Evaluating opportunities for soot-free, low-carbon bus fleets in Brazil: São Paulo case study

Tim Dallmann

International seminar

Electric mobility in public bus transport: Challenges, benefits, and opportunities

2018-05-09

Brasilia

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Presentation outline

- Soot-free, low-carbon public transport goals in São Paulo
- Evaluating the emissions benefits of alternative technology transit buses
- Procurement pathways to meet emissions reduction targets in São Paulo
- Evaluating the cost of technology transitions: Total cost of ownership assessment

Soot-free, low-carbon public transport goals in São Paulo

São Paulo has set ambitious goals to reduce pollutant emissions from its transit bus fleet

Diário Oficial
Cidade de São Paulo
João Doria - Prefeito

Ano 63 | São Paulo, quinta-feira, 18 de janeiro de 2018 | Número 12

LEI Nº 16.802, DE 17 DE JANEIRO DE 2018

(Projeto de Lei nº 300/17, dos Vereadores Milton Leite – DEMOCRATAS, Adilson Amadeu – PTB, Caio Miranda Carneiro – PSB, Conte Lopes – PP, João Jorge – PSDB, Natalini – PV, Ricardo Teixeira – PROS e Senival Moura – PT)

Dá nova redação ao art. 50 da Lei nº 14.933/2009, que dispõe sobre o uso de fontes motrizes de energia menos poluentes e menos geradoras de gases do efeito estufa na frota de transporte coletivo urbano do Município de São Paulo e dá outras providências.

JOÃO DORIA, Prefeito do Município de São Paulo, no uso das atribuições que lhe são conferidas por lei, faz saber que a Câmara Municipal, em sessão de 14 de dezembro de 2017, decretou e eu promulgo a seguinte lei:

Art. 1º O art. 50 da Lei nº 14.933, de 5 de junho de 2009, passa a vigorar com a seguinte redação:

"Art. 50. A partir da data de publicação desta lei, os operadores dos serviços de transporte coletivo por ônibus, integrantes do Sistema de Transporte Urbano de

Carbon dioxide (CO_2)

PARÂMETRO	AO FINAL DE 10 (DEZ) ANOS	AO FINAL DE 20 (VINTE) ANOS
CO_2 de origem fóssil	50%	100%

Air pollutants

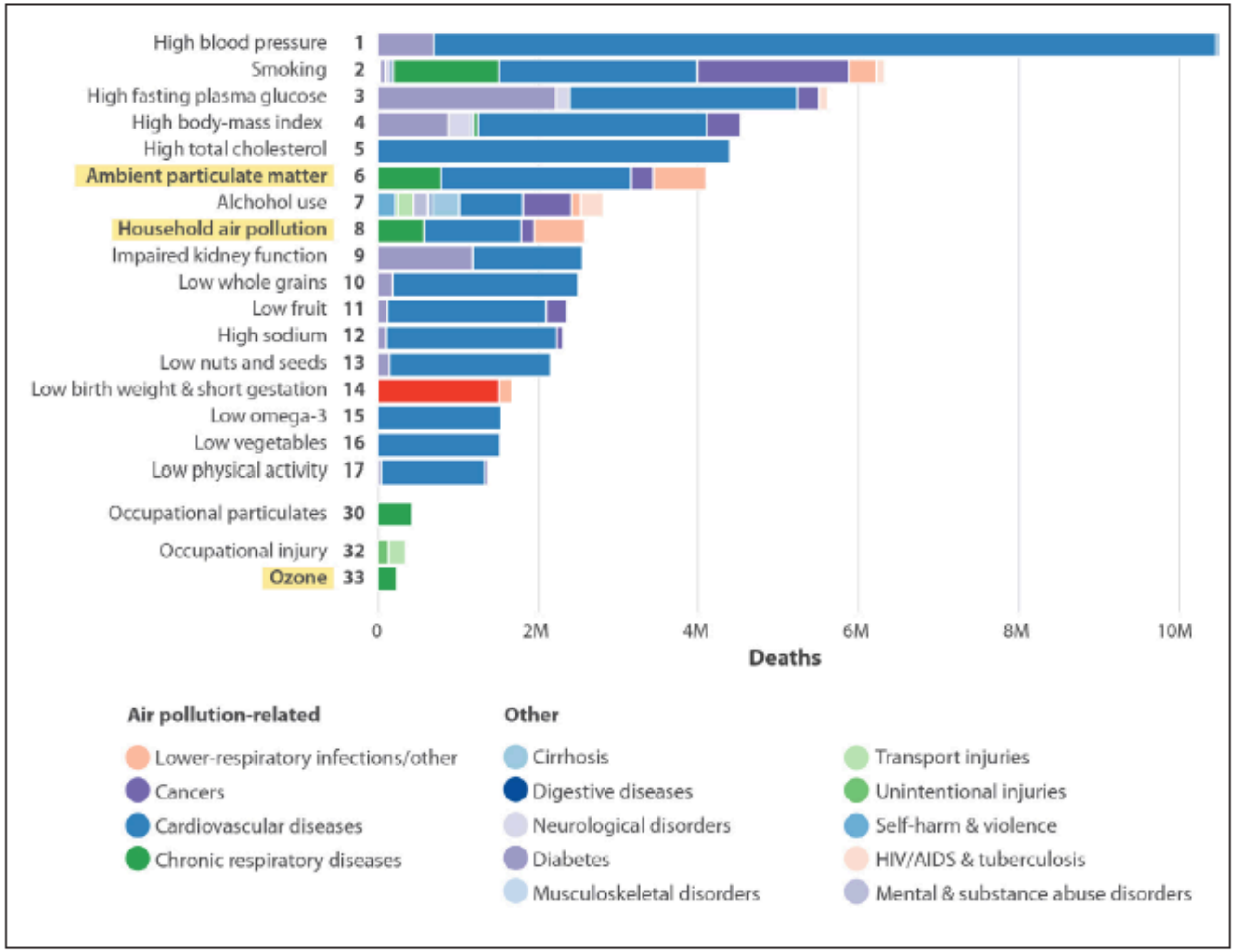
- Particulate matter (PM)
- Nitrogen oxides (NO_x)

PARÂMETRO	AO FINAL DE 10 (DEZ) ANOS	AO FINAL DE 20 (VINTE) ANOS
MP	90%	95%
NOx (expresso como NO_2)	80%	95%

http://www.docidadesp.imprensaoficial.com.br/RenderizadorPDF.aspx?ClipID=9ICQLJFS1CS92e1SVHP261TJJCA

This action addresses pollutants that harm human health and contribute to global climate change

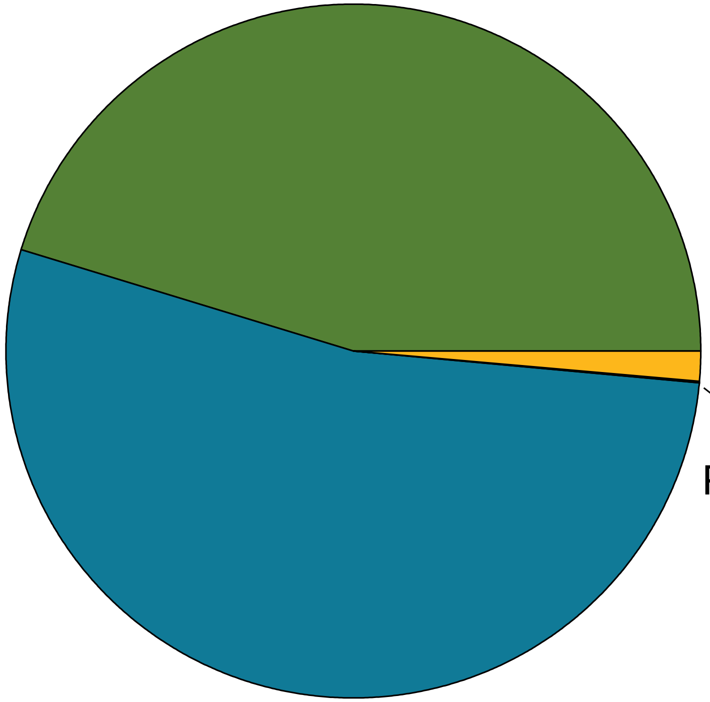
Figure 1. Global ranking of risk factors by total number of deaths from all causes for all ages and both sexes in 2016.



Explore the rankings further at the IHME/GBD Compare site.

Meeting targets will require accelerated transition to cleaner bus technologies and fuels

São Paulo transit bus fleet composition by technology type (Dec. 2017)



P5 and P7 diesel buses:

1. *Are not equipped with the best available technology to control PM emissions, the* ***diesel particulate filter***
2. *Are fueled primarily with petroleum diesel*

Evaluations of emissions and costs are critical for informed decisions regarding transit bus technology transitions

- Zero emission electric buses are one of several technologies which can contribute to compliance with mid-term and long-term emission reduction targets set forth in Lei N° 16.802.

