CiViTAS
Cleaner and better transport in cities

WIKI

CIVITAS Webinar - Clean buses for your city

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Smart choices for cities - Clean buses for your city

Cleaner bus options for your municipality

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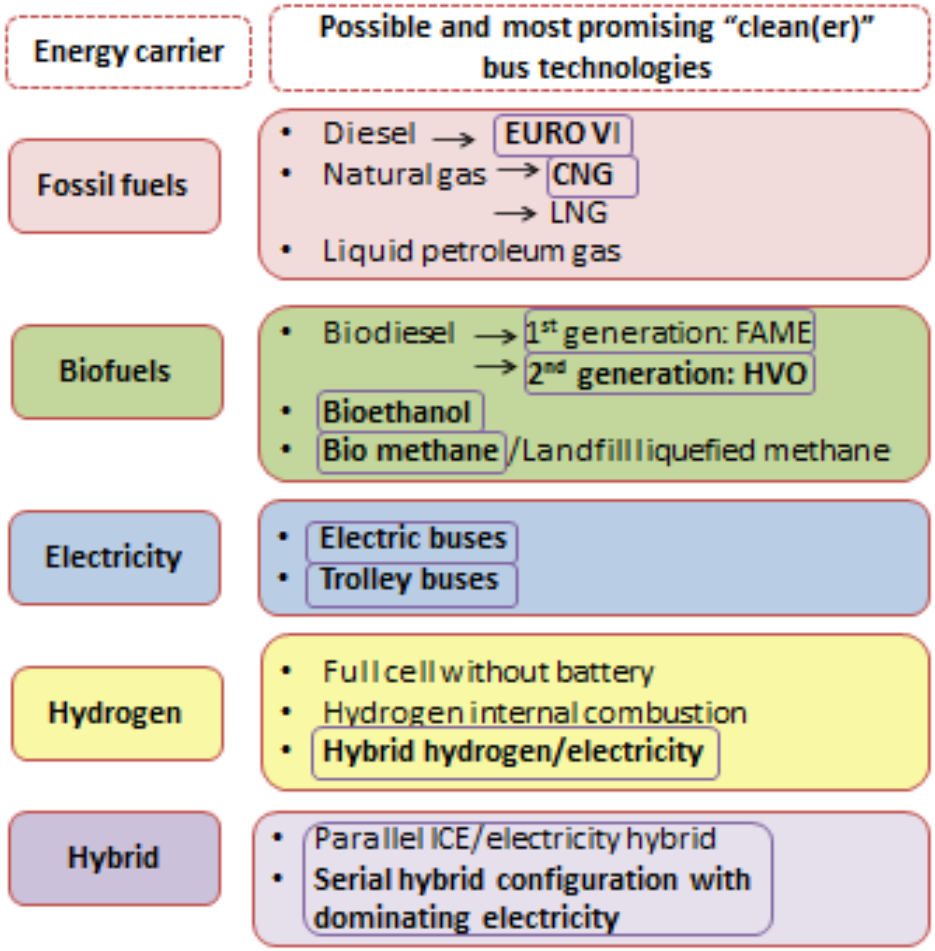
What are the clean(er) bus options?



Fossil fuels: Euro VI buses

Operational performance:

Range: 600 – 900km
High route flexibility

Energy consumption 2012: 4.13 kWh/km
Energy consumption 2030: 3.89 kWh/km

Refueling every 2nd day
Short refilling time: 5 – 10 min

Costs:

Purchase price : +/- 220.000 euro per bus
Maintenance cost: +/- 0.10 – 0.15 €/km

TCO Euro V 2012 : 2.1 €/km
TCO Euro VI 2030 : 2.5 €/km

Emissions:

GHG	Measure	Euro V	Euro VI
CO_2eq	g/km	1000	1000
NOx	g/km	3,51	1,1
PM10	g/km	0.10	0.03

Other:

High EU coverage with refilling stations
Predictable costs
Adaptable for the usage of biofuels
Growing concern of the fossil fuels shortage

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Fossil fuels: CNG buses

Operational performance:

Range: 350 – 400 km
High route flexibility

Energy consumption 2012: 5.21 kWh/km
Energy consumption 2030: 5.00 kWh/km

Refilling every 2nd day
Short refilling time: 5 – 10 min

Costs:

Purchase price: +/- 250.000 euro per bus
Maintenance cost: +/- 0.15 €/km

TCO 2012: 2.1 €/km
TCO 2030: 2.6 €/km

Extra costs from 20k € per CNG bus

Emissions:

GHG	Measure	CNG 2013	CNG 2020
CO2eq	g/km	1000	800 - 850
NOx	g/km	1.4-4.5	0.88
PM10	g/km	0.005-0.03	0.024

Other:

Special filling infrastructure
Usage of biogas further reduce emissions
Refueling system transferable to hydrogen
Non-renewable
High safety concerns

