

MOBILITY ENERGY ENVIRONMENT



The future moves us.

Riccardo Enei

«The coach of the future study : preliminary results»

IRU Conference - 20.10.2017

Introduction to the presentation

- Presentation of the preliminary conclusions of the study
- Need to validate the preliminary conclusions with stakeholders' consultation
- Final report of the study by end of October/early November 2017

Structure of the presentation

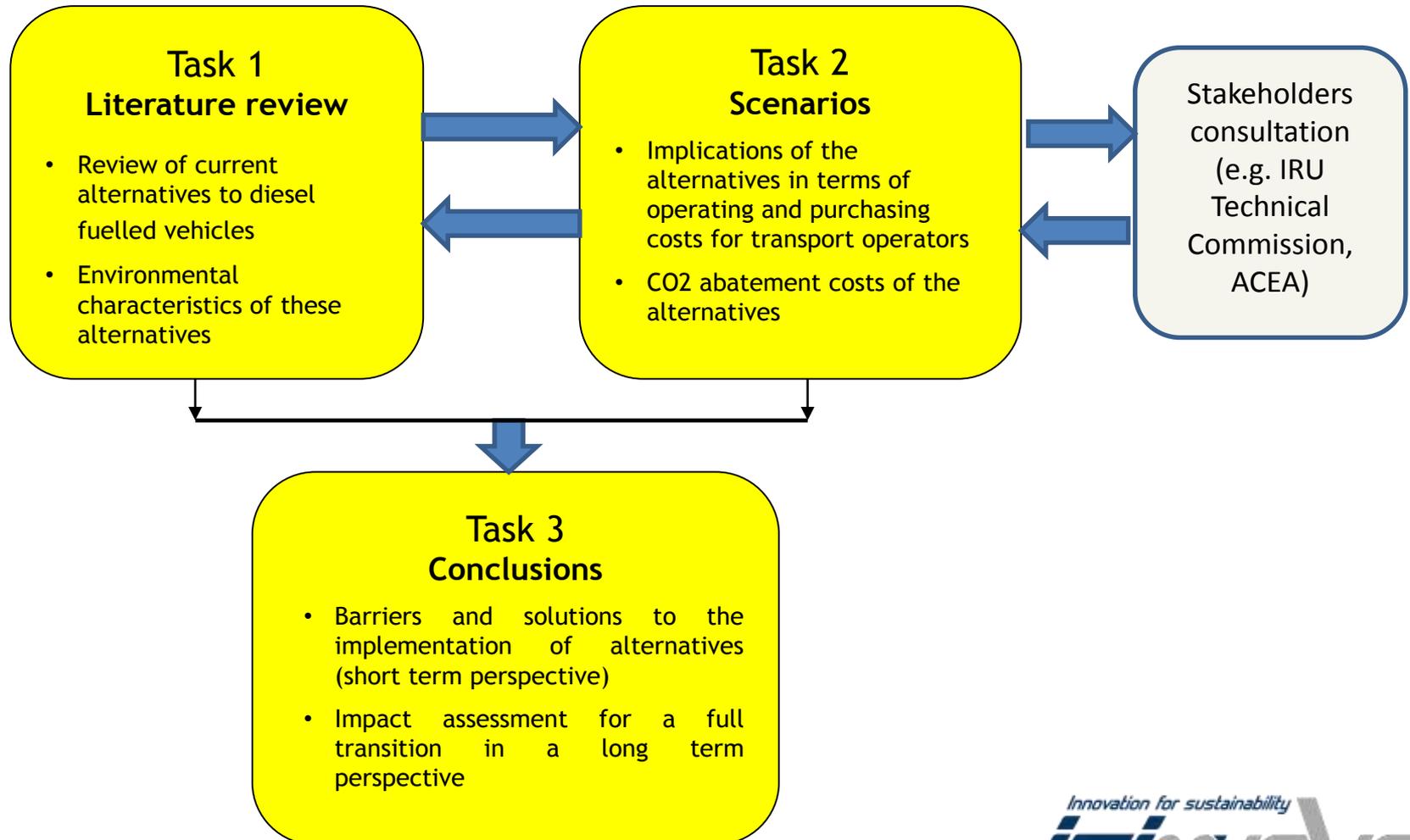
- Scope
 - Background and rationale of the study
 - Stages and topics
- Preliminary conclusions
 - Available alternative fuels
 - Environmental characteristics, business case and abatement costs
 - Barriers and solutions
 - Impacts of the transition
- Next steps

Background and rationale

- Decision to ban diesel vehicles taken by four major cities (Paris, Madrid, Mexico City and Athens) at the C40 meeting of urban leaders in Mexico (2016) – political announcement -

- What would be the implications for industry and operators of a «sudden» transition to alternative fuels?

Stages and topics of the study



Available alternative fuels

Alternative fuels: EC Communication on “Clean Power for Transport” (2018)

Alternative Fuels	Mode	Road passengers		
		Range*	Short	Medium
LPG				
Natural gas	LNG			
	CNG			
Electricity				
Biofuels (liquid)				
Hydrogen				

LPG mainly used in retrofitted cars.

