



# Energy use and CO<sub>2</sub> emissions of city buses in Curitiba, Brazil

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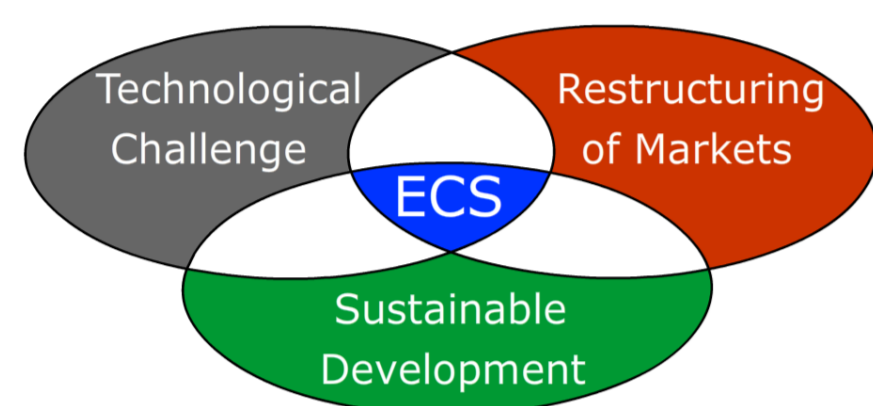
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- Bioenergy systems
- Energy access
- Energy systems efficiency
- Urban sustainability
- Energy and climate policy

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This research is part of a project aimed at sustainable technological solutions for the improvement of urban critical infrastructure in Curitiba, involving Swedish and Brazilian stakeholders.

IN COOPERATION WITH:



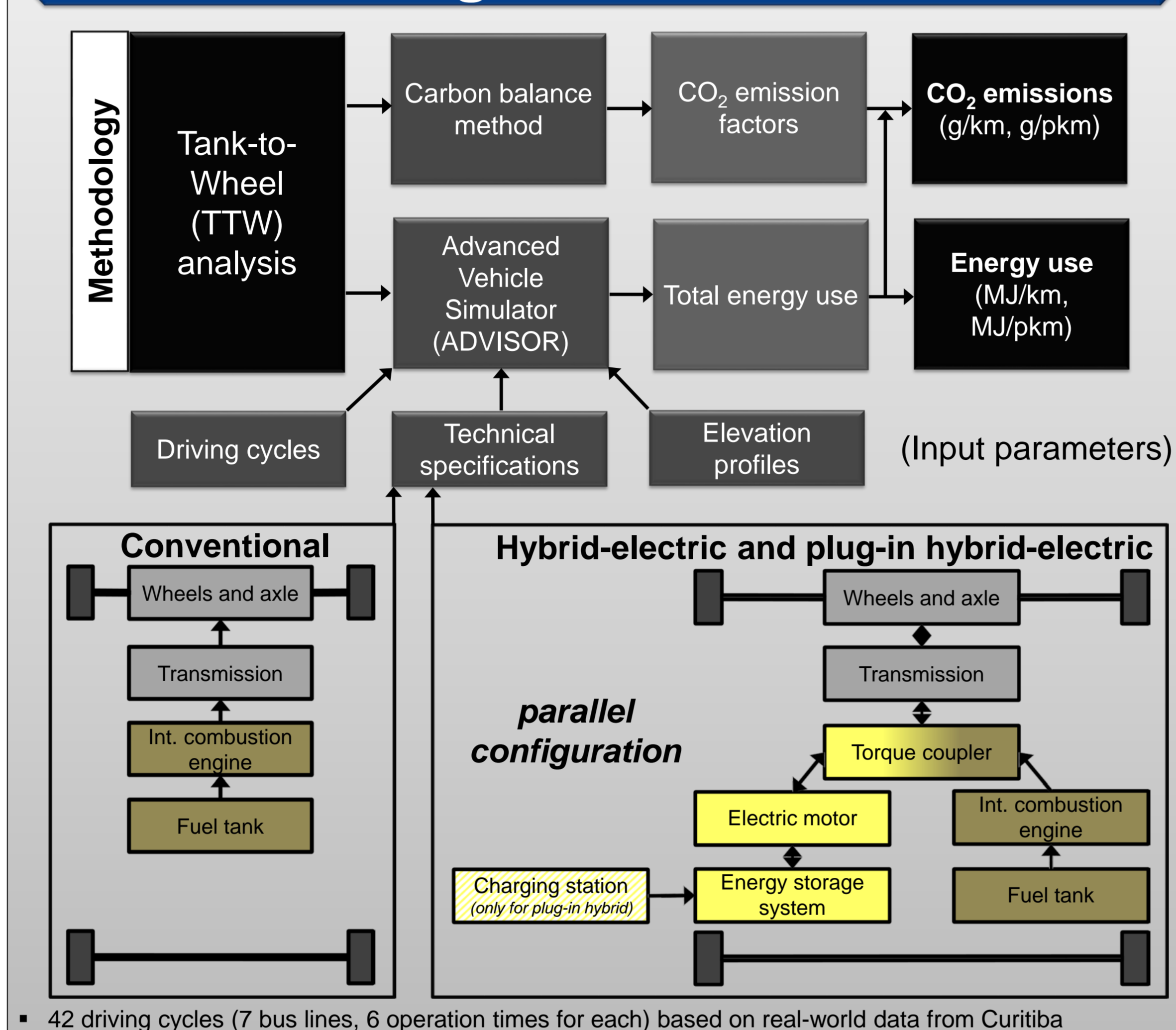
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## Curitiba's commitments

