



CIVITAS Policy Note on Clean Buses - Supporting decisions for clean buses

2014 ANNUAL POLIS CONFERENCE


28 November, 2014

Madrid, Spain

Teije GORRIS, CIVITAS & TNO



THE CIVITAS INITIATIVE IS CO-FINANCED BY
THE EUROPEAN UNION



› **TNO connects people and knowledge to create innovations that boost the sustainable competitive strength of industry and well-being of society.**

TNO innovation
for life

VISION

THEMES IN TRANSITION

INDUSTRY



HEALTHY LIVING



DEFENCE, SAFETY & SECURITY



URBANISATION



ENERGY





CIVITAS
Cleaner and better transport in cities

POLICY NOTE



Smart choices for cities
Clean buses for your city

CIVITAS

From
research
information

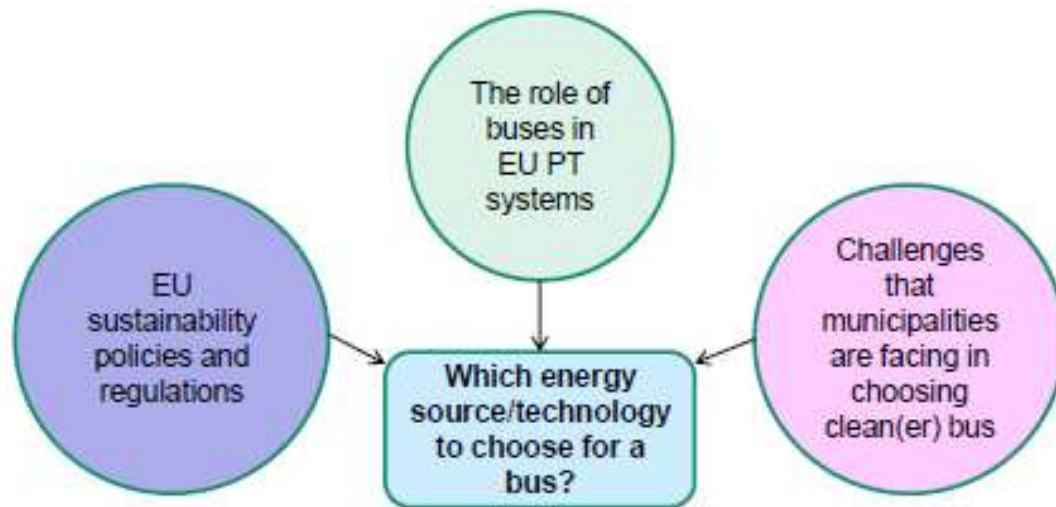
to

decision making
information



Why this policy note?

- It addresses the questions policy makers have: **What is the best bus for my city?**