LNG mainly used in medium-long range

Storage capacity and energy density is 5 times lower than LNG. Not viable over the long distance.

Full battery electrification coach fleets is not likely to happen in the short-term period.

Available alternative fuels

Preliminary conclusions:

- **In the short-medium term (2025)**, viable alternative fuels and propulsion systems to diesel have been identified as:
 - Natural gas (including blending with biomethane or synthetic biomethane fuels)
 - Liquid biofuels (biodiesel, HVO, synthetic fuels)
 - Electric plug-in propulsion (with diesel, gas or bio-fuels)
- **In the long-term**, the use of hydrogen (e.g. fuel cells) should also be considered.

Preliminary conclusions – Environmental characteristics

- Emissions expressed on a TTW basis:
 1. *Uncertainties in the evaluations.* The assessment of fuel lifecycle emissions may be problematic.
 2. *Perspective of the study.* The study focuses on transport operator and manufacturer. Hence, the analysis does not take into account environmental implications arising from the activity of other stakeholders, as fuel producers.
 3. *Scale of the analysis.* The transition to alternative and sustainable fuels implies both a global scale (e.g. decarbonisation of energy system) and a local one (air pollution reduction in urban areas).

Environmental characteristics

From Euro VI Coach EMEP/EEA. (2014). Air pollutant emissions inventory guidebook

Natural Gas, Biofuels and Hybrid from several sources: literature review (e.g. CIVITAS for last generation of urban bus) and stakeholders' consultation for coaches (Swedish case).

Type of fuel/ pollutants	Diesel VI	Natural gas (LNG)	Liquid biofuels	Diesel Hybrid	Hydrogen Fuel cell
CO ₂ (g/km)	100	↓	↓	↓	0
NO _x (g/km)	100	↓	↔	↓	0
PM (g/km)	100	↓	↓	↓	0

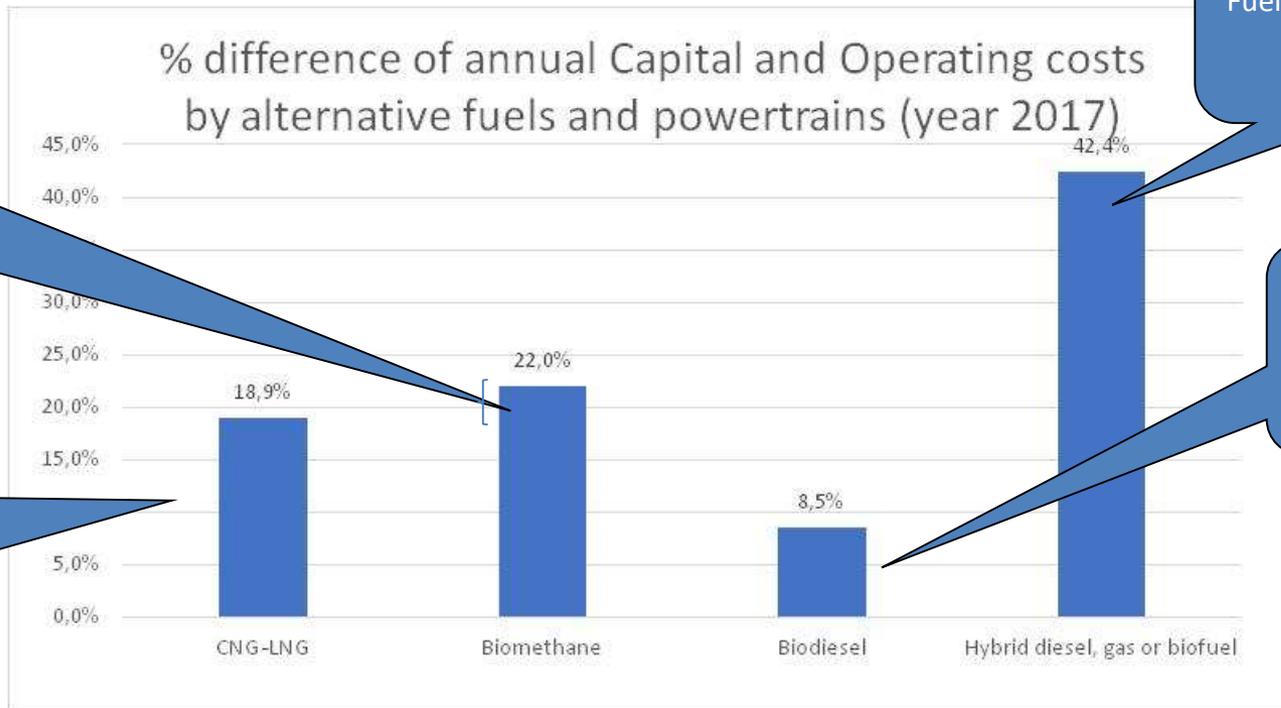
Compared to a Diesel Euro VI coach, we expect similar, "somewhat lower" NO_x emissions, and substantially lower PM and CO₂ TTW emissions. Concerning NO_x the difference tends to be negligible and, in specific cases (biofuels), may be controversial. THERE ARE VALID ALTERNATIVES, IN THE LONG AS WELL AS IN THE SHORT TERM, THE ISSUE AT STAKE IS THEIR COST