- Curitiba is member of the network C40 Cities Climate Leadership Group, committed to **reduce both greenhouse gas emissions and climate risks**
- C40 Clean Bus Declaration of Intent: Curitiba has committed to **reduce emissions from the transport sector** and to **improve air quality** through the **introduction of low or zero emission buses, e.g. city buses with advanced powertrains**

## Modelling and simulation



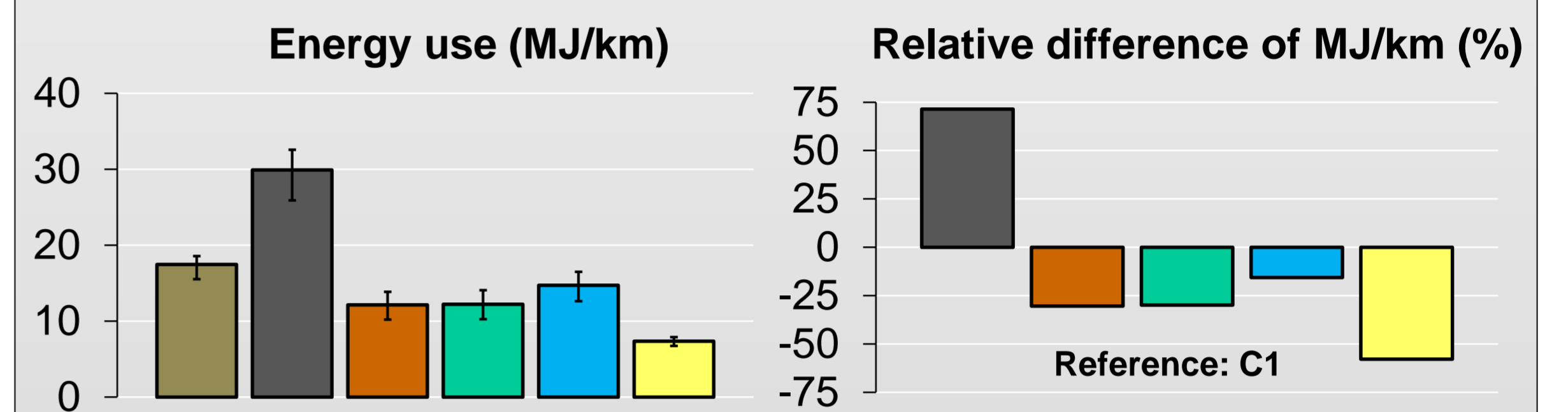
42 driving cycles (7 bus lines, 6 operation times for each) based on real-world data from Curitiba

## City buses

	City bus models	Powertrains	Chassis type	Passenger carrying Capacity	
Conventional powertrains		C1 Conventional	Two-axle	85	Operating today in Curitiba
		C2 Conventional	Bi-articulated	250	
Advanced powertrains		H1 Hybrid-electric (parallel)	Two-axle	79	Potential alternatives for Curitiba
		H2 Hybrid-electric (parallel)	Two-axle	95	
		H3 Hybrid-electric (parallel)	Articulated	154	
		P1 Plug-in hybrid-electric (parallel)	Two-axle	95	