- This presentation gives an overview of methods for assessing climate and air pollutant benefits of transitions to alternative technology bus fleets, and applies methods to demonstrate procurement pathways to meet emission reduction targets in São Paulo

Evaluating the emissions benefits of alternative technology transit buses

A variety of alternative bus and fuel options are commercially available

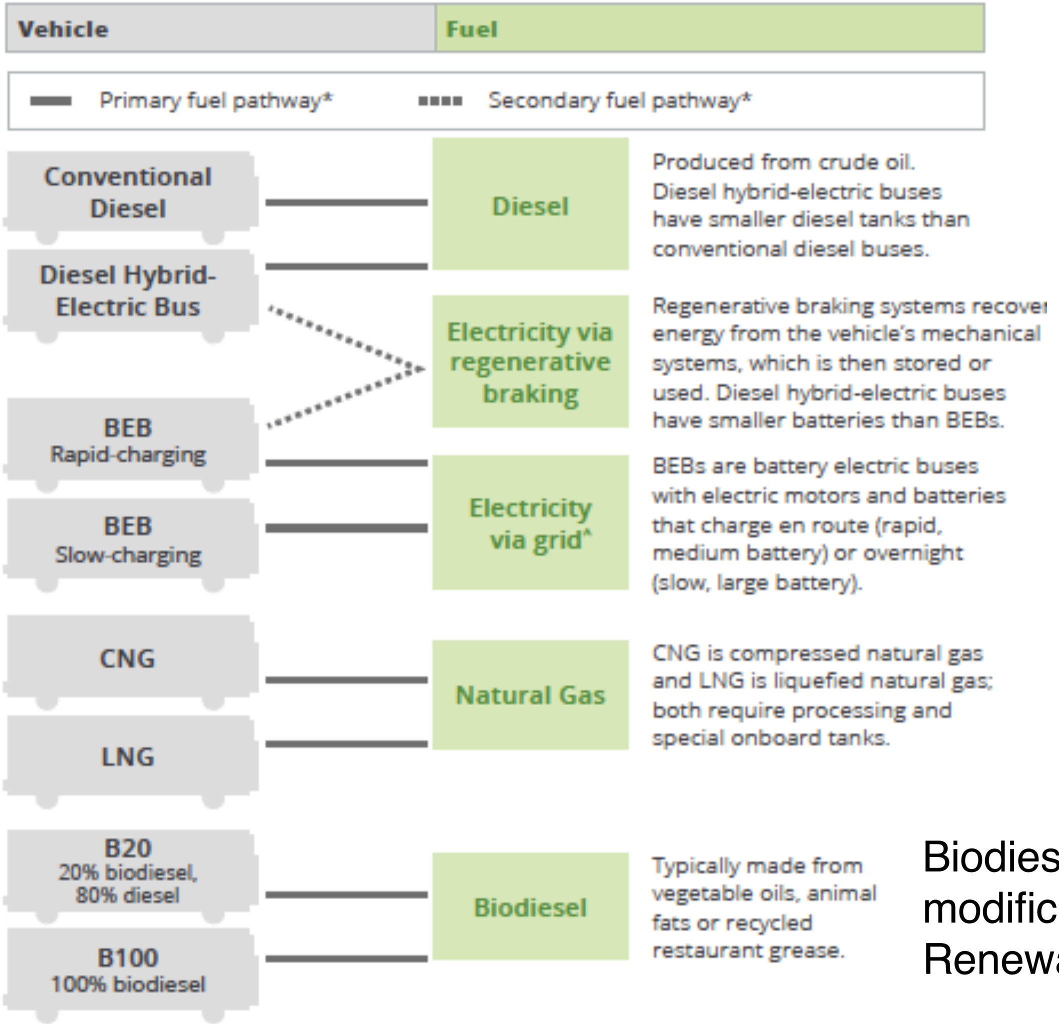
FIGURE 1.
Alternative fuel bus pathways and fuel descriptions.
Data Source: Tong et al.[2]

ACRONYM KEY:

B20	A blend of 20% biodiesel and 80% petroleum diesel
B100	Biodiesel (pure)
BEB	Battery electric bus
CAP	Criteria air pollutant
CNG	Compressed natural gas
GHG	Greenhouse gas
HEB	Hybrid-electric bus
LNG	Liquefied natural gas
O&M	Operation and maintenance

* The primary fuel is used to power and operate the bus. A secondary fuel is only used under certain drive cycles or driving conditions.

^ Electricity is considered a fuel.



Bioethanol/ED95

Biomethane can also be used to fuel CNG engines

Biodiesel (FAME): blending limits without engine modification
Renewable diesel (HVO): "drop-in" fuel

Source: Carnegie Mellon University (2017). Which Alternative Fuel Technology is Best for Transit Buses? Retrieved from https://www.cmu.edu/energy/education-outreach/policymaker-outreach/guides.html

Performance of alternative bus technology and fuel options relative to P7 diesel baseline

Engine	Fuel	PM, NO_x emissions	CO_2 emissions	Purchase price	Operating costs	Maintenance costs
Euro VI diesel	B10	↓ ↓	- - -	- - -	- - -	- - -
Euro VI hybrid	B10	↓ ↓	Depends on driving cycle	↑	↓	↓
Euro VI CNG	Fossil methane	↓ ↓	- - -	↑	↓	↑ ↑
	Biomethane	↓ ↓	Depends on feedstock	↑	Depends on fuel price	↑ ↑
Euro VI biodiesel	Biodiesel or renewable diesel (B100)	↓ ↓	Depends on feedstock	- - -	↑	↑
Euro VI ethanol	ED95	↓ ↓	Depends on feedstock	↑	↑	↑ ↑
Battery electric	Electricity	↓ ↓ ↓	Depends on grid mix	↑ ↑	↓ ↓	↓

How are CO_2 emissions estimated for urban transit buses?

CO_2 emissions (g CO_2/km) = Bus energy intensity (kWh/km) X Fuel carbon intensity (g CO_2/kWh)

Parameters influencing energy intensity

- Bus type
- Powertrain technology
- Bus weight
- Driving cycle
- Passenger loading
- Auxiliary power demands

Tailpipe emissions

- Direct emissions from fuel combustion in engine (counted as zero for biofuels)

Fuel lifecycle emissions

- Includes upstream emissions associated with production of fuel and feedstock
- Land use change emissions for biofuels

Battery electric buses offer significant efficiency benefits relative to other engine technologies

