Cost effectiveness of CO_2 reduction with hybrid and electric buses in developing countries

Summary

Hybrid and electric technologies are the future of urban surface transport. However, it is unclear whether the cost effectiveness of CO_2 reduction through the use of these technologies justifies its implementation in developing countries. Data from 2014 suggest that hybrid buses are close to reaching acceptable cost-effectiveness levels, but they require further reductions in battery prices to achieve these levels. With regard to electric buses, acceptable cost-effectiveness levels are still far away. We recognize the need to foster the use of these technologies in order to increase the cost-reducing learning curve. However, in fiscally constrained developing countries with mainly private operations and no relevant national bus-manufacturing industry, we recommend that these countries (a) conduct a thorough analysis before these technologies are adopted, and (b) consider focusing on system sustainability or more cost-efficient measures to boost CO_2 emission reductions.

Methodology and assumptions on emission-reduction calculation

We use the method for calculating greenhouse gas (GHG) emissions for subprojects in the "Urban Transport Transformation Project" (Scorcia 2011). The model includes the calculation of four variables: (A) a dynamic baseline of the emissions generated by public transport in the intervention corridor, without project; (B) the estimated emissions generated by public transport in the corridor, with project; (C) the estimated avoided emissions linked to passengers who shift from cars to the new system, with project; and (D) the estimated emissions of the old fleet that continues operating after the project is implemented. Total GHG emissions reduced by the project correspond to: A + C - B - D. For a more detailed explanation of the method and additional resources, we recommend the economic analysis in the Implementation Completion Report on the P114012 GEF–STAQ Project (Perez-Prada 2016).

For purposes of comparing the potential CO_2 reductions of different measures, we have built on data in the feasibility study for the Ecovía BRT Corridor in Monterrey, Mexico. This is a 30-km feeder trunk corridor with 42 stops and an expected 130,000 daily passengers. The main assumptions we used in the model are:

- Old fleet daily vehicles-kilometers (veh-km): 175,893 veh-km.
- Old fleet emissions factor: 0.001521557 metric tonnes CO_2/km.[1]
- Traffic and public transport use–annual growth (with and without project): 1%.
- Number of days per year: 312.
- Private vehicle–average occupancy: 1.2.
- Average kms travelled by private vehicles, per year: 10,000.
- Number of trips per person in private vehicles, per day: 2.

Under these assumptions, we compare the potential CO_2 emissions in the corridor by achieving:

- A 10-percent modal shift from private cars to buses: Modal shift data—usually calculated with surveys of car-owner bus users—range from the 3 percent reported for the Metropolitano in Lima, Peru, or the actual 3.7 percent for the Ecovía in Monterrey, to the 10 percent reported by Metrobus in Mexico City. We have chosen 10 percent for two reasons. First, because it is achievable in the proper context and with ancillary investments (Wright and L. Fulton 2005). Second, because from a dynamic perspective, and taking into account motorization growth with income, it is realistic to assume that the new system will prevent current transport users from buying cars.

[1] This corresponds to a weighted average of 12-m diesel bus (70 percent), gasoline microbus (25 percent), and liquefied petroleum gas (LPG) microbus (5 percent) emission factors. The percentages reflect the fleet composition in Mexico. Emission factors per vehicle are from Mexico City (Metrobus 2010).

- 30-percent fleet rationalization: Although it is highly dependent on the context and efficiency of the system in the baseline scenario, there are examples in Mexico that justify this figure (e.g., Red Q in Querétaro).
- 30-percent reduction in emission factors: This corresponds to the average fuel-consumption reduction of hybrid technologies relative to equivalent diesel technologies (see References for data sources).

Methodology and assumptions on cost-effectiveness calculations

General Method. We have used a marginal abatement cost (MAC) approach to calculate the economic cost of reducing a tonne of CO_2e through the use of hybrid and electric bus technologies. The MAC is defined as the economic cost of reducing an additional tonne of pollutants: CO_2e in our case. First, we have calculated the difference between the net present value (NPV) of the total life-cycle cost of a hybrid bus and an electric 12-m bus, and that of an equivalent diesel bus. From the resulting value, we have subtracted the economic benefits of local pollutant emission reductions linked to hybrid and electric technologies: particulate matter (PM), nitrogen oxides (NOx) and carbon monoxide (CO). The resulting value is the economic cost of shifting from diesel to hybrid or electric, without taking into account CO_2 reductions. Finally, we have divided the economic cost of shifting from diesel to hybrid or electric by the associated total emission reductions associated with hybrid and electric technologies. The final result is the economic cost of reducing a tonne of CO_2e. We have compared a model we developed with a model developed by Grütter,[2] which uses the same methodology with very similar assumptions.