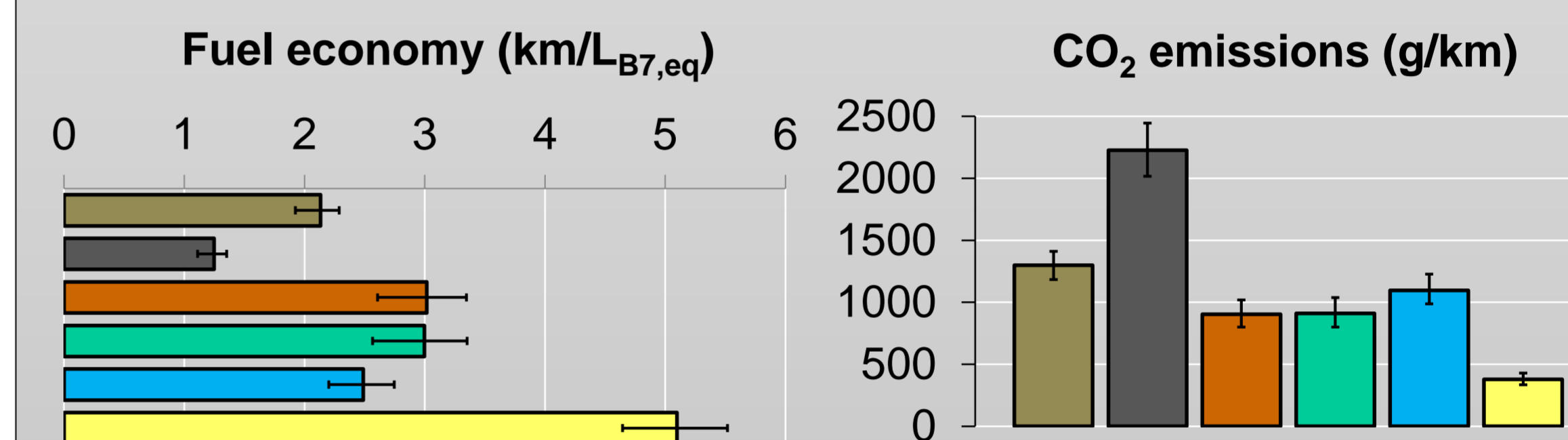
Picture sources of city buses: Urbanization Company of Curitiba (URBS) (<http://www.urbs.curitiba.pr.gov.br/>), Volvo Bus Corporation ([volvobuses.com](http://volvobuses.com)).

## How do advanced powertrains in city buses affect energy use and CO<sub>2</sub> emissions during operation in Curitiba?



- Advanced powertrains (hybrid-electric, plug-in hybrid-electric) can contribute to significant reduction of energy use<sup>a</sup> and CO<sub>2</sub> emissions of city buses

- H1, H2 and P1 consume 30%, 30% and 58% less energy (MJ/km) respectively, compared to C1 → enormous energy saving potentials



- H1, H2 and P1 drive 42%, 42% and 139% longer distances with the same amount of fuel<sup>b</sup> respectively, compared to C1 → high fuel efficiency