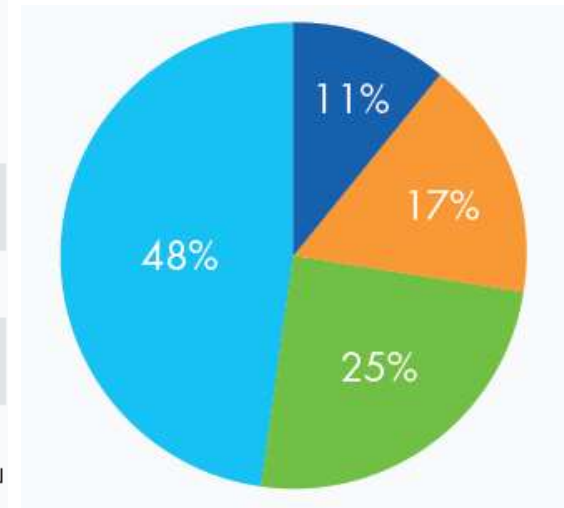
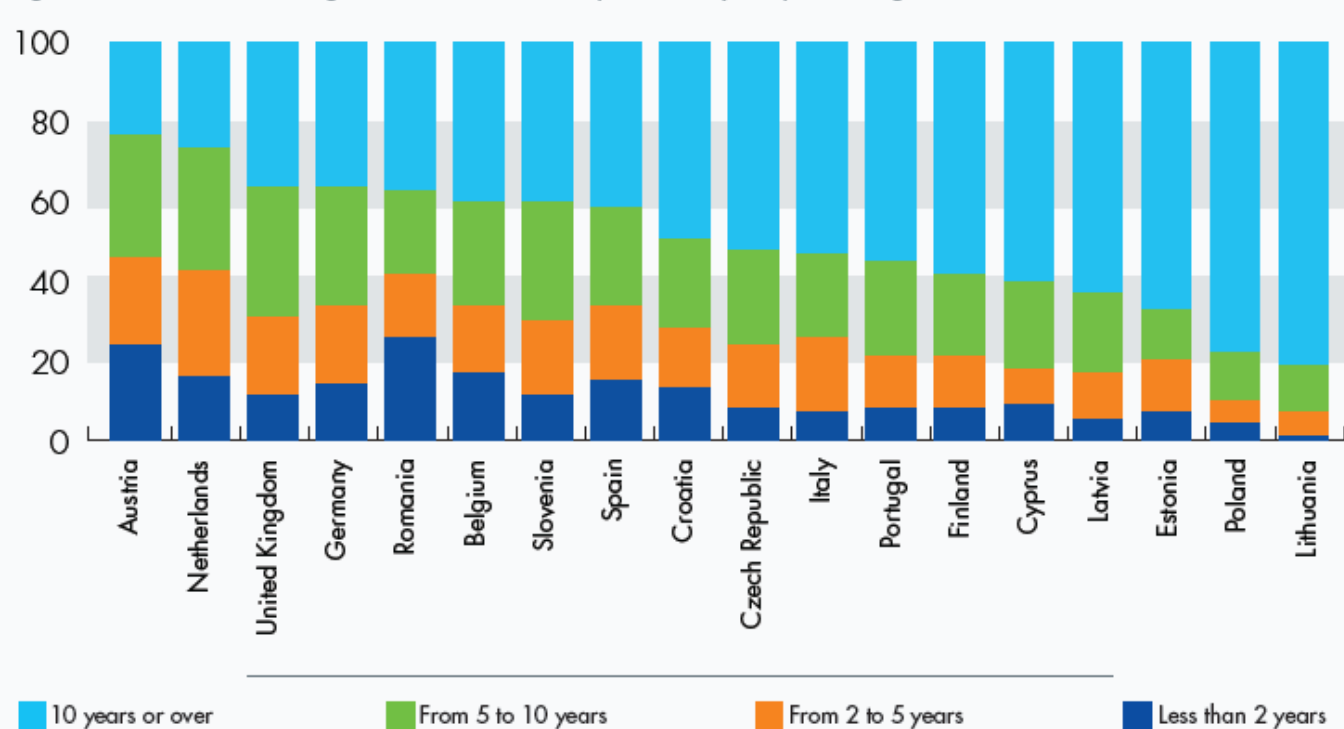
CIVITAS WIKI Policy Note “Clean Buses for your city”

- What are the options available and which energy source/technology to choose for a bus?
- What are the advantages/disadvantages of different options?
- What are the costs of these options?
- Which fuels require installation of additional infrastructure and what are associated to it costs?

The role of buses in EU public transport system

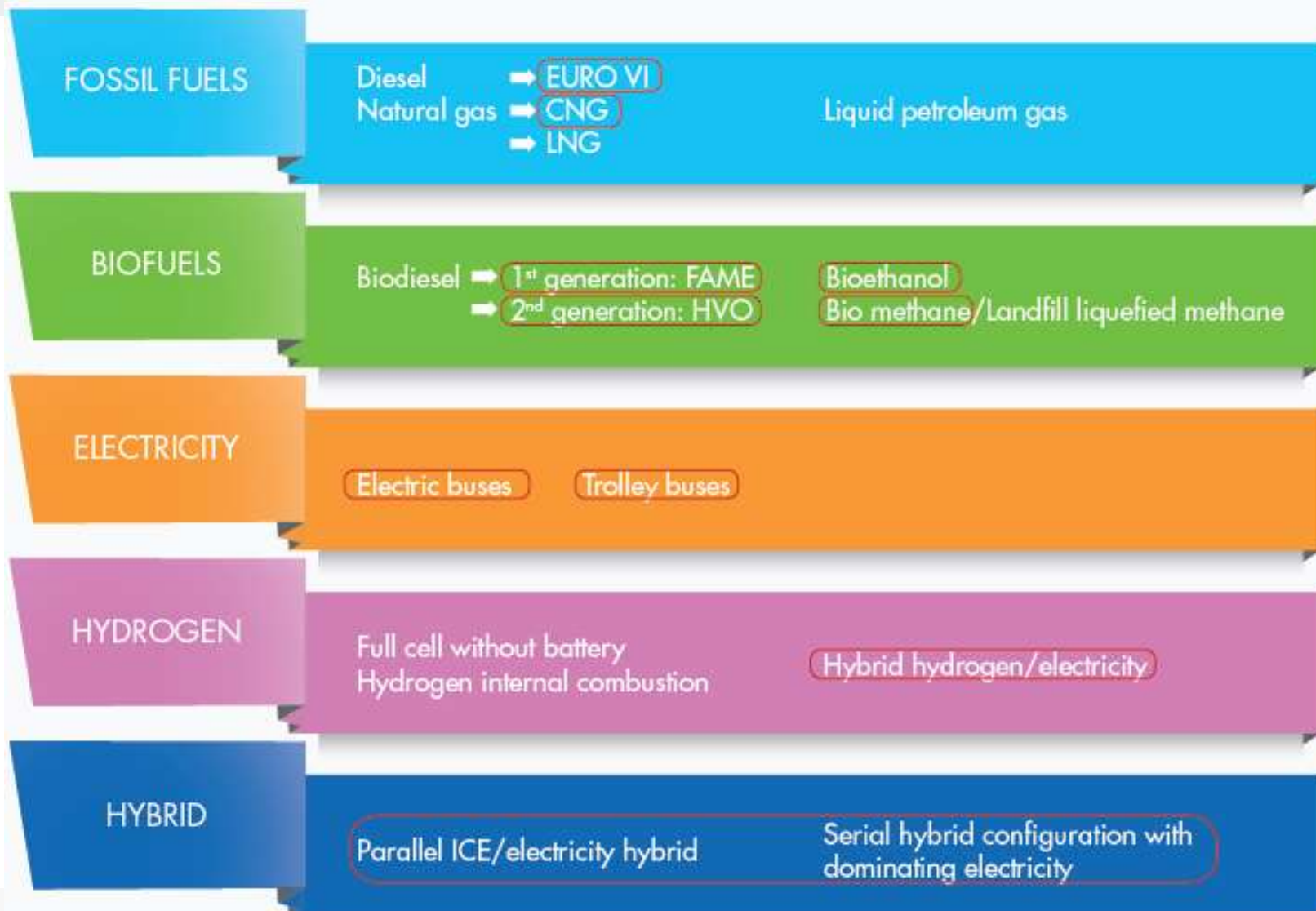
Backbone of many EU public transport systems, providing 7,8% of EU mobility in 2011