Business case

Business case

Capital (30%)
Fuel (40%)
maintenance costs (30%)
Fuel cost makes the difference

Capital (31%),
fuel (38%)
and maintenance costs (31%)



Capital (53%)
Maintenance (26,6%)
Fuel costs (20,4%)

Capital (28%)
Maintenance (31%)
Fuel costs (41%)

Abatement costs

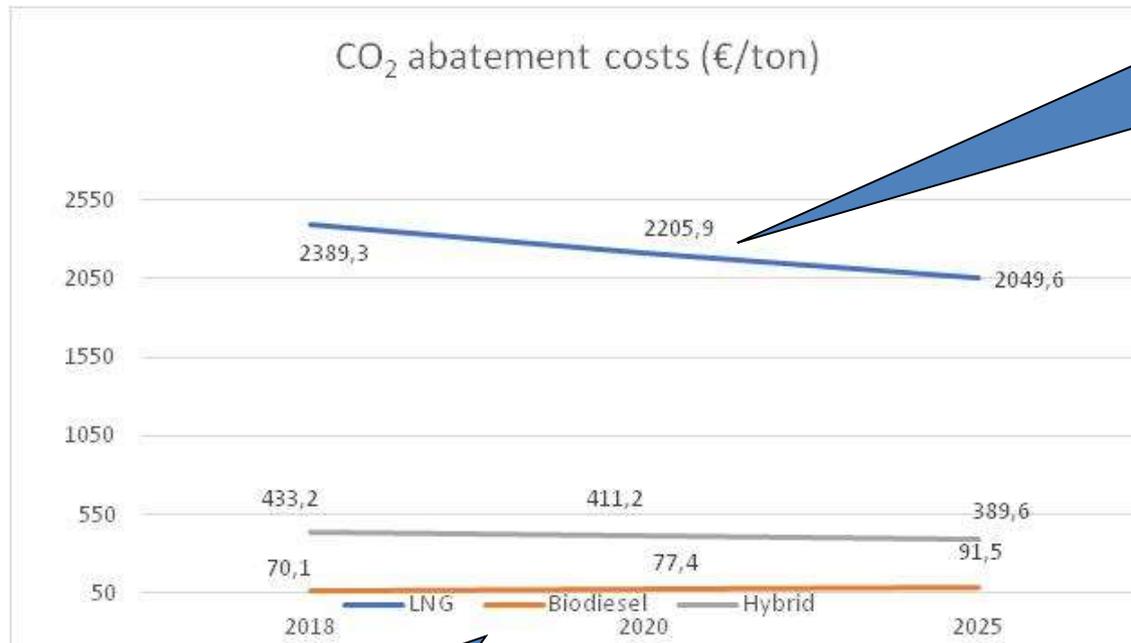
Cost effectiveness of the transition: € spent per tCO₂ , gNO_x and gPM abated

$$\text{Cost effectiveness} = \frac{I + \Delta\text{OC} - \Delta\text{fuel costs}}{\text{Annual CO}_2, \text{Nox and PM emission abatement}}$$

I = Annualised investment costs

ΔOC = Differential of O&M costs related to Diesel Euro VI vehicle

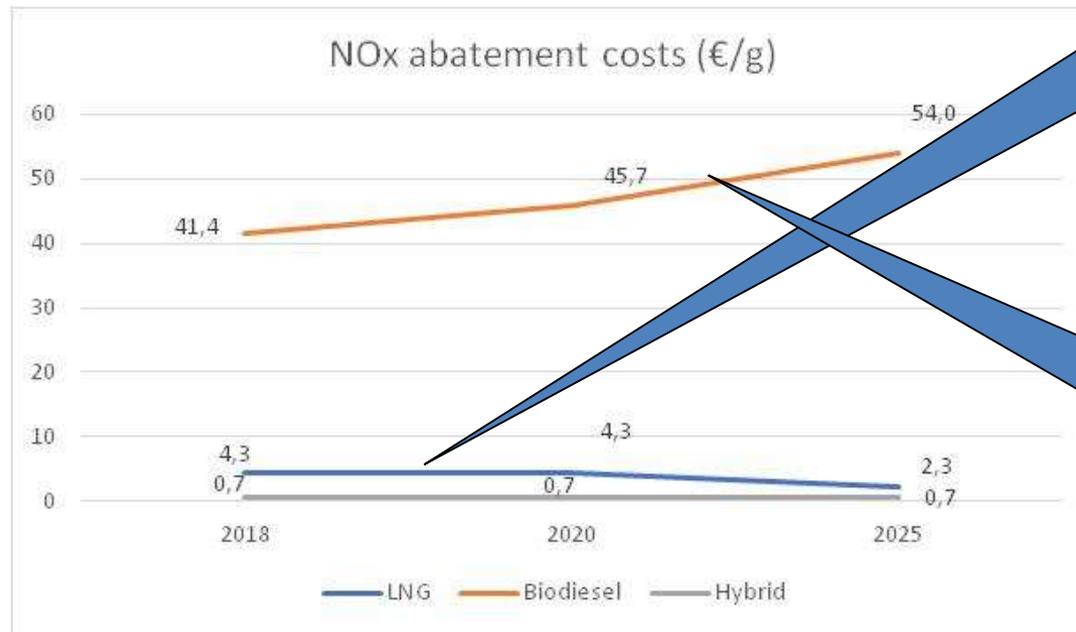
Abatement costs



Decreasing trends due to fuel efficiency and diminishing capital costs

Higher Biodiesel cost effectiveness due to higher CO₂ differential compared to Euro VI diesel emissions