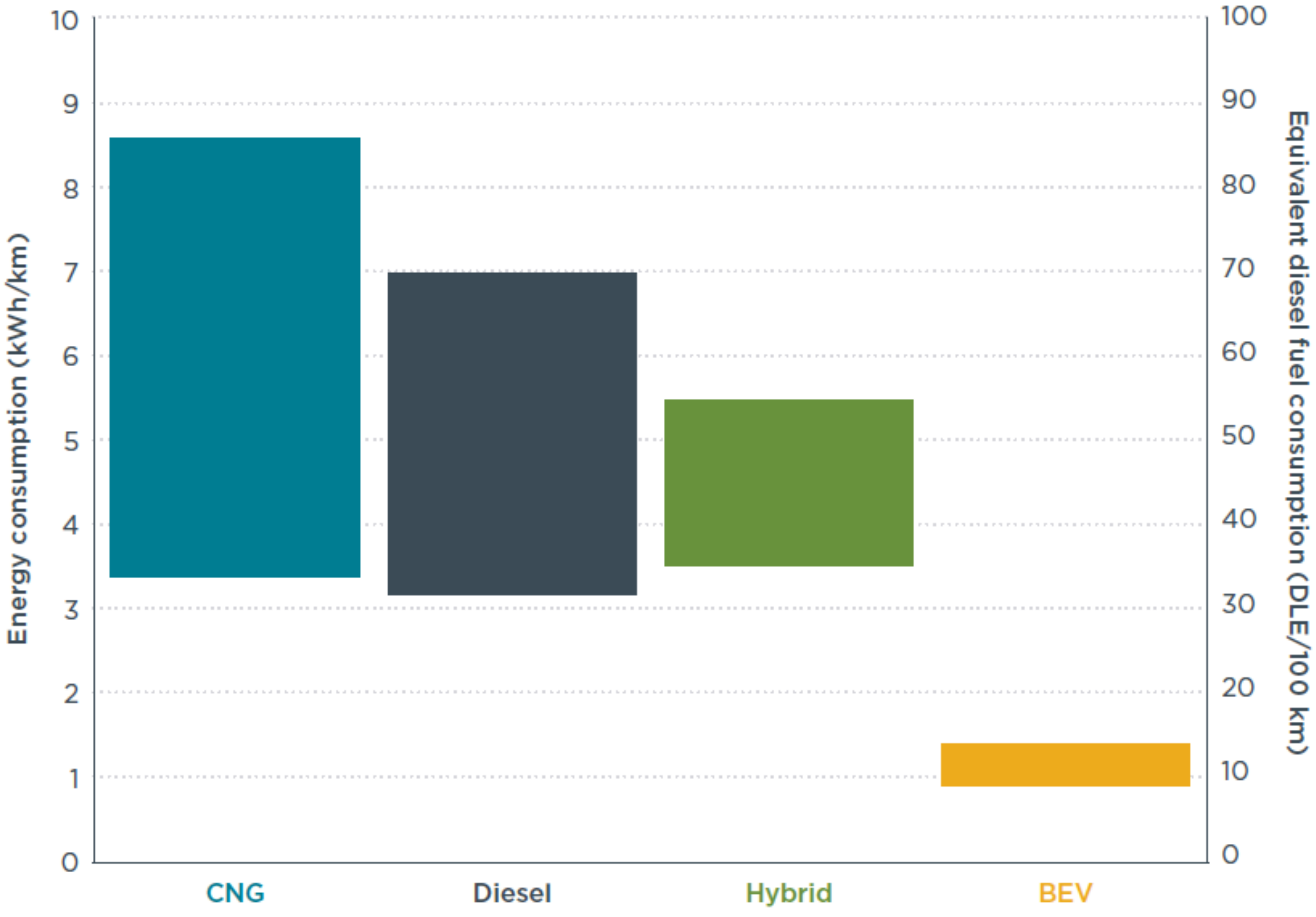
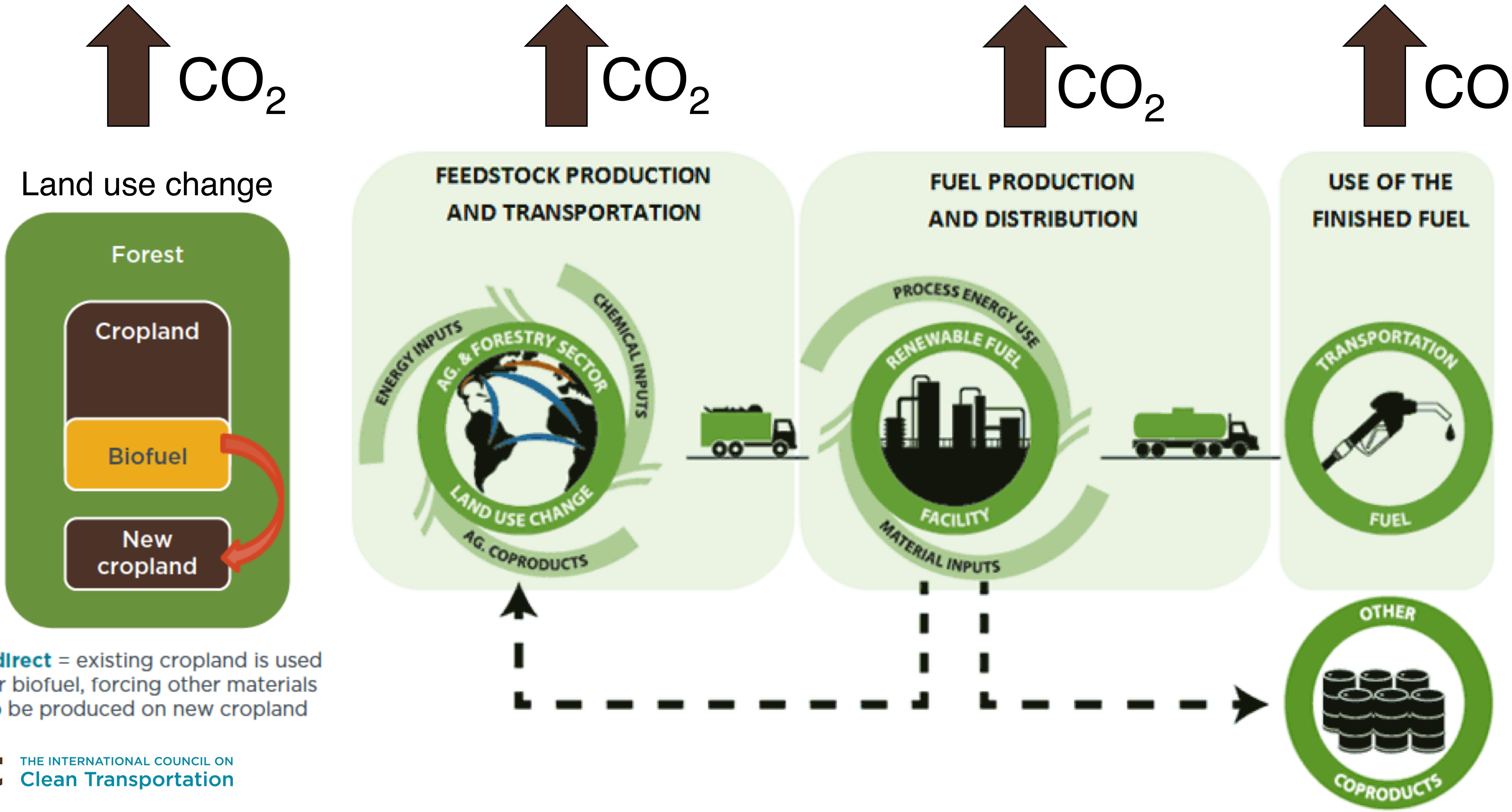


Figure 4. Range of average energy consumption values measured in the Altoona test program by powertrain type.

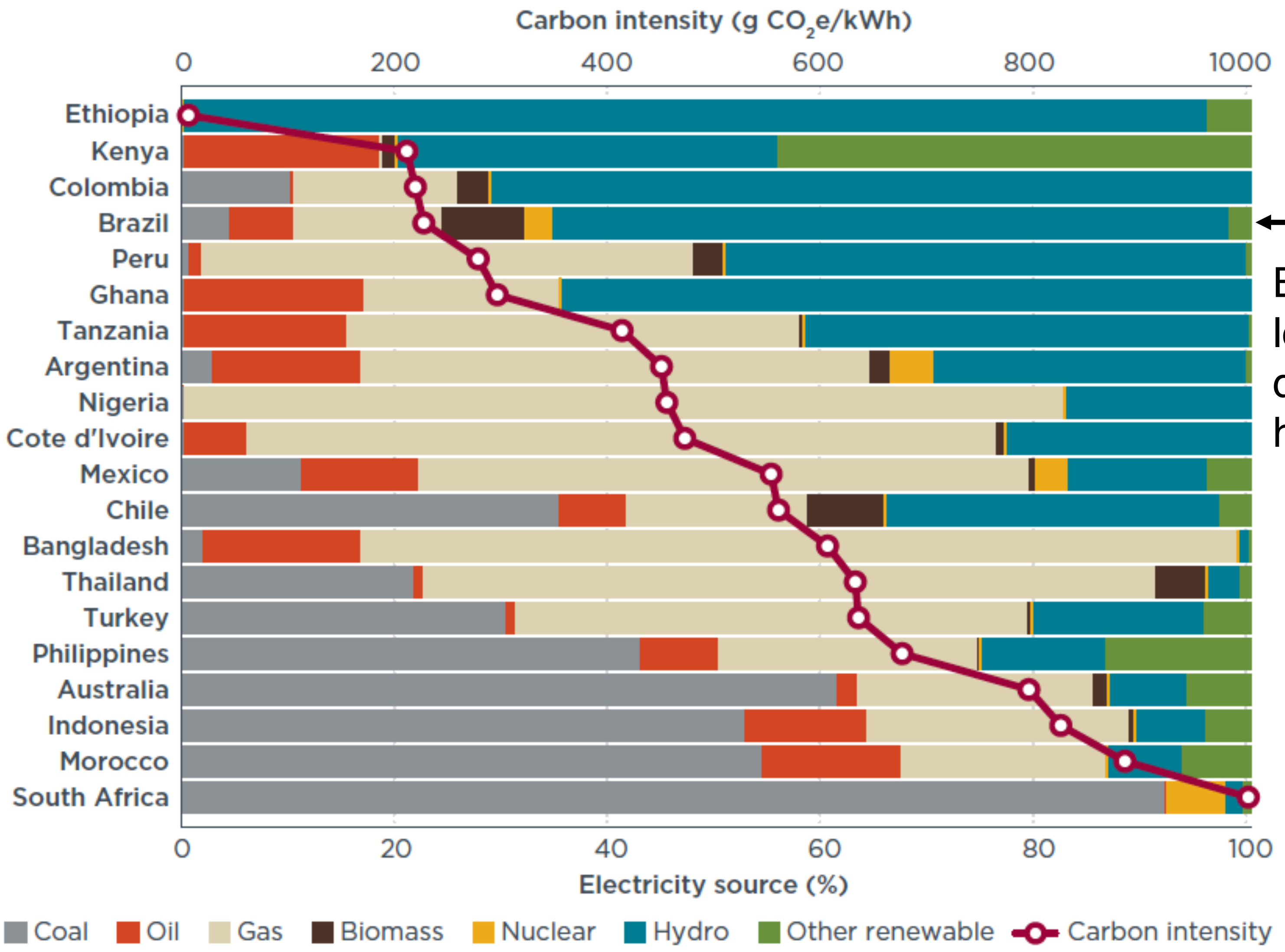
ICCT (2017). Low-carbon technology pathways for soot-free urban bus fleets in 20 megacities. https://www.theicct.org/publications/low-carbon-technology-pathways-soot-free-urban-bus-fleets-20-megacities

Fuel life cycle assessment provides a more accurate estimate of true climate impacts of transportation fuels



Indirect = existing cropland is used for biofuel, forcing other materials to be produced on new cropland

Regions with low carbon intensity electricity grids offer the greatest potential for CO_2 savings from battery electric bus transitions



Brazil has a relatively low grid carbon intensity due to heavy reliance on hydropower

