Agenzia nazionale per le nuove tecnologie,
l'energia e lo sviluppo economico sostenibile

Road Public Transport decarbonisation: a comparison among vehicle technologies

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EU GREEN DEAL, TOWARDS DECARBONISATION OF ROAD TRANSPORT

Setting more ambitiuos CO_2 standards for LVs, to **help the growth of the number of zero and low emissions vehicles**

Binding requirements for the rollout of **public charging and hydrogen refuelling stations** for cars, van and trucks

2025	2030	2040	2050
1 million	3.5 million	11.5 million	16.3 million

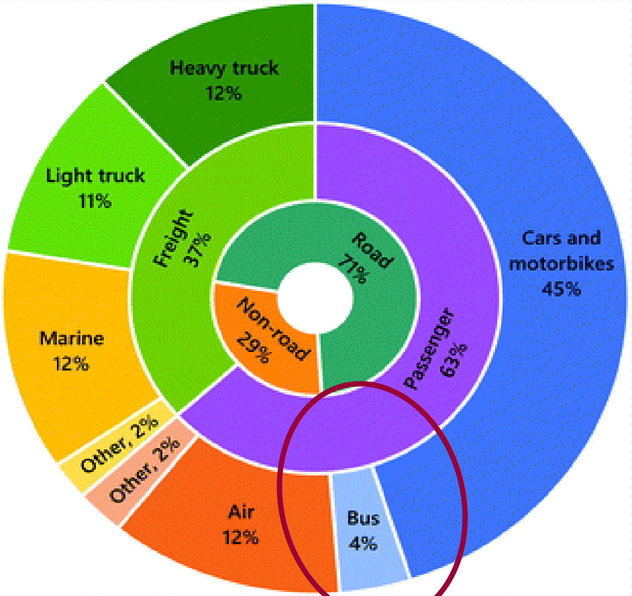
Charging station deployment target

Reduction in transport GHG intensity: -13% by 2030

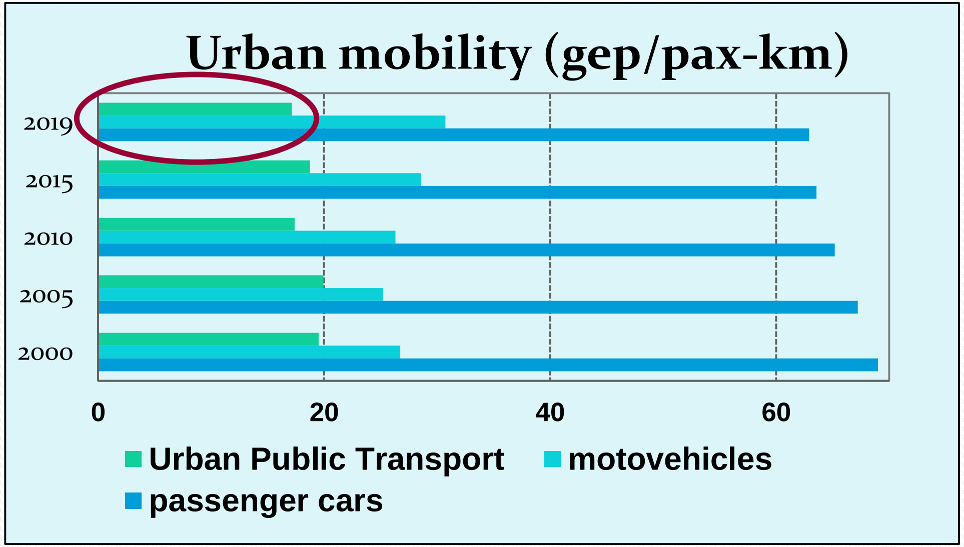
Targeted share of renewable H_2 and syntetic fuels: 2.6% by 2030

Targeted share of advanced biofuels: 2.2% by 2030

PUBLIC TRANSPORT ENERGY TOPICS



I. Staffell *et al.*, "The role of hydrogen and fuel cells in the global energy system," 2019



Source: ENEA on MiSE, MIMS, ISPRA data

PT accounts for few percents on energy consumption and GHG emissions of transport sector but it is a very efficient transport mode, when compared to private vehicles.