Abatement costs

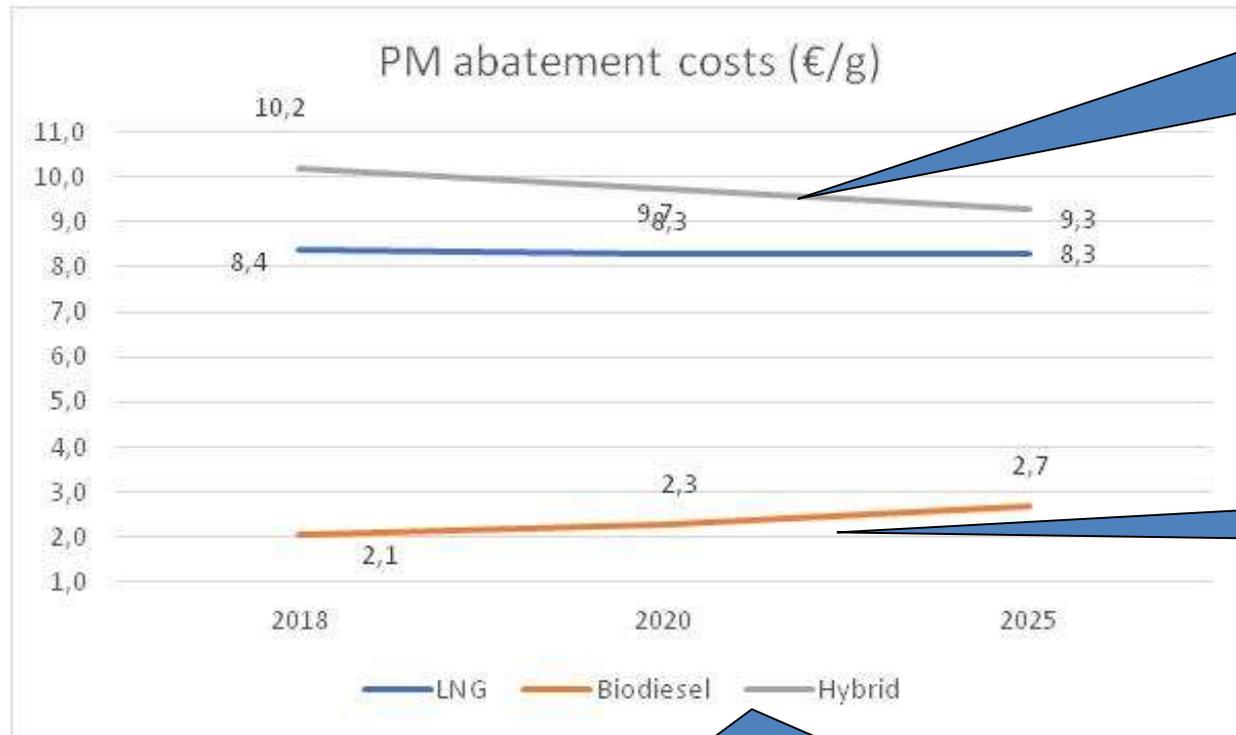


Decreasing trend due to fuel efficiency and diminishing capital costs

Higher trends due to rising and fuel price and uncertainties in NOx emissions

Higher Hybrid and Natural gas cost effectiveness due to higher NOx differential compared to Euro VI diesel emissions.

Abatement costs



Decreasing trend due to fuel efficiency and diminishing capital costs

Increasing trend due to fuel price dynamics

Higher Biodiesel cost effectiveness due to higher PM differential compared to Euro VI diesel emissions.

Preliminary conclusions – Environmental characteristics

- Emissions expressed on a TTW basis:
 1. Biodiesel shows better cost-effective ratios for CO₂.
 2. *Hybrid diesel, gas or bio-fuel and natural gas show better cost-effective ratios for NOx*
 3. Biodiesel shows better cost-effective ratios for PM (due to the Euro VI technology)

Barriers and solutions

Type of fuel and propulsion systems	Type of barriers by level of importance			
	Technological	Economic	Supply infrastructure	Fuel availability
CNG-LNG	Low (Mature technology)	Low (Higher vehicle acquisition costs)	Low/Medium (Not yet fully developed)	Low (Natural gas supply available)
Liquid biofuels Biodiesel- bioethanol	Low (Mature technology)	Low (Maintenance and vehicle costs)	Low/Medium (Lack of infrastructure (high blend biofuels))	High (Very limited resources)
Hybrid diesel, gas or bio-fuel electric	Low (Mature technology)	High (High vehicle acquisition and maintenance costs)	-	Medium (Long range batteries still lacking PHEV)