ICCT (2017). Low-carbon technology pathways for soot-free urban bus fleets in 20 megacities. https://www.theicct.org/publications/low-carbon-technology-pathways-soot-free-urban-bus-fleets-20-megacities

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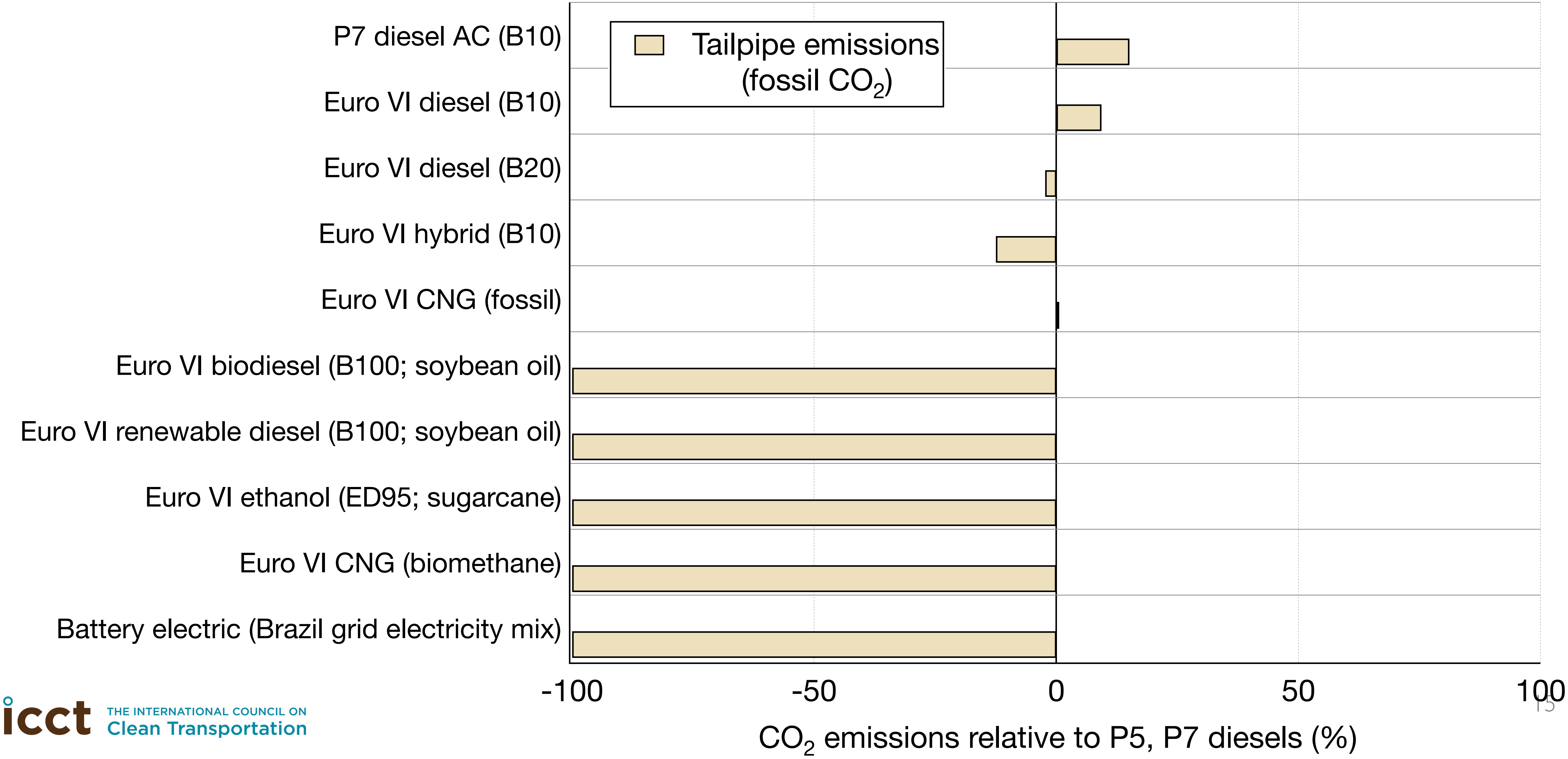
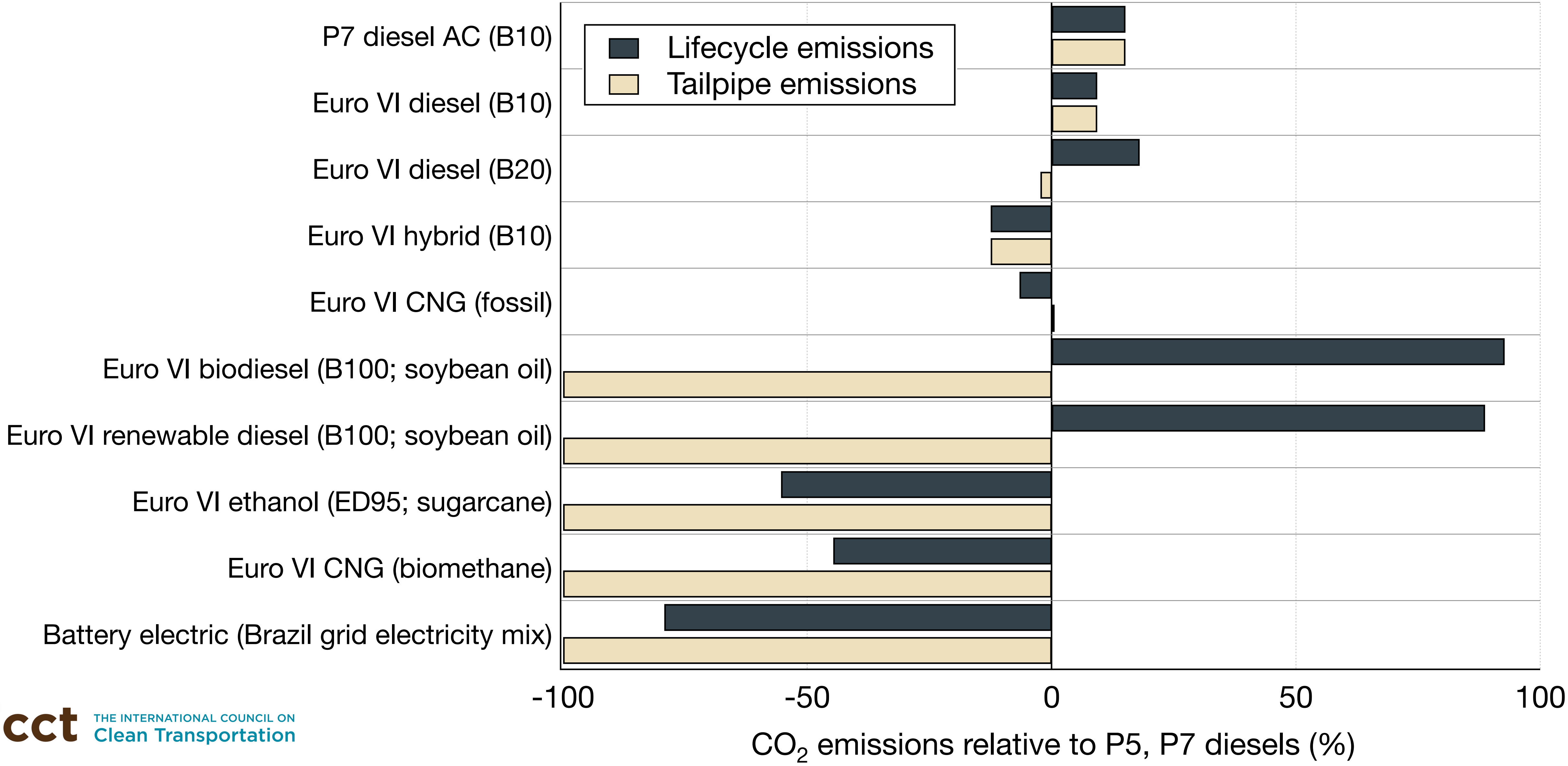
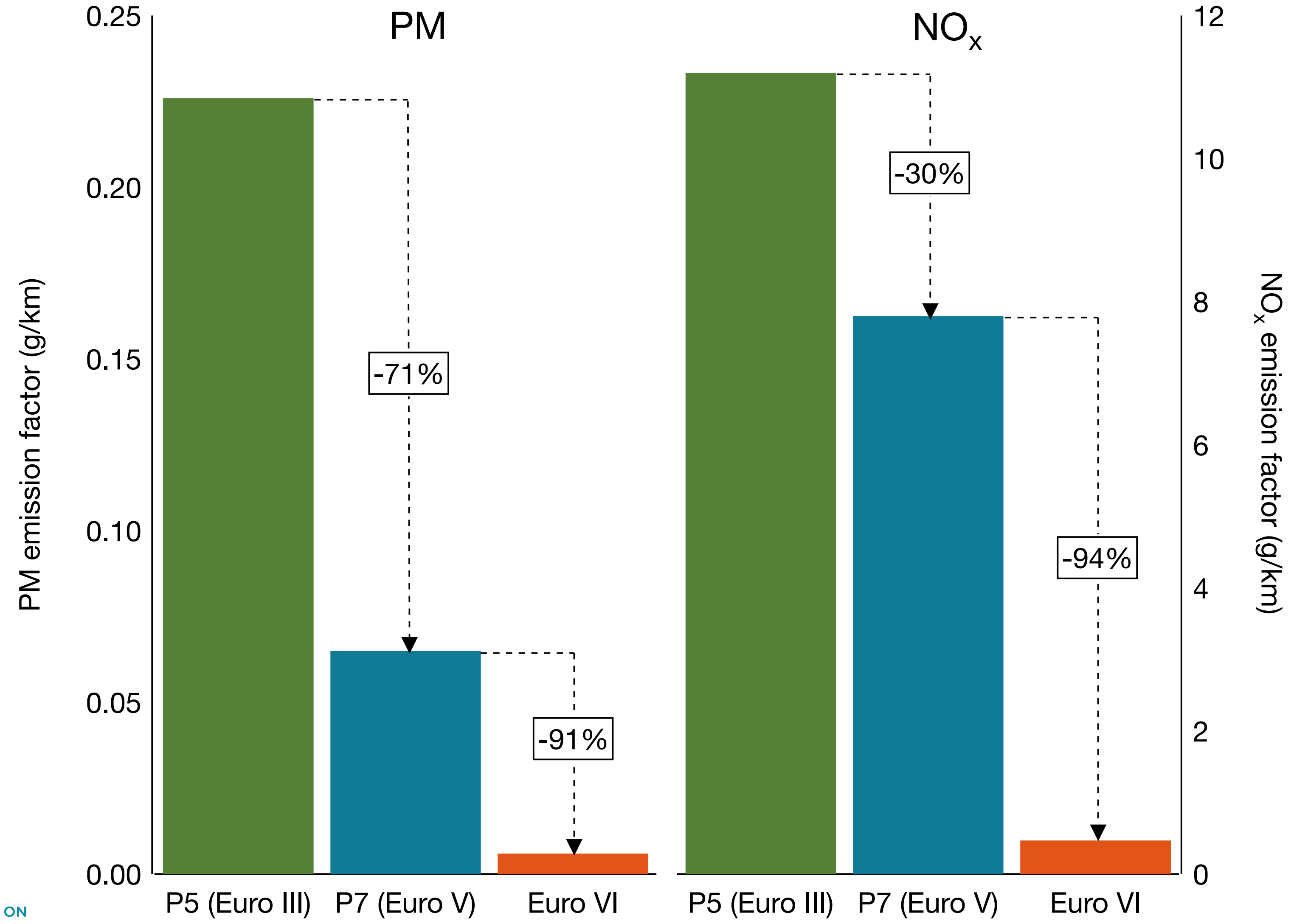
Battery electric and biofuel buses eliminate tailpipe emissions of fossil CO_2