Polycies to make transport greener attribute a major role to modal shift towards PT in urban areas

BEBs & HFCBs to the fore

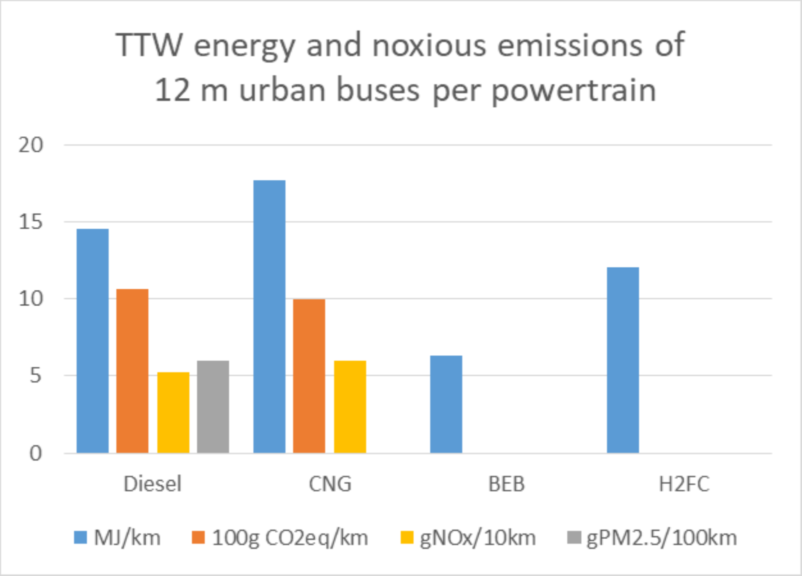
"…..2019 will be remembered as the year when the electric bus sales volumes definitive ramp up also in Europe……. **5,087 e-buses have been delivered since 2012**…… nearly 75% of them have been handed over in 2019 and 2020…….

……100 YUTON hydrogen buses are bound to Beijing's public transport operation. 30 HFC units have been delivered on December 2021" Source: https://www.sustainable-bus.com/ 19 May 2020

Although urban PT accounts for a minority of the total passenger road transport energy consumption and GHG emissions it is considered to be an optimal testbed for new vehicles technologies, due to the possibility of taking advantages from "economies of scale" and scheduled vehicles operation

EVS ENERGY AND ENVIRONMENTAL CHARACTERISTICS

Electric buses are optimal for urban contexts, thanks to Zero Exhaust Emissions and less noise at point of use, than conventional ones.



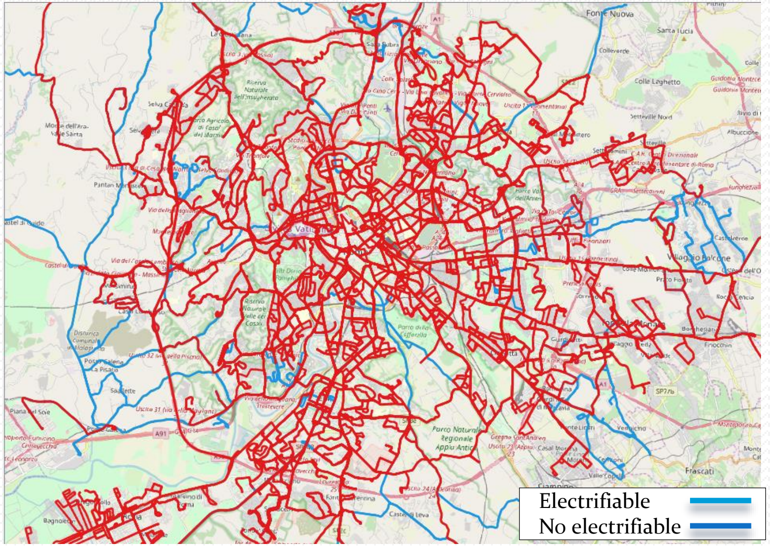
Source: ENEA on ISPRA & CNR data

Moreover they are more efficient from an energetic point of view

But what about the economic aspects, from the operator point of view???