Barriers and solutions

Alternative fuels propulsion systems	Type of solutions		
	Political	Economical	Technological
CNG-LNG	Short-medium Term (Implementation of EU Directive (DAFI)*)	Short-medium Term (Appropriate incentives and taxation)	-
Liquid biofuels Biodiesel-bioethanol	Short-medium Term (Implementation of EU Directive (ILUC))	Short-medium Term (Appropriate incentives and taxation, investment in infrastructure)	Long term (New production capacity, new engines)
Hybrid diesel, gas or bio-fuel-electric	-	Short-medium Term (Reaching economies of scale in vehicle and maintenance costs)	Long term (Batteries availability for long range journeys)

(*)Deployment of Alternative Fuels Infrastructure (2014/94/EU)

Methodology (1)

- Scenarios of fleet substitution (30% and 50%) at 2025 for the EU coach fleet.

	2020	2023	2025
EU coach fleet (*)	335,000	326,000	322,000

(*) TML VISION 2030 FOR BUSES AND COACHES study and Steer Davies & Gleave

- **Tourism coach market**, whose average distance travelled is above 500km, mainly in motorways or non-urban roads.

Impacts

Methodology (2)

- Scenarios of fleet substitution (30% and 50%) at 2025 for the entire EU coach fleet

Scenarios	Hypothesis	
	Renewal rate (yearly)	% of fleet substitution at 2025
Average (2004-2015)	2%	≈ 15%
Scenario 1	5%	≈ 30%
Scenario 2	7%	≈ 50%

Business as usual scenario: renewal rate of about 2%, which in 2025 could lead to the renewal of the entire European coach fleet by about 15%.

Methodology (3)

- Elaboration of benefit to costs ratios according to the following formula.

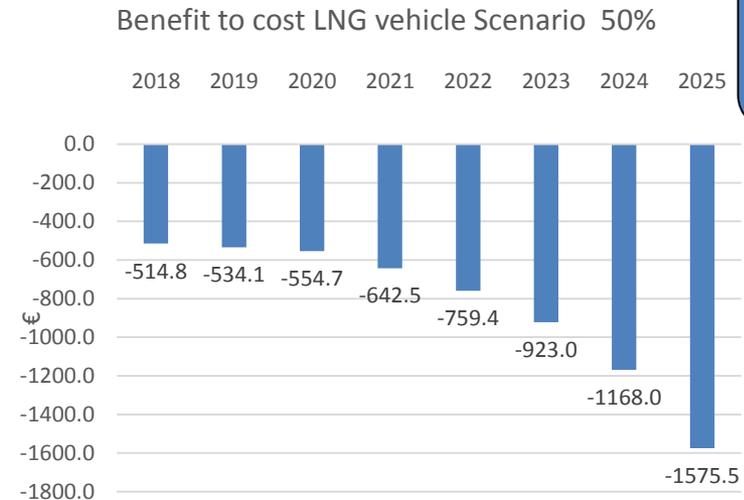
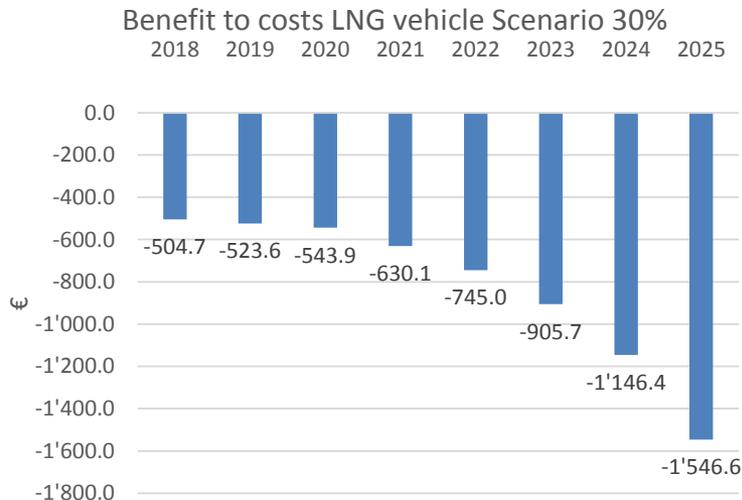
$$\text{Benefit-Cost} = \frac{\Delta \text{CO}_2 \text{ (WtW)}, \text{NOx}, \text{PM benefits}}{\Delta I + \Delta I_{\text{Infra}} + \Delta \text{OC} - \Delta \text{fuel costs}}$$

- Benefits are the monetary evaluations of environmental costs from shifting fleet composition (Dieselenvcost – Alter_fuelenvcost) ; if > 0 there are benefits
- Costs result as the difference from shifting fleet composition (Dieselcost – Alter_fuelcost) ; if > 0 there are benefits (lower costs of the transition)

Impacts

Results:

- benefit to cost ratios= benefits per € spent



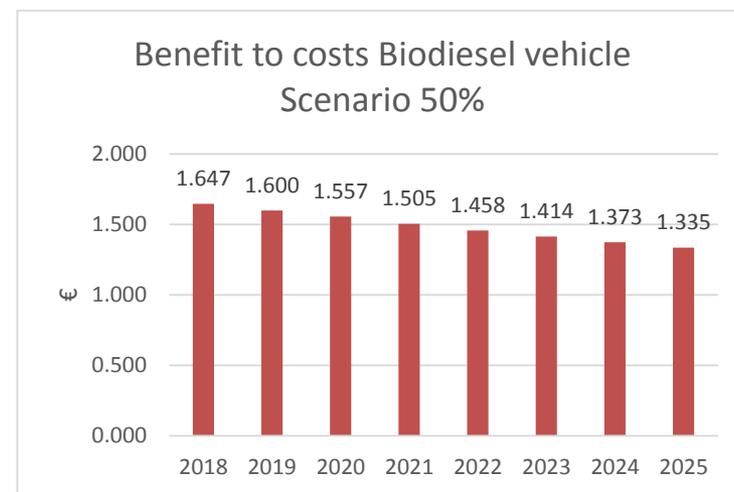
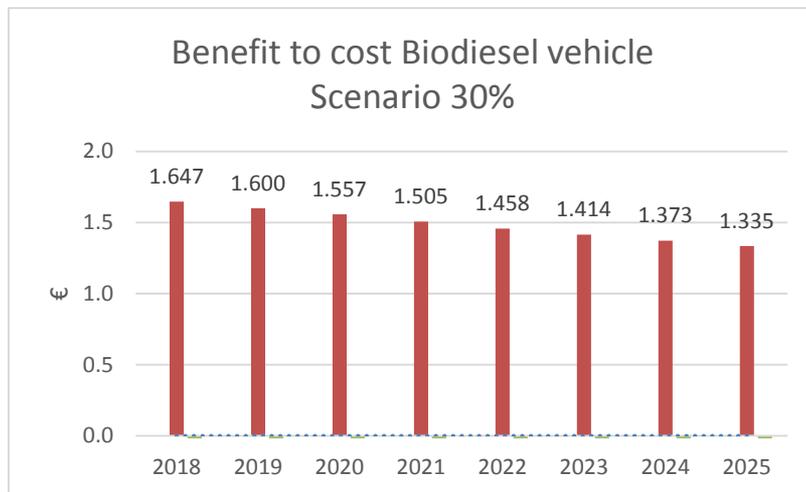
50% scenario: higher costs due to the higher losses due to lack of depreciation: about 20m/year

Growing trends due to the higher infrastructure costs (compared to diesel)

Impacts

Results:

- benefit to cost ratios= benefits per € spent



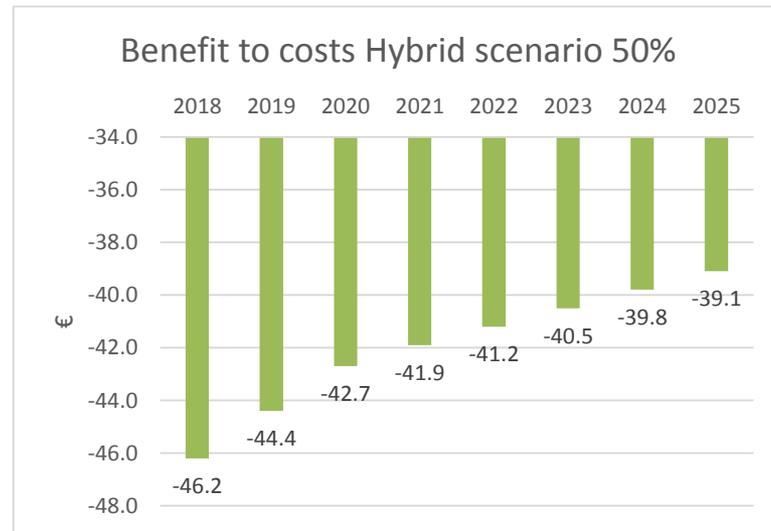
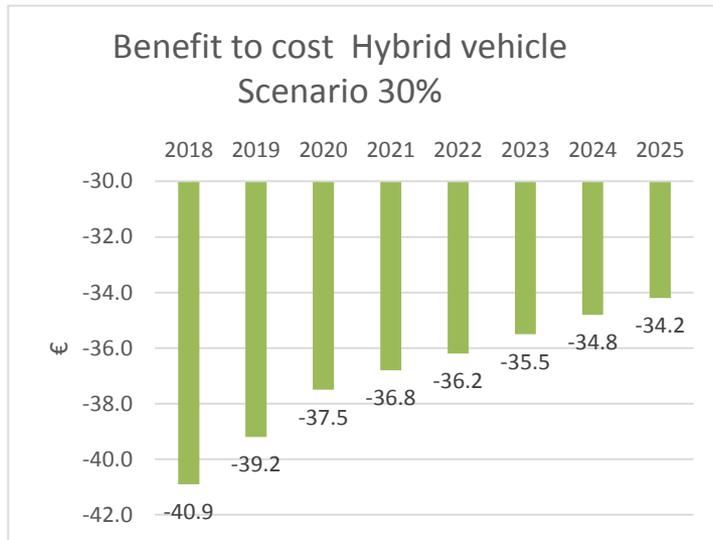
30% and 50% scenarios:
Same benefit to cost ratio due to the same vehicle acquisition costs compared to a diesel

Net benefit for the society: about 56m/year in scenario 30% and 77m/year in 50% scenario

Impacts

Results:

- benefit to cost ratios= benefits per € spent.



