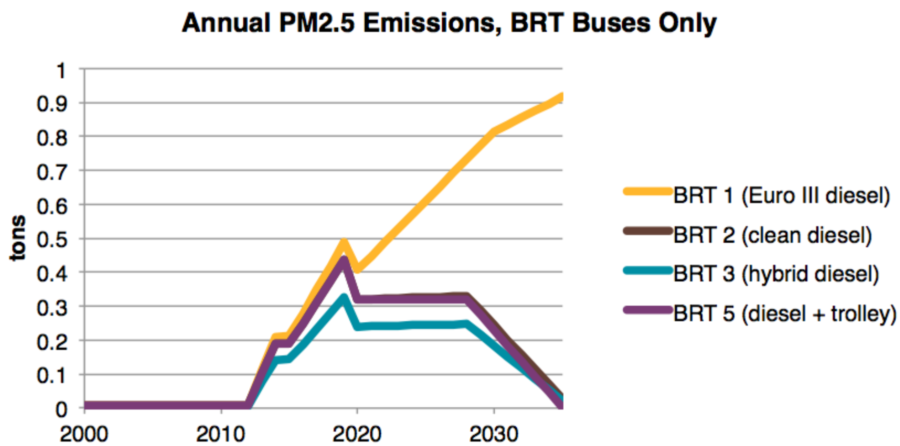

Figure 7. Comparative annual emission by technology

Health benefits for Kampala

The health benefits from the BRT scenarios stem from reductions in exposure to harmful pollutants. For this study, the focus is on reduction of exposure to $PM_{2.5}$, which is translated into a reduced incidence of premature mortality. The reduction in mortality is assigned a value given by the Value of Statistical Life (VSL) based on willingness to pay studies. In this case, the ICCT applied the same methodology as was used by ICF in their recent assessment of the cost and benefits of lower sulfur fuels in Sub-Saharan Africa[3]. Figure 8 and 9 illustrate the health benefits over time.

[3] ICF International. 2009. Final Report: Sub-Saharan Africa Fuel Refinery Project. World Bank and Africa Refiners Association.

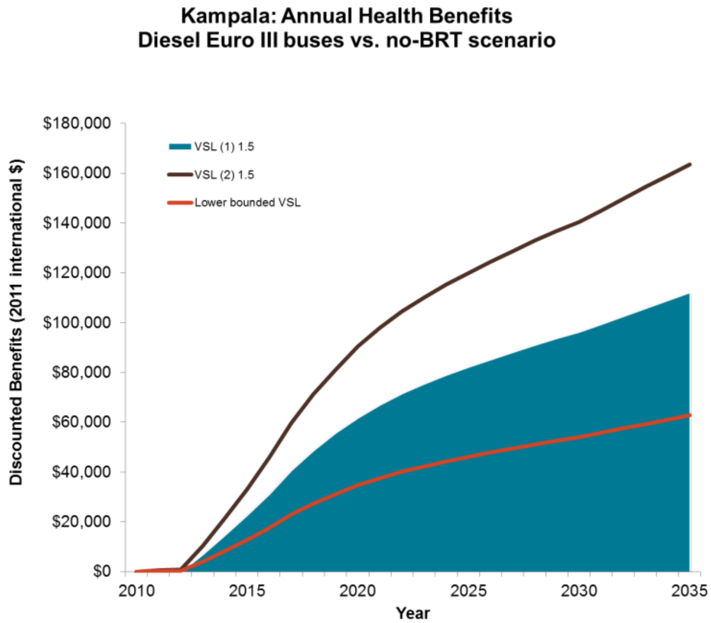

Figure 8. Health benefits of diesel BRT (Euro III) compared to no-BRT

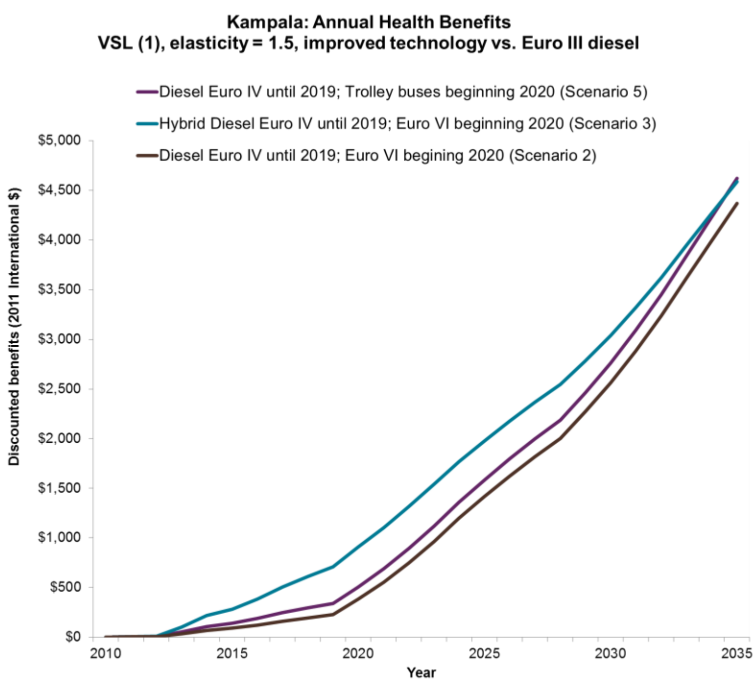

Figure 9. Health benefits of clean technologies compared to diesel BRT (Euro III)