A TCO ANALYSIS TO COMPARE ECONOMIC FEATURES OF BUS TECHNOLOGIES

282 weekday lines of which 59 circular, 12-year analysis, 1% discount rate



A: mainly overnight recharge at depot; large battery, low recharge rates
B: mainly recharge at bus-terminals during operation time, plus overnight; medium battery, high nominal recharge rates
C: mainly recharge at bus-stops and terminals, plus overnight; small on-board storage, very high nominal recharge rates

Tech.	Purchase cost [k€]	Maintenance cost [€/km]	Payload [n. pax]	Lifespan [km]	Battery [kWh]
BEB A	365-415	0.15*	103-75	1,000,000	200÷324
BEB B	327	0.15*	103	1,000,000	70
BEB C	334	0.15*	103	1,000,000	2.8 + 30
Diesel	230	0.26	103	900,000	
CNG	250	0.35	103	700,000	
HEV	345	0.28	103	1,000,000	
H2FC	670	0.8	84	1.000.000	

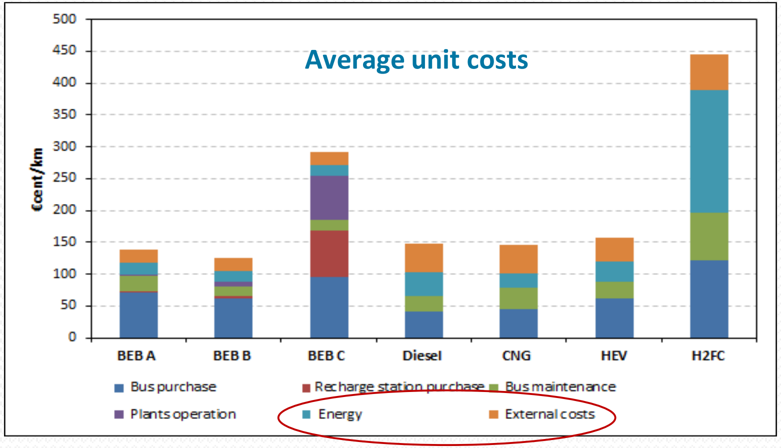
Battery Type	Lifespan cycles	Specific cost [€/kWh]	BEB solution
LiFePO	3.000	400	A
LTO	15.000	700	B
Ultracap	1.000.000	15.000	C

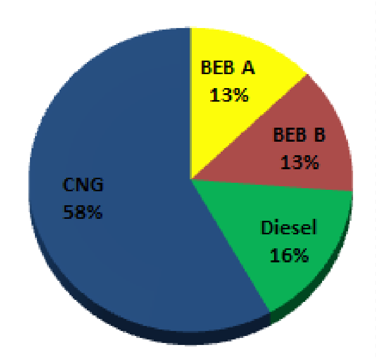
Recharge station location	BEB solution	Power [kW]	Purchase and installation cost [k€]
Depot	A	30 ÷50	15÷25
Depot	B-C	6÷16	7÷10
Terminal	B	30÷300	45÷135
Stop	C	600	260

MAIN RESULTS

N° of BEB solutions applicable to line	% of lines	HFCB	% of lines
1	25.2%	1	100%
2	51.1%		
3	18.1%		
Total BEB	94.3%	Total HFCB	100%

Technology applicability to lines



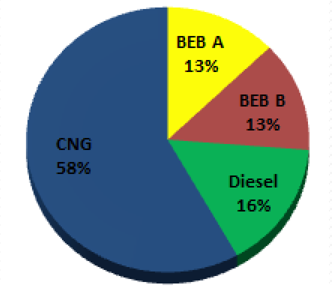


Economic prevalence on internal costs 2019 distribution

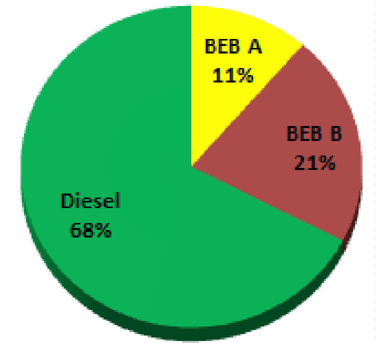
- A and B solutions for battery powertrain are equally competitive respect to conventional alternatives
  - A is upgraded through an additional opportunity recharge at midday and tailorization on the specific operational needs of the bus-line. In general, the payload results lower than conventional buses, due to the battery incidence on weight and volumes of the vehicle
    - Solution B is more expensive as for recharge infrastructures but investments for vehicles are lower than A, thanks to a reduced battery capacity. Moreover payload capacity is similar to conventional alternatives
      - Solution C and HFC are not currently competitive due to the high CAPEXs and OPEXs. C represents an interesting alternative to the new construction of trolleybus lines or to extend existing ones