50% scenario: higher costs due to the higher losses due to lack of depreciation: About 170m/year

Slightly negative cost –benefit: trend toward the improvement of the ratio, due to savings from energy consumption and emissions

Preliminary conclusions – scenarios

- How to reconcile scenarios with actual market capacity – supply and demand side
?
 1. Are there enough products on the market (gas, biodiesel, hybrid) ?
 2. The starting date for the fleet renewal only when products are available.

Next steps

- Long term transition to alternative fuels
 - Timing and analysis of potential
 - Barriers and solutions
- Who benefits from the transition?
 - Stakeholders involved
 - Assessment of impacts (qualitative)

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Thank you for your attention!

Any questions?

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Assumptions
Business case

Business case

What is the business case for the purchase and use of these alternatives, in terms of purchase costs, operational costs and operating range for transport operators?

Preliminary conclusions – business case

Key costs categories (transport operators)

For representative vehicle characteristics (lifetime, km travelled, fuel consumption):

1. Fuel costs (short term scenario 2018-2025)
2. Vehicle acquisition costs (capital costs)
3. Key operating costs categories (maintenance and repair)

Business case

Vehicle characteristics

Vehicle characteristics		Mileage	Fuel	Lifetime	Fuel price
		annual km	l/100 km	year (*)	€/l
Diesel	Diesel IV	120000	27.7	13	0.68
	Hybrid diesel	120000	22.2	13	0.68
Natural	LNG	120000	59.1	13	0.40
Gas	LBM	120000	59.1	13	0.85
Liquid biofuels	Biodies el	120000	30.5	13	0.95

Lifetime from literature review , i.e. Spanish fleet, maybe not representative of EU average

Fuel retail “at the pump” prices assuming diesel price from EU statistics and other fuel prices from stakeholders’ consultation

Business case

Fuel costs

Trends in fuel prices, from CLEAN FLEETS (2014), and US-Energy Administration (2012).

Fuel costs		Vehicle costs
		€/year
Diesel	Diesel IV	22636
	Hybrid diesel	16997
Natural gas	LNG	26711
	LBM	28522
Liquid biofuels	Biodiesel	25806

Fuel price trend (% cumulative, 2017)	2017	2020	2025
Diesel	-	4,92%	12,79%
LNG	-	3,14%	10,46%
LBM	-	3,27%	4,86%
Biodiesel	-	6,11%	15,34%

Extreme volatility in fuel prices, difficulties in getting reliable projections (e.g. biofuels)

Business case

Acquisition costs

From stakeholders consultations and literature review (bus)

Vehicle acquisition costs		Vehicle costs
		€/unit
Diesel	Diesel IV	231000
	Hybrid diesel electric	572880
Natural gas	LNG	274800
Liquid biofuels	Biodiesel	231000

Business case

Operating costs

Operating costs		Vehicle costs
		€/year
Diesel	Diesel IV	18000
	Hybrid diesel	22240
Natural Gas	LNG	21600
Liquid biofuels	Biodiesel	19800
	HVO	18000

Average operating and maintenance costs from VTT study “Overall Energy Efficiency and Emission Performance” and stakeholders consultation

From natural gas to biodiesel, operating costs decrease by 10% (even more if to Hydrotreated Vegetable Oils)

Business case

Trends in fuel efficiency and operating costs

	2020	2025
Fuel efficiency	+0.1%	+0.6%
Capital costs	-0.1%	-0.3%

AEA (2012) "A review of the efficiency and cost assumptions for road transport vehicles to 2050"



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Assumptions Scenarios

Assumptions (benefits):

- Benefits are the monetary evaluations of environmental costs from shifting fleet composition ($\text{Diesel}_{\text{envcost}} - \text{Alter_fuel}_{\text{envcost}}$); if > 0 , there are environmental benefits. Emissions are multiplied for the below monetary evaluations:

	External costs (€/tonne)		
	CO ₂ e	NOx	PM
EU average (*)	90	10,640	70,258

(*) Source: Update of the Handbook on External Costs"Ricardo-AEA et al. , 2014

Assumptions (benefits):

- WTW CO2 emissions depend on feedstock and production methods (biofuels), production and distribution patterns (gas) and energy mix (electricity) . Average data from literature review.

Annual CO2t (*)	Diesel	LNG	Diesel Hybrid	Biofuels ILUC
WTT	133	138	126	129
TTW	87	83	87	87
WTW	221	221	213	135

Indirect Land Use Change costs play an important role in the WTW biofuels costs.