However…fuel lifecycle CO_2 emissions from these technologies and fuels vary considerably, and can even be greater than for diesel buses



Euro VI engines reduce air pollutant emissions by > 90% relative to engines certified to current Brazilian national emission standards, PROCONVE P7



Data source: Handbook Emission Factors for Road Transport (HBEFA 3.3, 2017). http://www.hbefa.net/e/index.html

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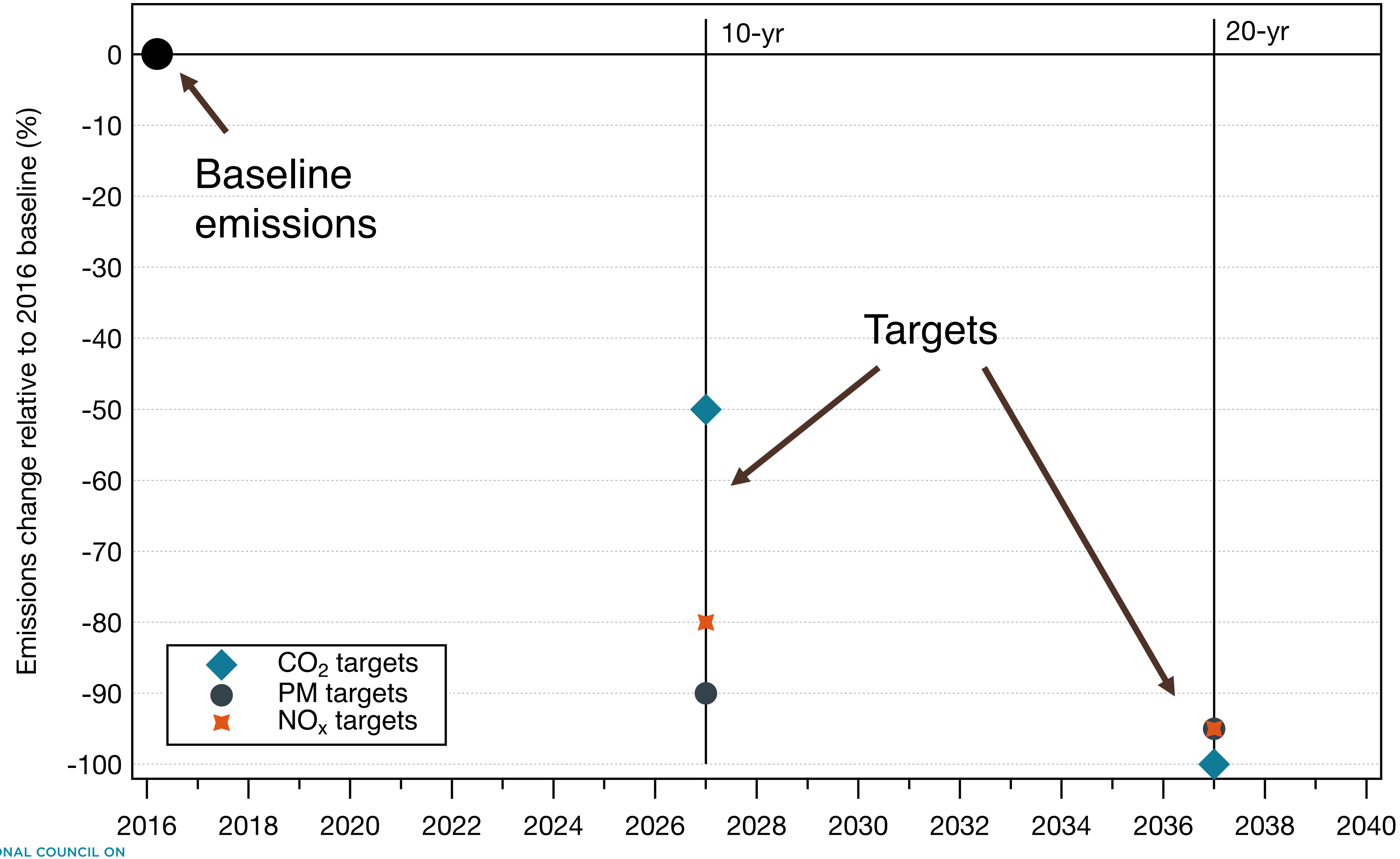
Procurement pathways to meet emissions reduction targets in São Paulo