Figure 2. Distribution of age of buses in EU-28, per country, in percentages, 2011



Source: Eurostat

What are the clean(er) bus options?



Short term targets (2020)



Municipality perspective:

- Euro VI, VI diesel buses, diesel hybrid/electric buses and buses running on biofuels

EU perspective:

EU 2020 targets: 10% biofuels content, 6% GHG reduction of conventional fuels, 20% GHG emission reduction

- High blends of first or second generation biodiesel - to increase the renewable energy share above the blending limit
- Biogas (in CNG buses) - to increase the renewable share (up to 100%)
- Hybrid drivelines with diesel or gas engines - to further reduce GHG emissions by about 20%.

Long term targets (2050)



Municipality perspective:

- Technologies with lowest (well to wheel) energy consumption and good possibilities for using renewable fuels (e.g. electric buses, trolleybuses, hydrogen fuel cell buses)

EU perspective:

- EU 2050 targets: 60% reduction of GHG emissions from transport
- Full electric buses – with clean(er) electricity supply and cheaper bus battery
- Hydrogen buses – with production of hydrogen in a renewable way with solar and wind energy

Fact sheets



Euro V and Euro VI buses

Bus technology with conventional diesel combustion engine and fulfilling Euro V and Euro VI emission standards for bus

Emissions

GHG	Masses	Euro V	Euro VI
CO ₂ eq	g/km	1000	1000
NO _x	g/km	3,51	1,1
PM10	g/km	0.10	0.03

Thanks to expected improvements in bus driveline and body by 2020, CO₂ emissions from buses will be further reduced to 900 g/km.

Noise emissions: standing 80 dB, pass by 77 dB (McKervey, 2012)

- Operational range: 600-1000 km
- High route flexibility
- Good performance
- Energy consumption
- Refueling ease
- Short refueling time
- Infrastructure: High Europe
- Costs: Indicators: cost/ton, Vehicles life span, TCO* Euro, TCO** Euro



Buses running on FAME/HVO

This bus technology uses biofuels to power the bus. With biofuels, each type and blend of biofuel requires specific buyers must have a clear initial understanding of what kind is used in the specific bus.

Emissions

GHG	Masses	Euro V diesel	Euro V FAME 100	Euro V HVO100
CO ₂ eq	g/km	1000	500 and more	500 and more
NO _x	g/km	3,51	4.39	3.16
PM10	g/km	0.10	0.04	0.08

Emissions from biofuel buses depend on the feed stock used to produce the biofuel and on the biofuel blend used. For lower blends, emission benefits will be proportionally less.

Noise: Liquid biofuels have no significant effect on noise.