Time saving benefits for Kampala

The benefits of reduced congestion were estimating by assigning the value of the prevailing wage ($0.64/hour) to the estimated travel time saved. Absent data specific to the Kampala BRT system, traffic speeds from the Chinese city of Guangzhou with and without BRT were used to approximate travel time savings in Kampala. The average traffic speed without BRT are based on estimates for Kampala (10 km/hour). It is important to note that the time saving benefits are technology independent so they apply equally to all the BRT scenarios considered.

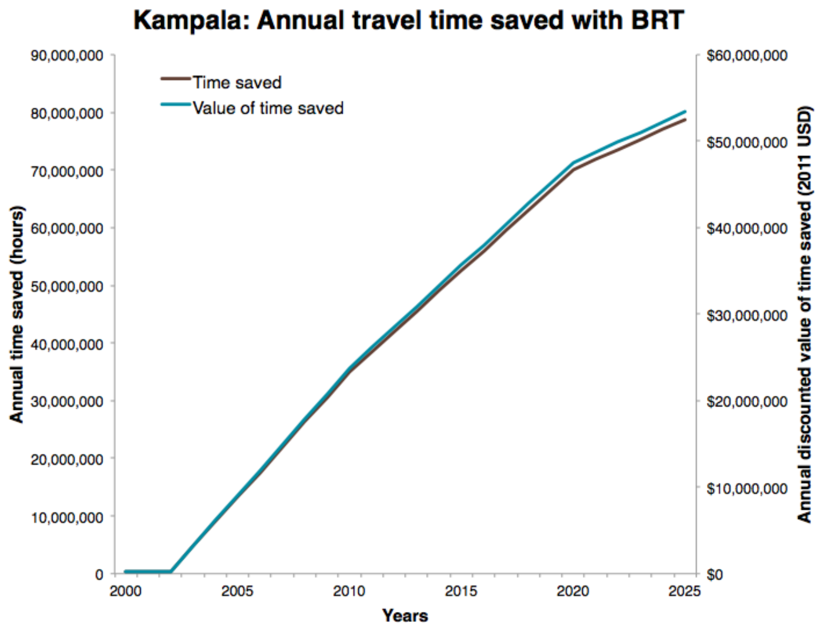

Figure 10. Time saving benefits over time

Costs and benefits in 2035 for Kampala

The following table summarizes the technology costs and health, fuel, and time savings benefits assessed for the four technology scenarios considered for Kampala. The quantifiable benefits from a BRT system are substantial and in line with the estimate annual costs of purchasing and maintaining a bus fleet. When considering the benefits that are beyond the scope of this project (i.e. occupational exposure, fuel foreign exchange fees, mobility, access), it is clearly a valuable mass transit investment. Incorporating clean technology alternatives provides additional health and fuel savings benefits at a relatively modest incremental cost. Ultimately the choice of technology for the Kampala BRT should be based on more refined and project-specific input data. Ongoing projects to compile and maintain a basic transportation information database (i.e. fleet size, vkt, modal shares) will be valuable resources for similar future efforts.

Table 6. Summary of cost and benefits of technology scenarios in 2035

Scenarios	Annual technology cost	Annual health benefits	Annual fuel savings benefit	Annual time savings benefit
BRT 1: Diesel BRT	$21	$0.11 to $2.1	$25	$53
BRT 2: Clean diesel BRT	$23	$0.12 to $2.2	$25	$53
BRT 3: Hybrid diesel BRT	$23	$0.12 to $2.2	$27	$53
BRT 4: LPG BRT	n/a	n/a	n/a	n/a
BRT 5: Diesel + Electric trolley BRT	$26	$0.12 to $2.2	$32	$53

About ICCT

The International Council on Clean Transportation is an independent non- profit organization founded to provide first-rate objective research and technical and scientific analysis to environmental regulators. Our mission is to improve the environmental performance and energy efficiency of road, marine, and air transportation, in order to benefit public health and mitigate climate change.

UN-HABITAT
FOR A BETTER URBAN FUTURE

Debashish Bhattacharjee
Human Settlements Officer - Lead, Urban Mobility
Urban Basic Services Branch
UN-HABITAT
PO Box 30030, Nairobi 00100, Kenya
Tel: (+254)-20 7625288
E-mail: debashish.bhattacharjee@unhabitat.org