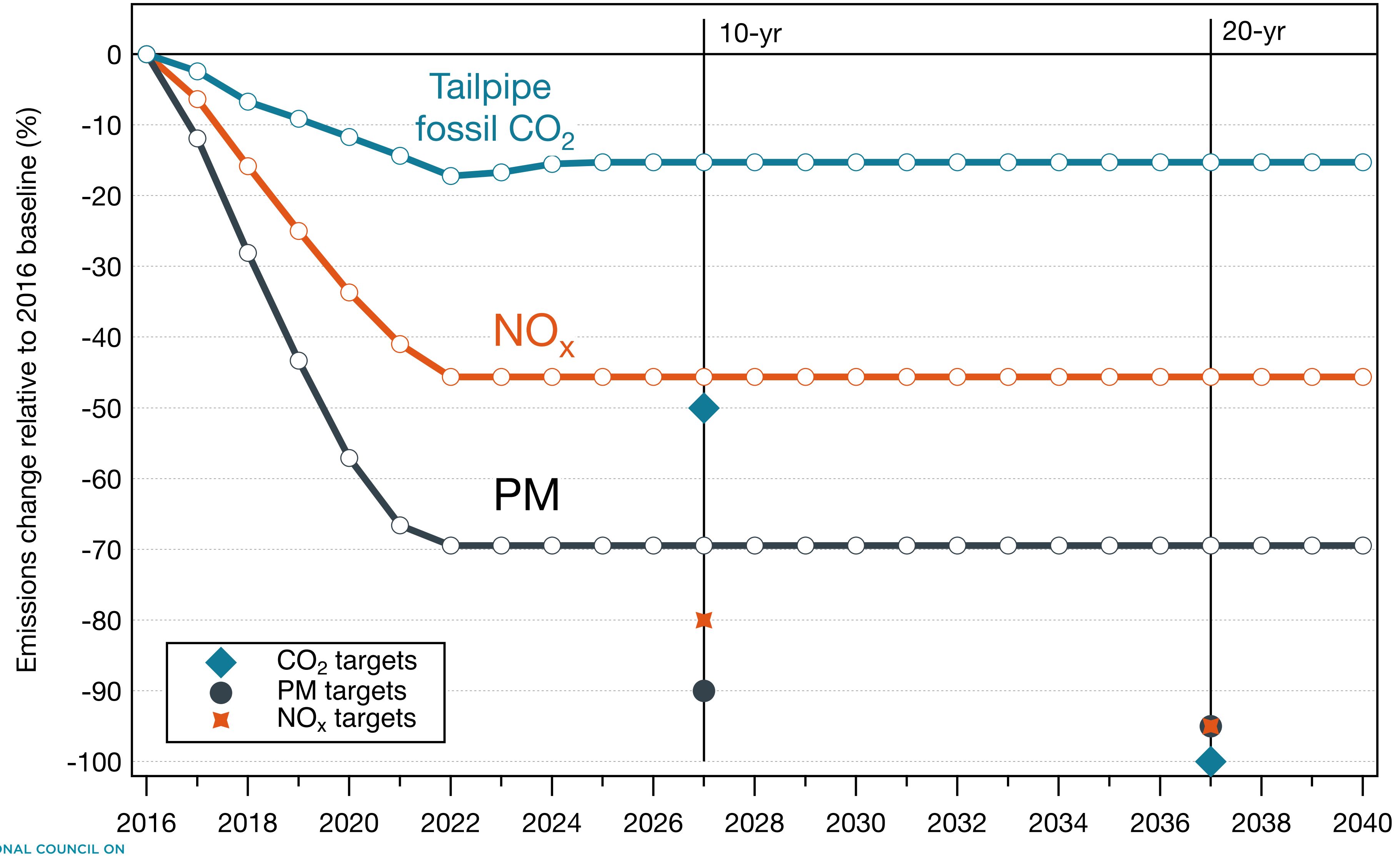
Approach

- Apply ICCT transit bus fleet emissions and cost model to evaluate the degree of technology transition needed to meet emissions reduction targets set forth in Lei N° 16.802
- Estimate CO_2, PM, and NOx emissions for alternative procurement scenarios
- Model accounts for changes to the municipal transit fleet expected with system reorganization
- Fleet turnover model assumes buses are retired after 10 years of service

Overview of emissions reduction targets

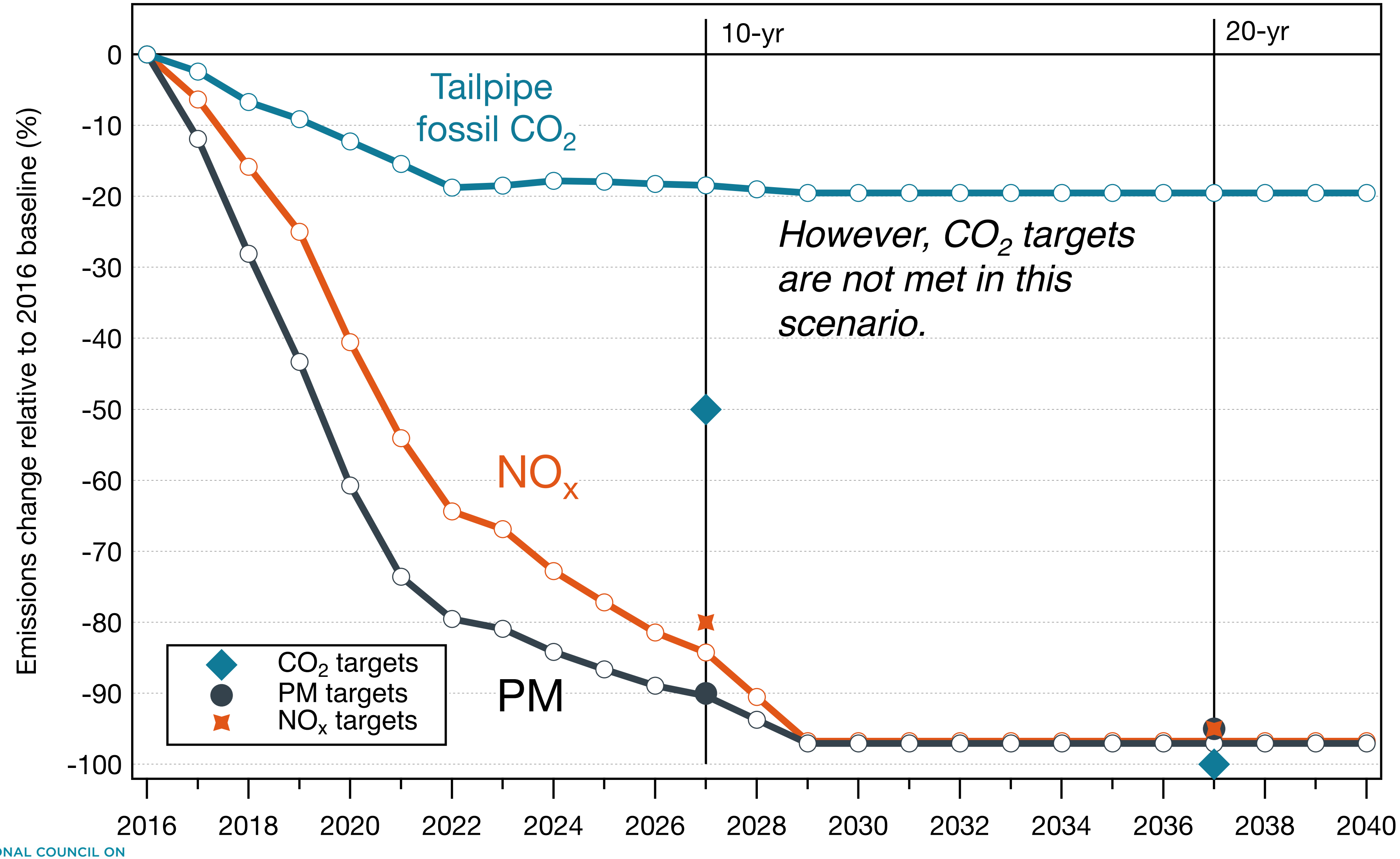


If no changes are made to current procurement practices, emission reduction targets will not be met



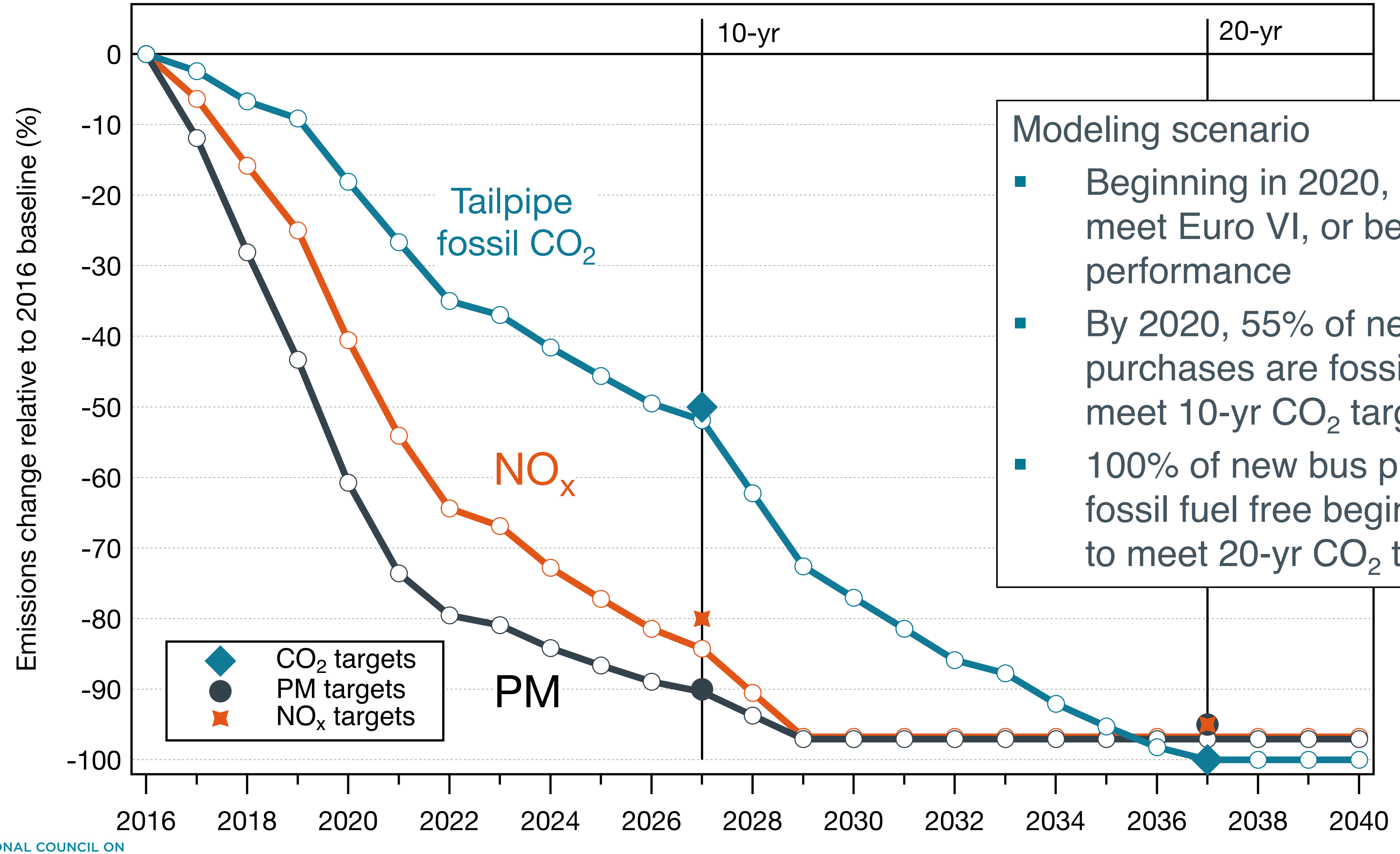
Modeling scenario: All new bus purchases are P7 diesels, B10 fuel