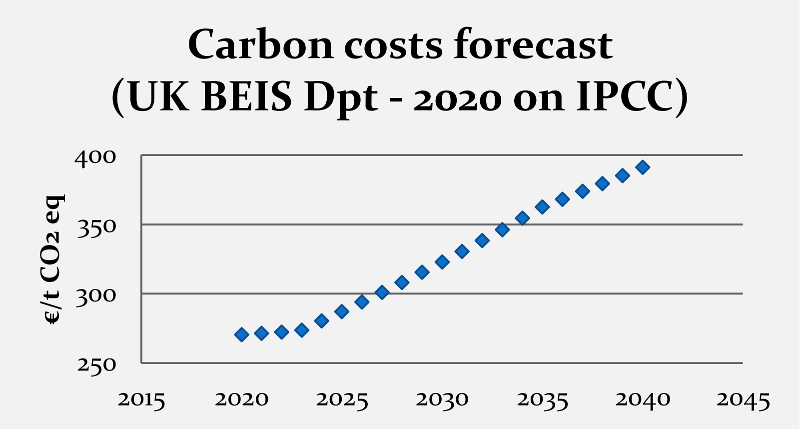
RELEVANCE OF EXTERNAL COSTS AND ENERGY PRICES

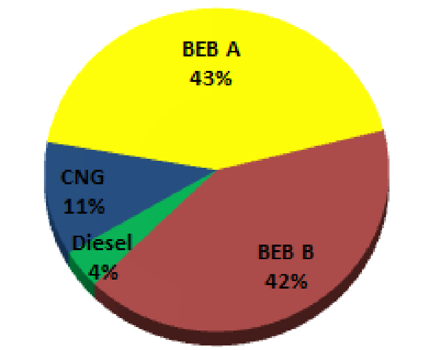
TCO on internal costs - 2019



TCO on internal costs - 2021







TCO on internal & external costs 2019

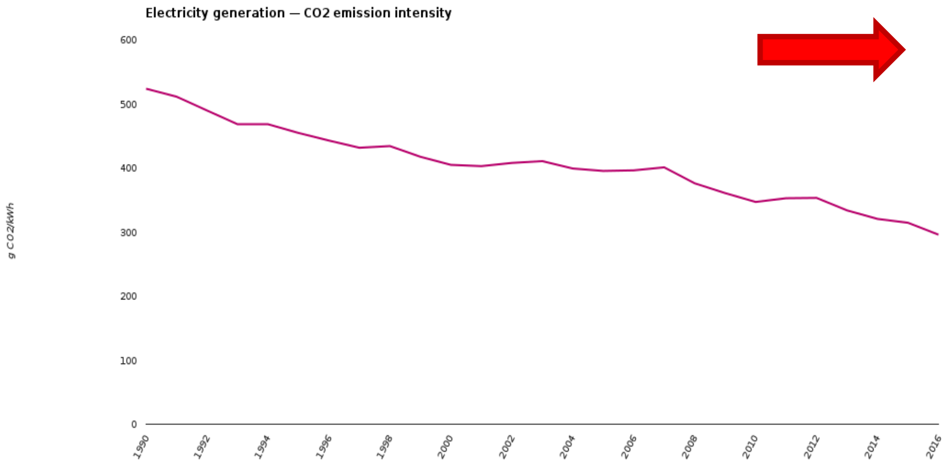
	EE Power [€/kW/year]	EE Withdrawal [€/year]	EE Energy [€/kWh]	Diesel [€/l]	CNG [€/kg]	H2FC [€/kg]
2019	25.70	616.3	0.119	1.0	0.649	6.16
2021	25.99	627.1	0.171	1.2	0.9735	9.24

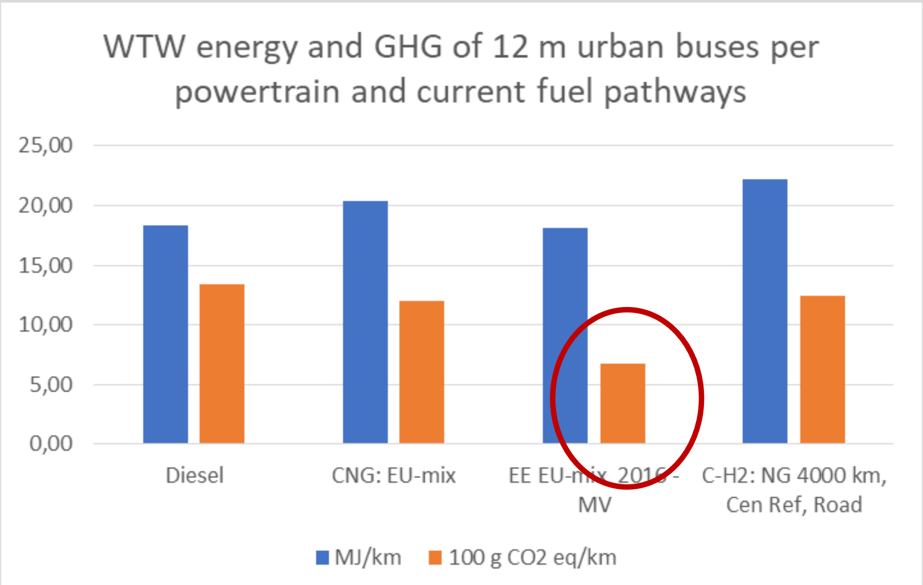
Pollutant	Area	€/t
NOx	Urban	25,400
$PM_{2.5}$	Metropolitan	409,000
	Urban	132,000