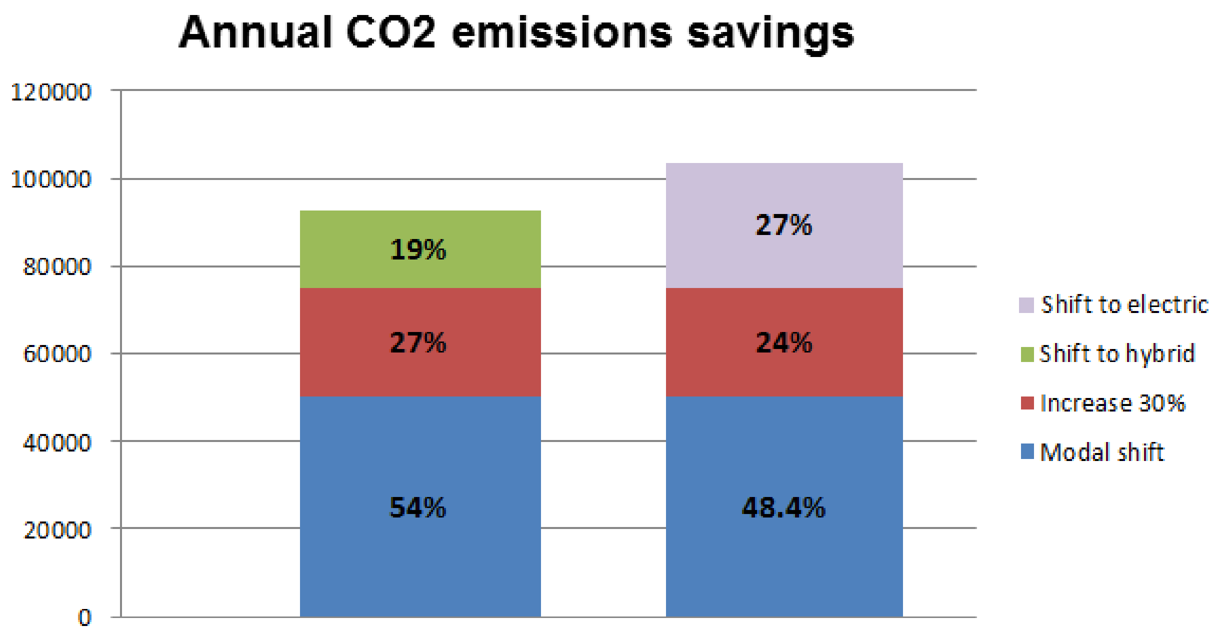
Assumptions. For purposes of the analysis, we have made the following assumptions:
- No marginal cost of public funds.
- No penalization on availability linked to electric batteries because of limited battery life.
- Diesel, electric and hybrid buses' operation and maintenance (O&M) costs are the same, except for fuel consumption.
- Lifespan of a bus: 10 years.
- Lifespan of a battery: 6 years.
- Diesel cost: US$1/liter.
- Km per year per vehicle: 75,000.
- Hybrid fuel efficiency relative to diesel equivalent: 31.29%.
- Market interest rate: 8 percent.
- Cost of a 12-m diesel bus: US$150,000.
- Premium[3] acquisition cost of hybrid bus relative to equivalent diesel bus: 60%.
- Premium acquisition cost of electric bus relative to equivalent diesel bus: 100%.
- Battery replacement cost for hybrid bus: 15% of vehicle's initial value.
- Battery replacement cost for electric bus: 50% percent of vehicle's initial value.
- Electricity consumption of electric bus: 1 kilowatt hour (kWh)/km.
- Emission factor of grid: 0.60 kg of CO_2e/kWh.
- Fuel consumption of 12-m diesel bus: 2 km/l.
- PM economic value: US$20,000 per tonne.
- NOx economic value: US$1,500 per tonne.
- CO economic value: US$500 per tonne.

Results

Modal shift has the greatest CO_2e emission reduction potential. The first result we obtained is that modal shift has greater potential to achieve CO_2e emission reductions. As shown in the image below, we estimate that achieving a 10-percent modal shift can triple the CO_2e reduction when compared to shifting to hybrid buses, and nearly double it when compared to electric buses.