Air pollutant targets met if all new buses meet Euro VI (or better) emissions performance by 2020



Modeling scenario: Beginning 2020, all new bus purchases are Euro VI diesels, B10 fuel

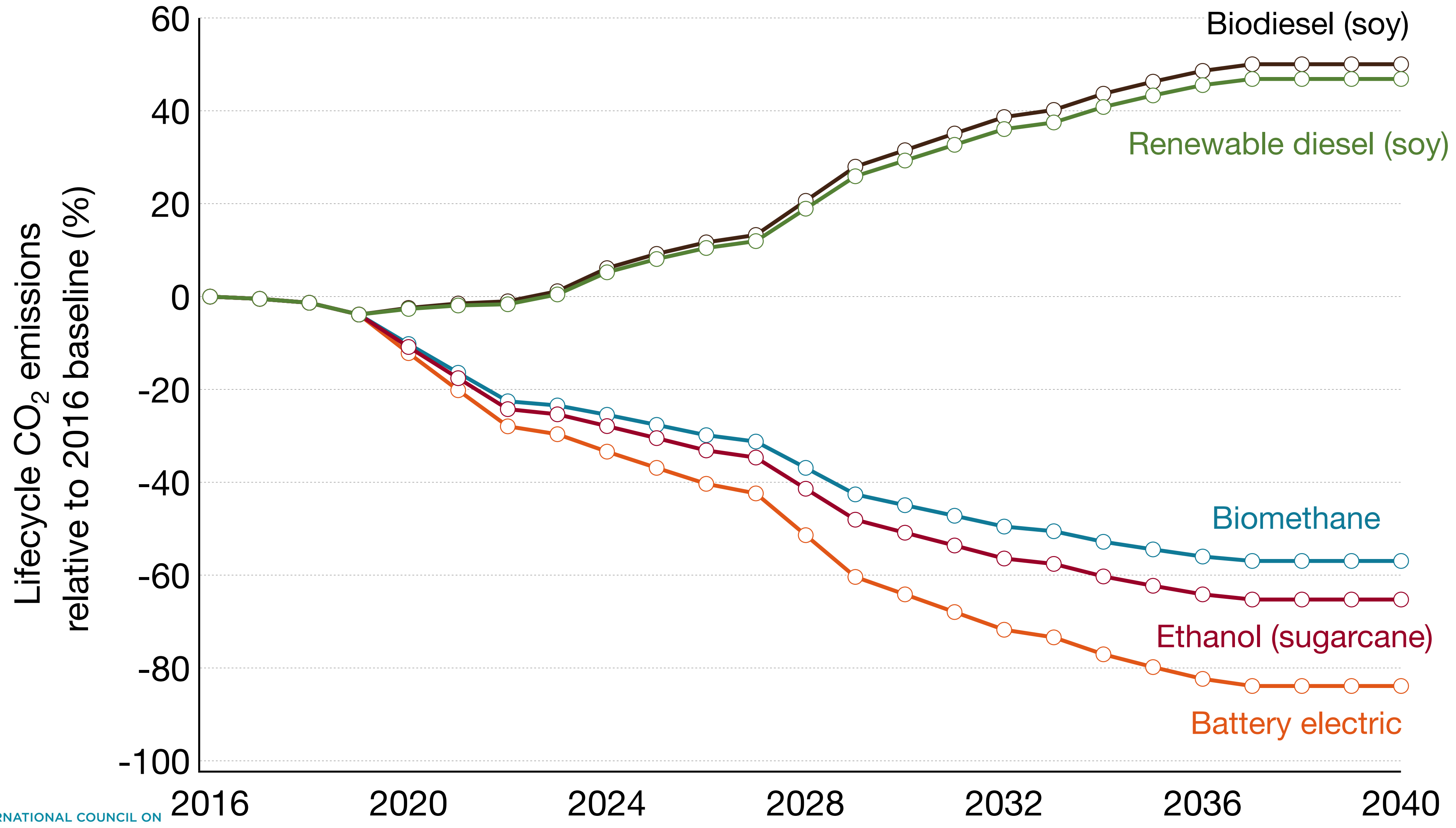
Transition to fossil fuel free technologies and fuels is needed to meet CO_2 targets



Modeling scenario

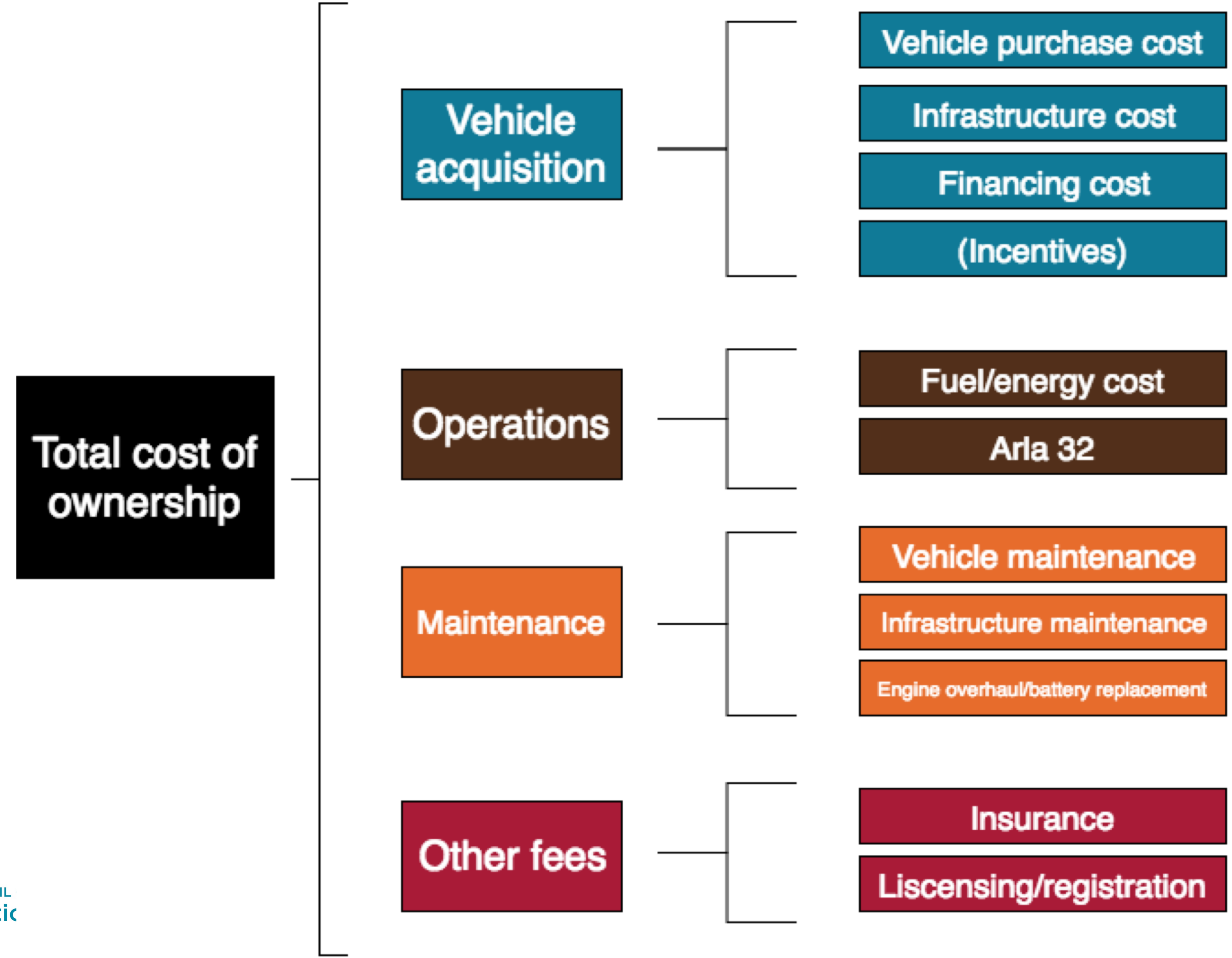
- Beginning in 2020, all new buses meet Euro VI, or better, emissions performance
- By 2020, 55% of new bus purchases are fossil fuel free to meet 10-yr CO_2 targets
- 100% of new bus purchases are fossil fuel free beginning in 2028 to meet 20-yr CO_2 targets

Lifecycle CO_2 emissions show risks of scale-up of current soy-based biofuels; biomethane, ethanol, and battery electric options provide greatest climate benefits