Economic covenience is highly affected by energy and environmental prices

……..AND ENERGY PATHWAYS

BEBs have a positive impacts not only on local pollution and noise, like HFCBs as well, but also on Global Warming, thanks to an EU electricity mix which already includes large amount of generation from RES

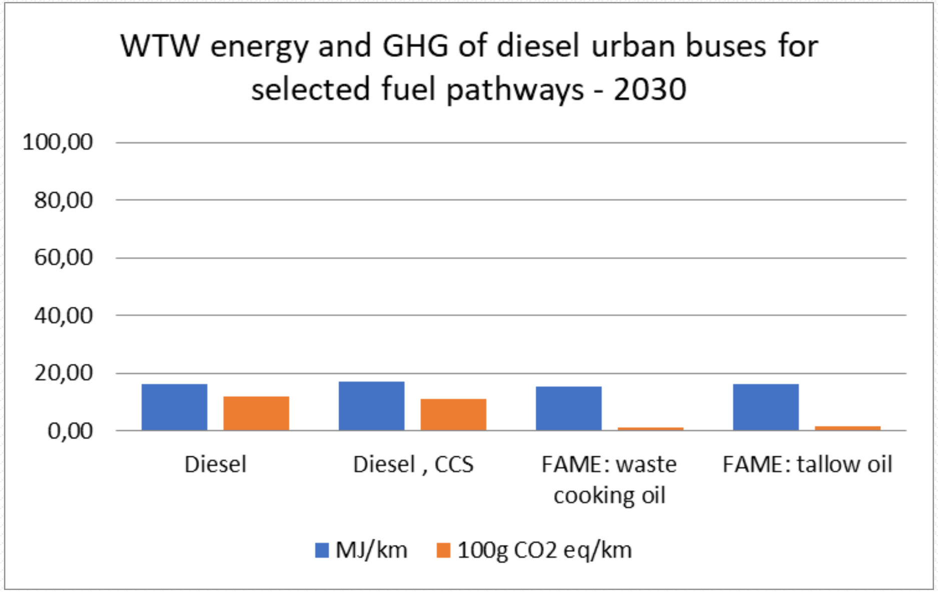




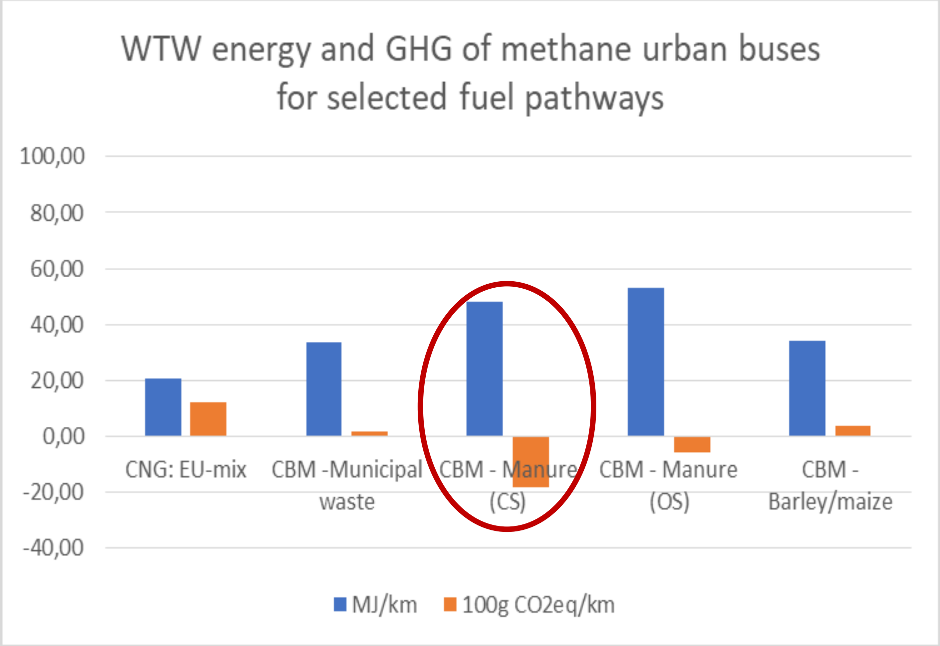
Source: ENEA on JRC-Concawe data 2020

On the contrary, hydrogen production for HFCB is currently mainly linked to Natural Gas, via SMR, so that GHG emissions along the whole WTW cycle result equal or at least higher than conventional solutions