- Operational range: 370-1000 km
- High route flexibility
- Good performance
- Energy consumption
- Refueling ease
- Short refueling time
- Infrastructure: Some fully widespread some cases
- Costs: Indicators: TCO* Euro, TCO** Euro



Smart choices for cities
Clean buses for your city

Electric bus

A bus that is driven by a purely electric motor powered by batteries charged with electricity. The vehicle has no other power source other than the battery. Two types are available:

- Opportunity e-buses aim to minimize the weight of the battery by recharging en route at passenger stopping points. They have medium battery capacity (typically 40-60 kWh) and need regular charging from the grid at intermediate stops.
- Overnight e-buses carry the weight of battery required to drive the entire route without recharging. They have a large battery capacity (typically >200kWh) and recharge the battery from the grid only at the depot.

Emissions

GHG	Masses	Electric bus
CO ₂ eq	g/km	500
NO _x	g/km	0
PM10	g/km	0

Note: Lower noise level than standard diesel buses (electric motor is quieter than combustion engine).

Operational performance

- Opportunity - charging buses:**
 - Short line range of <100 km.
 - Unlimited route flexibility
 - Recharging needed multiple times a day
 - Short recharging time: 5-10 min
 - Energy consumption 2012 (based on prototypes): 1.8 kWh/km
 - Energy consumption 2020: 1.58 kWh/km
- Overnight - charging buses:**
 - Medium line range: 100 - 200 km
 - Higher route flexibility
 - Recharging at the end of each day
 - Very long recharging times: more than 3 hours
 - Energy consumption 2012 (based on prototypes): 1.91 kWh/km
 - Energy consumption 2020: 1.68 kWh/km

Both for opportunity and overnight-charging buses charging time depends on the power of charging station and battery technology.

Its service life is estimated to be 12-15 years, depending on duty cycle, ambient conditions and charge rate.



Factors to take into consideration

Opportunity electric buses are considered promising but projected costs.

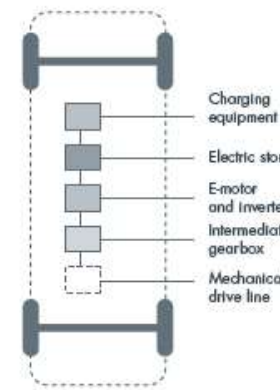
Overnight electric buses are not expected to meet long range requirements nor carry a sufficient number of passengers due to the weight of the batteries within 10 years.

Recent advances in technology, therefore careful studies need to be done before the purchase in order to select the best possible option available on the market.

Operational advantages: one of the cleanest technologies

Operational disadvantages: high purchase price, investment in infrastructure

Electric powertrain



What energy carrier to choose?

Table 2. Comparison of bus technologies on some operational characteristics

Bus technology/energy source	Fossil fuel			Biofuel			Electricity			Hydrogen	Hybrid
	diesel	diesel	CNG	FAME B100	HVO B100	Bio-methane	Opportunity	Overnight	Trolley	Hybrid hydrogen/electric	Serial hybrid electricity/diesel

Table 3. Comparison of bus technologies on their environmental performance

Bus technology/energy source	Fossil fuel			Biofuel			Electricity			Hydrogen	Hybrid
	diesel	diesel	CNG	FAME B100	HVO B100	Bio-methane	Opportunity	Overnight charging	Trolley bus	Hybrid hydrogen/electric	Serial Hybrid electricity/diesel

Table 4. Comparison of bus technologies by economic performance

Bus technology/energy source	Fossil fuel			Biofuel			Electricity			Hydrogen	Hybrid
	Euro V	Euro VI	CNG	FAME B100	HVO B100	Bio-methane	Opportunity	Overnight	Trolley	Hybrid hydrogen/electric	Serial hybrid electricity/diesel
Indication purchase price, 1000 euros											
TCO 2012, euro/km											
TCO 2030, euro/km											
Additional Infrastructure Investment, 1000 euros											

Source: TNO, where green represents the cheapest option, red the most expensive option

operations

environmental performance

economic performance

If financial resources allow

municipalities and public transport operators should aim for the zero-emissions or closest to it options.

Otherwise,

especially within current conditions of economic and financial crises conventional diesel buses (Euro VI) and their hybrid configurations represent a very good environmentally friendly option as well.

Want to learn more? Join us!



1. Go to “www.civitas.eu”

2. Go to “working groups”

3. Select one of the CIVITAS Thematic groups

- Clean vehicles and fuels (moderated by Ivo Crè - ICre@polisnetwork.eu)
- Collective passenger transport (moderated by Cosimo Chiffi - chiffi@trt.it)

4. Register yourself as user

5. Post your question // engage in discussions

Thank you!

Teije Gorris

Contact Details

TNO // CIVITAS WIKI

teije.gorris@tno.nl // teije.gorris@civitas.eu

<http://www.civitas.eu>

TNO innovation
for life



THE CIVITAS INITIATIVE
IS CO-FINANCED BY THE
EUROPEAN UNION