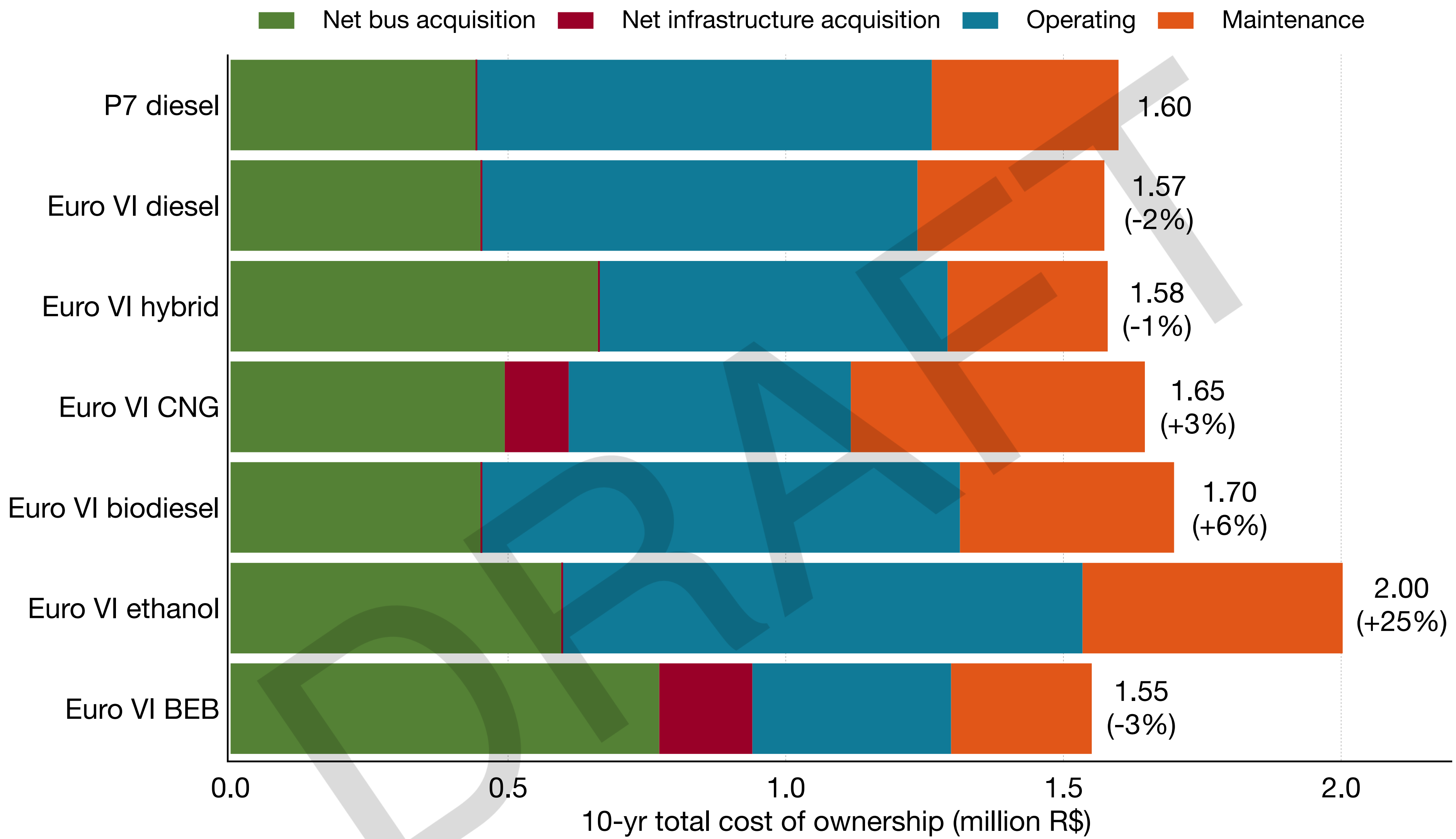


Evaluating the cost of technology transitions: Total cost of ownership assessment

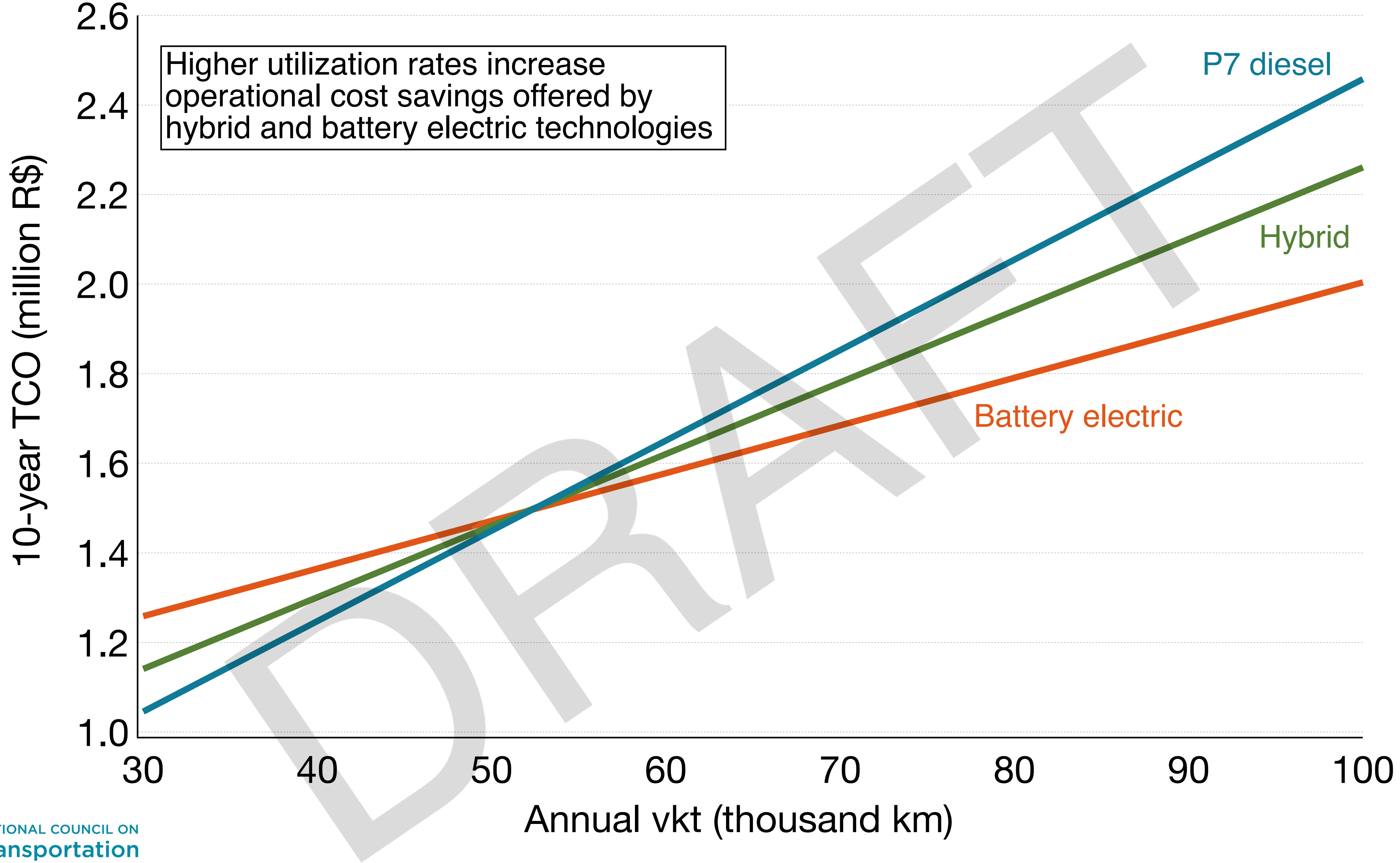
Total cost of ownership (TCO) includes all costs incurred throughout the lifetime of a bus



Most alternative bus technologies are competitive with P7 diesel buses when lifetime costs are considered



Sensitivity of TCO estimate to annual activity



Summary

- São Paulo has set ambitious CO_2, PM, and NO_x emissions reduction targets for its transit bus fleet
- ICCT transit bus fleet emissions and cost model applied to investigate procurement strategies for meeting these targets
- Model results suggest all new buses purchased from 2020 onwards should meet Euro VI, or better, emissions performance in order to meet PM and NO_x targets.
- From 2020-2027 ~55% of new buses purchased should be fossil fuel free to meet 10-yr CO_2 target; all new buses should be fossil fuel free from 2028 onwards to meet 20-yr target
- Fossil fuel free buses have a wide range of lifecycle CO_2 emissions performance. A transition to soy-based biofuels could increase CO_2 emissions by about 50%, due to the high level of LUC emissions associated with this feedstock. Biomethane, ethanol and battery electric bus options offer greatest climate benefits.
- While the purchase price of battery electric buses remains high relative to other technologies, this technology is financially competitive when total cost of ownership is considered
- Unique barriers and challenges to technology transitions exist for each alternative bus and fuel type. These must be considered when formulating long-term procurement strategies.

Contact information
Tim Dallmann
Researcher, ICCT
t.dallmann@theicct.org