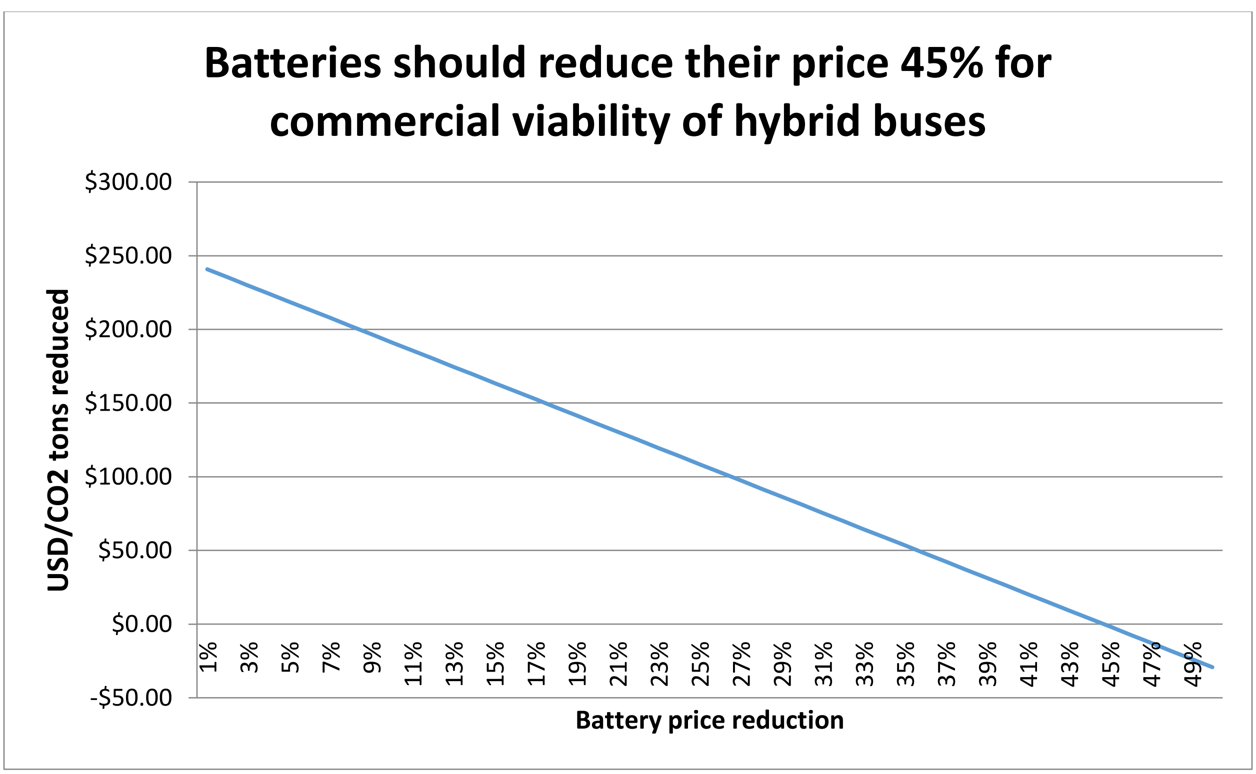
[2] (Grütter and Dang 2014)

[3] Although prices differ in various countries and regions, premiums for hybrid and electric buses are similar.