ENERGY PATHWAYS FOR ICES: FROM FOSSIL TO BIOFUELS

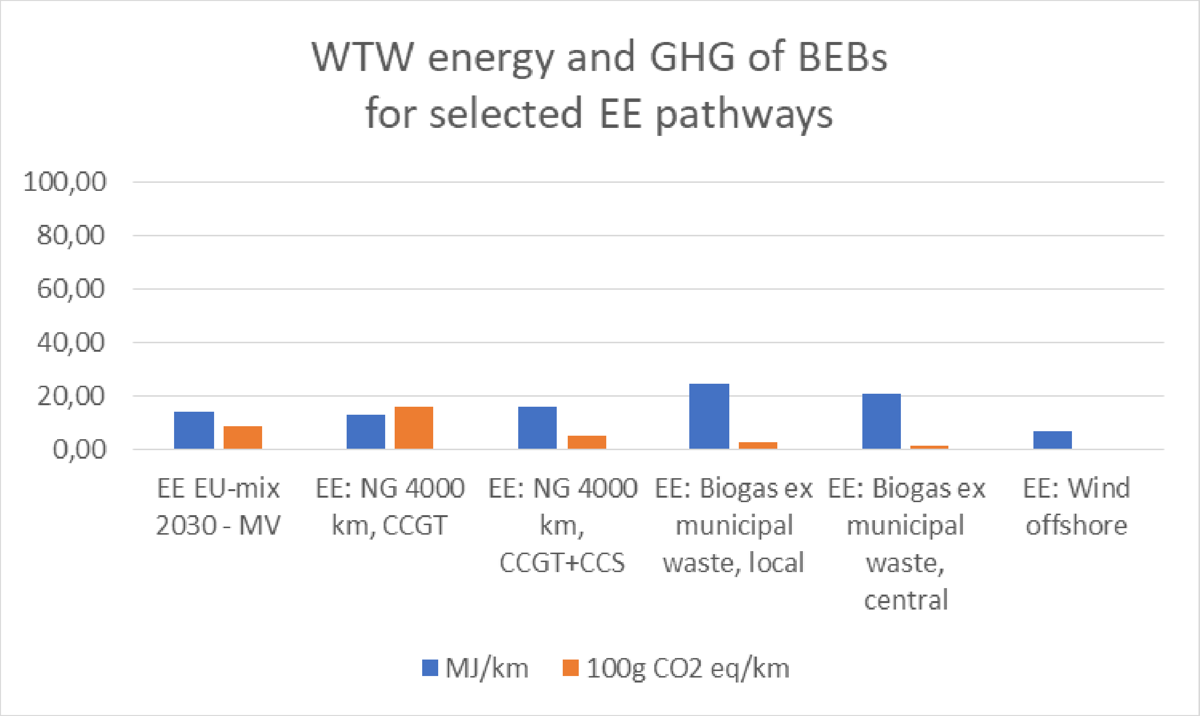


Source: ENEA on JRC-Concawe data 2020



Passing from fossil fuels to biofuels the GWP highly reduces, in some cases becoming even positive, thanks to the re-use of organic resources which would have produced GHG emissions in any case, such as for manure from farms or municipal organic waste.
On the contrary, energy expenditure increases, due to a more complex process to produce fuel from organic resources than from fossil fields