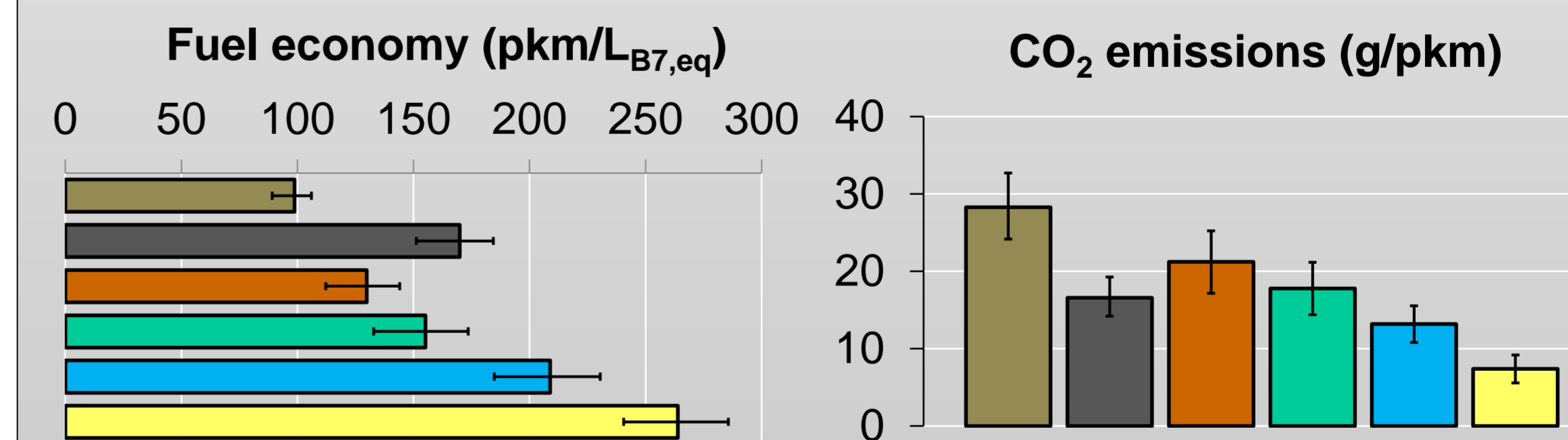
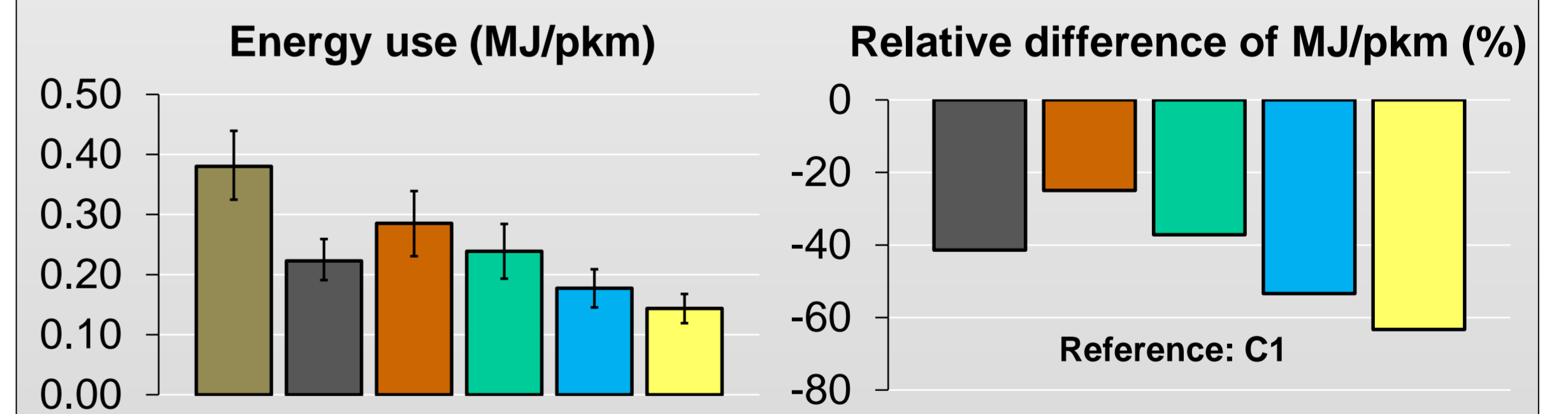
- CO<sub>2</sub> emissions (only from the tailpipe) are linearly proportional to energy use trends following from the applied carbon balance method

- Future work: Scaling up the analysis to city-wide public bus systems

<sup>a</sup> Ranges represent maximum and minimum estimations averaged over seven bus lines.

<sup>b</sup> Fuel properties of biodiesel blend (B7): Density: 0.856 kg/L; Lower heating value (LHV): 42.272 MJ/kg.

## How do passenger carrying capacities affect energy use and CO<sub>2</sub> emissions of city bus operation in Curitiba?



- Large passenger carrying capacities (articulated, bi-articulated chassis) can reduce energy use and CO<sub>2</sub> emissions per passenger-kilometre, however high occupancy rates are required during operation

- Large bus C2 uses less energy (MJ/pkm)<sup>c</sup> than H1 and H2

- Future work: Logistics and economic analysis related to introduction of hybrid-electric and plug-in hybrid-electric city buses in Curitiba

<sup>c</sup> Passenger-kilometre (pkm): Total travelled distance by all passengers when carried one kilometre.

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