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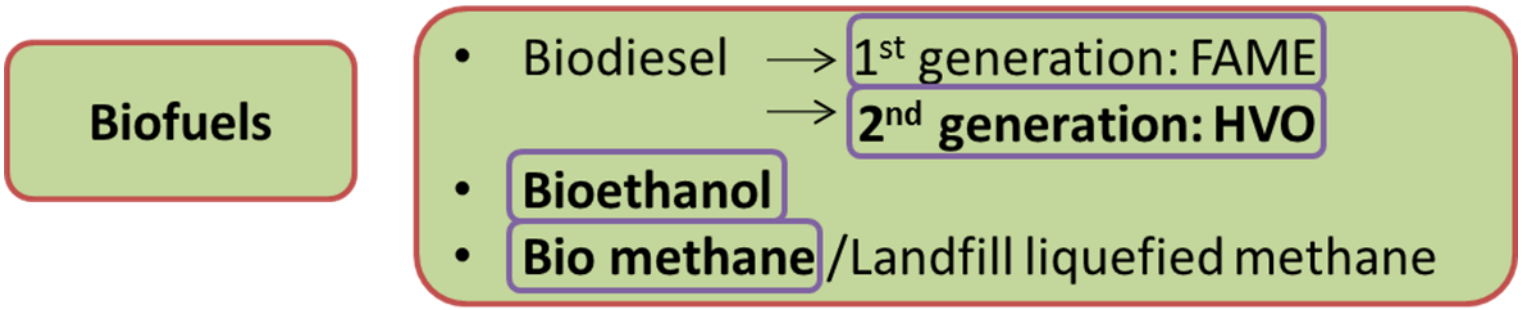
Biofuels



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Biofuels: buses running on FAME/HVO

Operational performance:

Range: 570-850 km
High route flexibility

Energy consumption 2012: 4.13 kWh/km
Energy consumption 2030: 3.89 kWh/km

Refilling every 2nd day
Short refilling time: 5 – 10 min

Costs:

Purchase price: +/- 220.000 euro per bus

TCO FAME (B100) 2012: 2.22 €/km
TCO HVO (B100) 2012: 2.35 €/km

Currently both HVO and FAME are more expensive than regular diesel fuel

Emissions:

GHG	Measure	Euro V diesel	Euro V FAME 100	Euro V HVO100
CO2eq	g/km	1000	500 and more	500 and more
NOx	g/km	3,51	4.39	3.16
PM10	g/km	0.10	0.04	0.08

Other:

Same filling infrastructure as for diesel
Each type and blend of biofuel requires specific motor modification
Very limited current supply of HVO
Sustainability concerns with FAME

Not directly suitable for Euro VI buses

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Biofuels: bus running on bioethanol

Operational performance:

Range: 400 – 600 km (depending on tank volume)
High route flexibility

Energy consumption 2012: 4.13 kWh/km
Energy consumption 2030: 3.89 kWh/km

Refilling every 1 or 2 days
Short refilling time: 5-10 min

Costs:

Purchase price: +/- 250.000 euro per bus

TCO 2012: 2.52 €/km

Emissions:

GHG	Measure	Euro V diesel	Euro V bioethanol
CO2eq	g/km	1000	400-600
NOx	g/km	3,51	3.51
PM10	g/km	0.10	0.10

Other:

Same filling infrastructure as for diesel
Specific pump for bioethanol to be installed and larger storage tank
Very limited current worldwide production of bioethanol
Limited choice of buses

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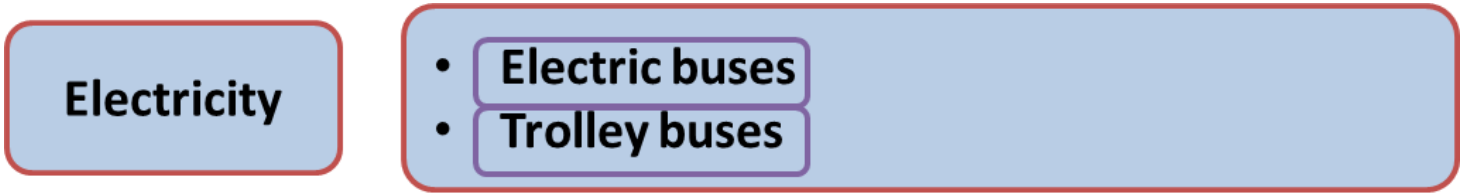
Electricity



Electricity: electric buses

Operational performance:

Opportunity – charging buses:

Short free range of <100 km
Limited route flexibility
Energy consumption 2012: 1.80 kWh/km
Energy consumption 2030: 1.58 kWh/km
Recharging multiple times a day
Short recharging time: 5-10 min

Overnight – charging buses:

Medium free range: 100 - 200 km
Higher route flexibility
Energy consumption 2012 : 1,91 kWh/km
Energy consumption 2030: 1,68 kWh/km
Recharging at the end of each day
Very long recharging times: > 3 h

Costs:

Estimations based on prototype phase:

Opportunity – charging buses
TCO 2012: 3.2 €/km
TCO 2030: 2.9 €/km

Overnight – charging buses
TCO 2012: 5.5 €/km
TCO 2030: 3.8 €/km

Emissions:

GHG	Measure	Electric bus
CO2eq	g/km	500
NOx	g/km	0
PM10	g/km	0

Other:

Charging points in bus depots and along route
Infrastructure cost +/-10k €/per bus /per station

Electricity: trolleybuses

Operational performance:

Range: unlimited within the network
Flexibility within the network

Energy consumption 2012: 1.80 kWh/km
Energy consumption 2030: 1.71 kWh/km

Power supply for major route via overhead network

Costs:

Purchase price: 400.000 - 450.000 € per trolleybus
Infrastructure construction cost: 1-1,5 mln €/km

TCO 2012: 3.1 €/km
TCO 2030: 3.4 €/km

Emissions:

GHG	Measure	Trolley bus
CO2eq	g/km	500
NOx	g/km	0
PM10	g/km	0

Other:

Require an overhead wiring network
Existing tram network could lower investment costs
Currently costs are double than conventional diesel

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Hydrogen

Hydrogen

- Full cell without battery
- Hydrogen internal combustion
- **Hybrid hydrogen/electricity**

Hybrid hydrogen fuel cell/electricity bus

Operational performance:

Range: 200 – 400 km
High flexibility in routes

Energy consumption 2012 (test fleets): 3.2 kWh/km
Energy consumption 2030: 2.72 kWh/km

Refilling every day at the end of operation
Short refilling time: 10 min

Costs:

Purchase price: +/- 800.000 euro per bus
Projections based on the test fleet

TCO 2012: 4.6 €/km
TCO 2030: 3.2 €/km

Fuelling and supply infrastructure are very expensive
Very high maintenance cost

Emissions:

GHG	Measure	Hydrogen
CO_2eq	g/km	1500
NOx	g/km	0
PM10	g/km	0

Other:
Requires specific filling infrastructure (relatively scarce in EU)
Great potential due to availability of resources
Safety precautions needed

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Hybrid

Hybrid

- Parallel ICE/electricity hybrid
- **Serial hybrid configuration with dominating electricity**

Serial hybrid diesel/electricity bus

Operational performance:

Range: 600-900 km.
High route flexibility

Energy consumption 2012(test fleets):3.34 kWh/km
Energy consumption 2030: 3.17 kWh/km

Refilling needed only after every 2nd day
Short refilling times: 5 – 10 min

Costs:

Purchase price: +/- 270.000 euro per bus
Projections based on the test fleet

TCO 2012: 2.4 €/km
TCO 2030: 2.6 - 2.7 €/km

Emissions:

GHG	Measure	Hybrid diesel/ electric	Euro V diesel
CO2eq	g/km	700	1000
NOx	g/km	2.8	3.51
PM10	g/km	0.08	0.10

Other:
Regular diesel filling infrastructure
Short distances often possible in pure electric drive
Heavier bus

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Comparing technology, infrastructure, operational performance

Bus technology/energy source	Fossil fuel			Biofuel				Electricity			Hydrogen	Hybrid
	Euro V	Euro VI	CNG	FAME B100	HVO B100	Bio-methane	Bioethanol	Opportunitiy	Overnight	Trolley	Hydrogen/electric	Serial hybrid electricity/diesel
Fuel caracteristics												
Renewable/not												
Energy security												
Operational performance												
Range, km												
Zero emission range, km												
Route flexibility												
Infrastructure												
Current market penetration												

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Comparing emissions

Bus technology/energy source	Fossil fuel			Biofuel				Electricity			Hydrogen	Hybrid
	Euro V diesel	Euro VI diesel	CNG	FAME B100	HVO B100	Bio-methane	Bioethanol	Opportunitiy	Overnight charging	Trolley bus	Hybrid hydrogen/electric	Serial Hybrid electricity/diesel
CO2eq, g/km												
NOx, g/km												
PM10, g/km												
Noise standing, dB												
Noise passing by, dB												

Comparing economy

Bus technology/	Fossile fuel			Biofuel				Electricity			Hydrogen	Hybrid
energy source	Euro V	Euro VI	CNG	FAME B100	HVO B100	Bio-methane	Bioethanol	Opportunitiy	Overnight	Trolley	Hydrogen/electric	Serial hybrid electricity/diesel
Indication purchase price, 1000euro												
TCO 2012, euro/km												
TCO 2030, euro/km												
Additional infrastructure investment, 1000 euro												

Conclusions

- Diesel Euro VI buses are currently the most economical buses, becoming very low in air and CO_2 emissions.
- Natural gas buses are more expensive. Pollutant emissions advantages compared to diesel have diminished with the introduction of Euro VI.
- Buses running on biofuel have comparable cost to diesel buses. Their emission will depend on the particular type of biofuel and particular blend ratio.
- Diesel hybrid buses and diesel bus have comparable costs, but hybrids can reduce GHG emissions up to 20%
- Full electric buses and trolleybuses are so far the most environmentally friendly bus options but also the more expensive ones.
- Hydrogen fuel cell buses are considered as a promising option, but are currently still in an experimental stage and are the most expensive.
- For both electric and hydrogen fuel cell buses high investment costs in infrastructure are necessary.