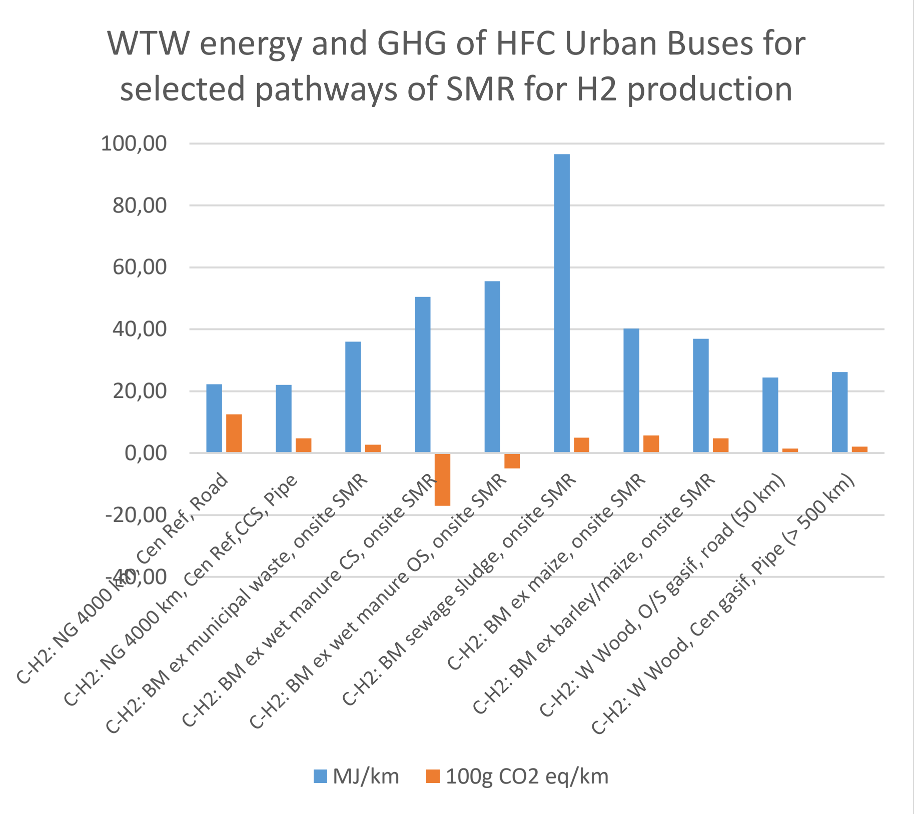
ENERGY PATHWAYS FOR BEVs: RES AND BIOGAS TO ELECTRICITY

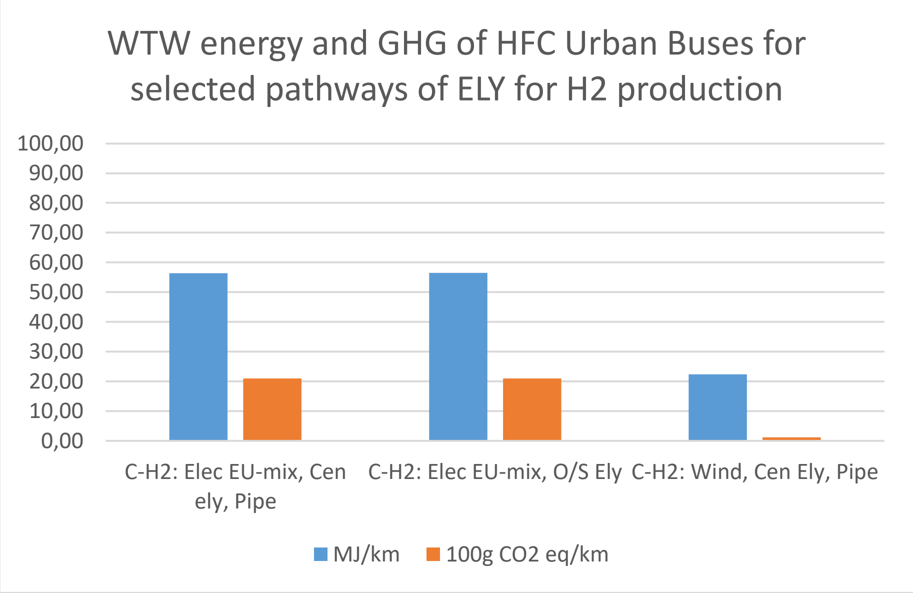


Source: ENEA on JRC-Concawe data 2020

Also for the electricity generation, less carbon intensive pathways are possible and, in some cases, like offshore wind, energy expenditure reduces too, respect to CCGT, which is the current reference technology for electricity generation from fossil sources (NG)