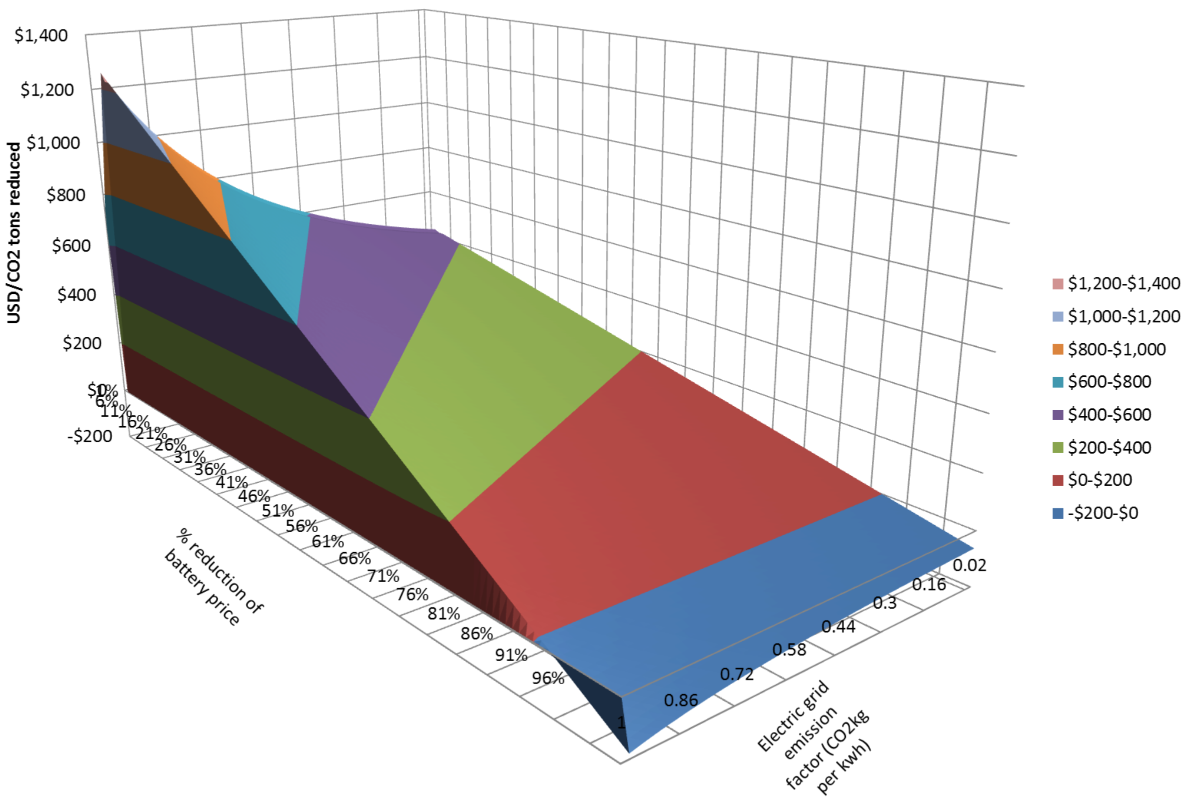


Reducing CO_2e by shifting to hybrid or electric technologies may not yet be cost efficient. Subsidizing hybrid buses results in costs of US$100 to US$250 per CO_2 ton. This same figure can reach US$750 for electric buses. Both are over the US$100 threshold of acceptable cost efficiency for GHG emission reductions.

Hybrid battery prices must decrease by 45 percent to achieve commercial viability. In the case of hybrid buses, our simulation estimates that battery prices should drop by 45 percent in order to achieve higher profitability than that of their diesel equivalents. There is a linear relationship between the cost of batteries and the cost-efficiency of hybrid vehicles. We estimate that for each percentage point to reduce the cost of batteries, reducing one ton of carbon will be approximately US$5 cheaper (see chart below).



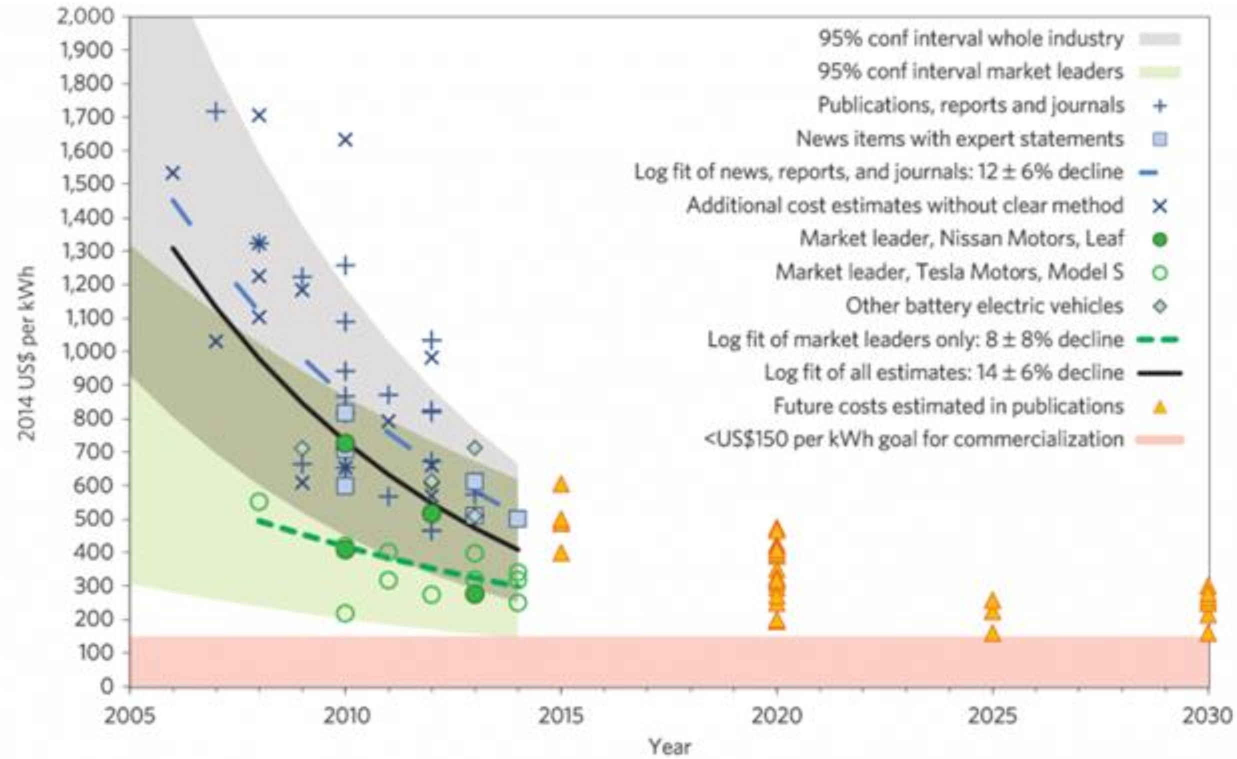
With regard to electric buses, viability would require a reduction of around 90 percent of the cost of batteries, while the effect of the energy matrix's efficiency on commercial viability is practically negligible. The analysis is slightly more complex because in the case of electric buses, in addition to the price of batteries, we must take into account the efficiency level of the country's or region's electricity production (the kilograms of carbon that electricity generators emit to produce 1 kWh of electricity, with which we charge the batteries). A standard order of magnitude for the emissions of an energy matrix in Mexico is 0.6 kg of CO_2e/kWh generated, while that of Spain is 0.3 kg of CO_2e/kWh. An electric bus consumes 1 kWh per km traveled, so that kilometer would be emitting 0.6 kg of CO_2 if it operated in Mexico and 0.3 kg of CO_2e in Spain. The relatively large reduction in the price of batteries to achieve commercial viability leads to the not-very-intuitive result that the effect of the energy matrix's efficiency on the cost of the buses is not very relevant. The figure below is a graphic example of this approach.



Political economy implications

For systems in developing countries with large fiscal constraints and private operations, the additional resources required to introduce hybrid and electric technologies can be much better utilized by supporting the systems' sustainability or more efficient complementary investments. In contexts such as private bus concessions in Latin America, many systems that operate with diesel buses have major liquidity problems which endanger these systems. In these cases, any available resources must be used to safeguard the systems' sustainability and, once this is achieved, be used in a way that presents the greatest cost efficiency for reducing emissions.

However, it is advisable to continue to support new technology production in order to increase the learning curve and maintain the downward trend in battery prices. Although we are still far from a 90-percent reduction in battery prices that will make electric buses viable, a 45-percent reduction is just around the corner. In the last 10 years, battery prices have collapsed, with reductions of up to 90 percent. Although the drop in prices has begun to slow down, the trend indicates that we are most likely to achieve reductions, such as those needed, between 2020 and 2025. Therefore, it may make sense to publicly support hybrid and electric technologies in regions with public operators. The existence of such operators makes it possible to reduce the transaction cost/inefficiency associated with the subsidy which, in this case, would constitute a higher cost to public operators.



From: Nature Climate Change (2015). Available at http://www.nature.com/nclimate/journal/v5/n4/pdf/nclimate2564.pdf.

The existence of a national industry and public operators are factors that can favor support to new technologies. A national bus-manufacturing industry can justify the subsidies to strategically increase the learning curve and position the national industry at the forefront of the production of technologies of the future. Moreover, the existence of public operators makes it possible to reduce the transaction cost/inefficiency associated with the subsidy which, in this case, would constitute a higher cost to public operators. According to the map below (presented by the WRI at the 2017 Transforming Transportation Conference), it seems that the market is already positioning itself in this way by concentrating the production of these technologies in the U.S., China and Europe where there are public operators and local bus-manufacturing industries.

Source: WRI presentation

Next steps

Due to fast-changing figures in terms of battery prices and the age of data, we plan to update this report in the following months with data from after 2014. We will also refine the emissions model by adapting the United Nations-approved emissions reduction estimation model for Metrobus Line 1 (Insurgentes Corridor) in Mexico City.

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