ENERGY PATHWAYS FOR HFCVs: SMR AND ELECTROLYSIS

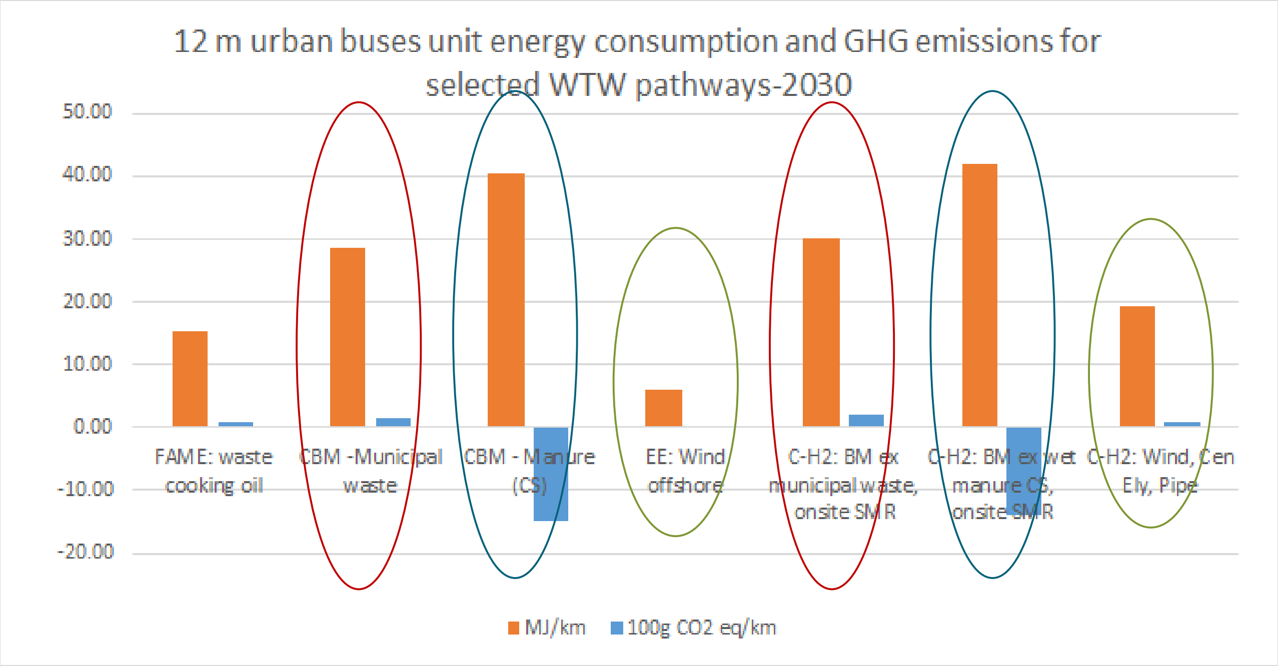




Hydrogen is produced from either SMR or electrolysis, in practice from methane or electricity.
As a consequence, if methane is from biological resources and electricity is from renewables, such as PV o wind, the hydrogen become green, and the overall GWP reduces respect to current SMR with NG

Source: ENEA on JRC-Concawe data 2020

Powertrain comparison for different energy pathways



WTW energy consumption and GHG emissions for compressed biomethane buses and HFC buses fuelled with reformed biomethane are comparable

WTW energy consumption and GHG emissions for battery buses powered with green electricity are lower than HFC buses fuelled with hydrogen from green electrolysis

FINAL REMARKS

- In a comprehensive strategy for Transport decarbonisation, battery and HFC for electric vehicles should coexist, also considering the potential of Power to X (P2X) technologies to store the excess of RES generation as hydrogen.
- In this view, also the electricity costs will be more acceptable for both
- A mindful use of electricity (directly or by e-fuels) for automotive uses must be carried out in a future where electricity demand is expected to strongly grow for all end uses, not only for transport, and electric energy will be more and more “green”, expensive and scarce respect to demand; the most efficient solutions along the WTW cycle must be preferred
- Regarding hydrogen from biomass, it represents a valid alternative for HFCVs but its production could be limited by finite biomass stocks
- At the current state of road electric vehicles technologies and commercialisation, hydrogen use should be preferred for applications where wide ranges and flexibility are leading requirements, like long haulage or, more in general extra-urban transport
- Further analysis are being carried out on the energy and carbon impacts of vehicles and infrastructures construction and dismantling, for a more comprehensive comparison of different vehicles technologies role in the EU energy transition and decarbonisation.

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END
THANK YOU

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