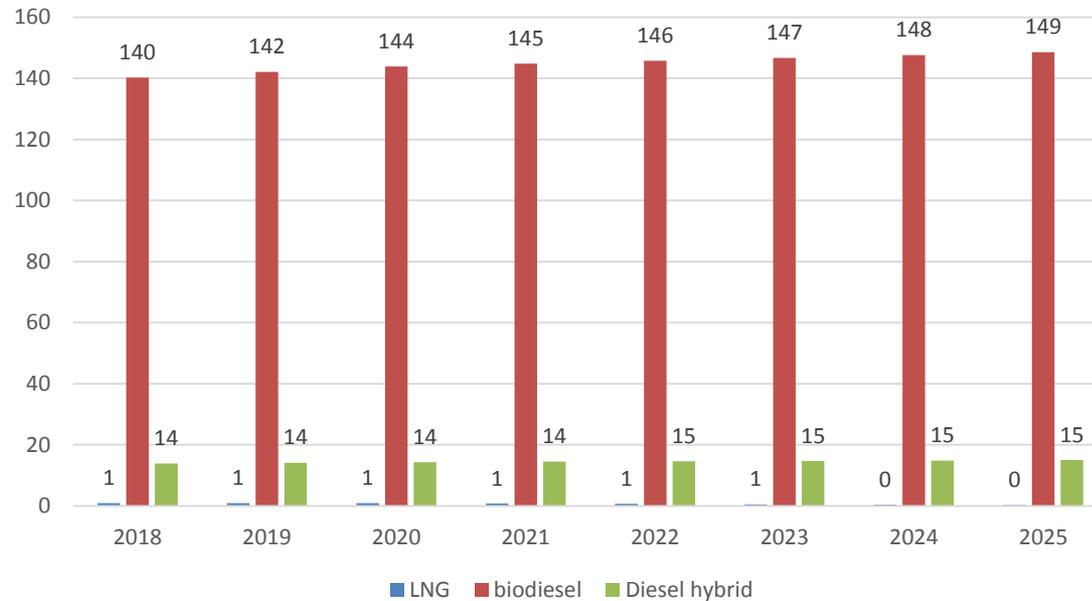
Based on EU electricity energy mix

(*) Calculated on 120,000km of annual mileage

Impacts

$$\text{Diesel}_{\text{envcost}} - \text{Alter_fuel}_{\text{envcost}}$$

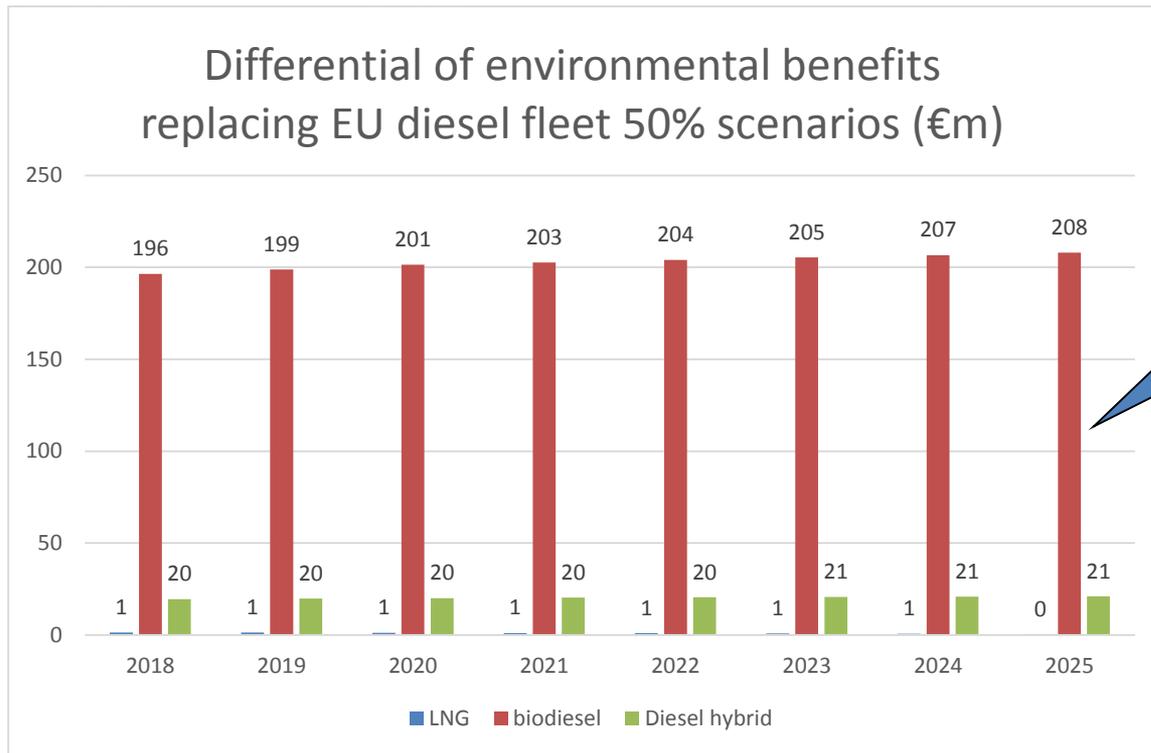
Differential of environmental benefits replacing EU diesel fleet 30% scenarios (€m)



High benefits in Biodiesel vehicles, depending on CO2 WTW emissions, particularly for biodiesel in case feedstock is not used as food or feed.

Impacts

$\text{Diesel}_{\text{envcost}} - \text{Alter_fuel}_{\text{envcost}}$



The higher the renewal rate, the higher the benefit (Diesel Hybrid and Biofuels vehicles)

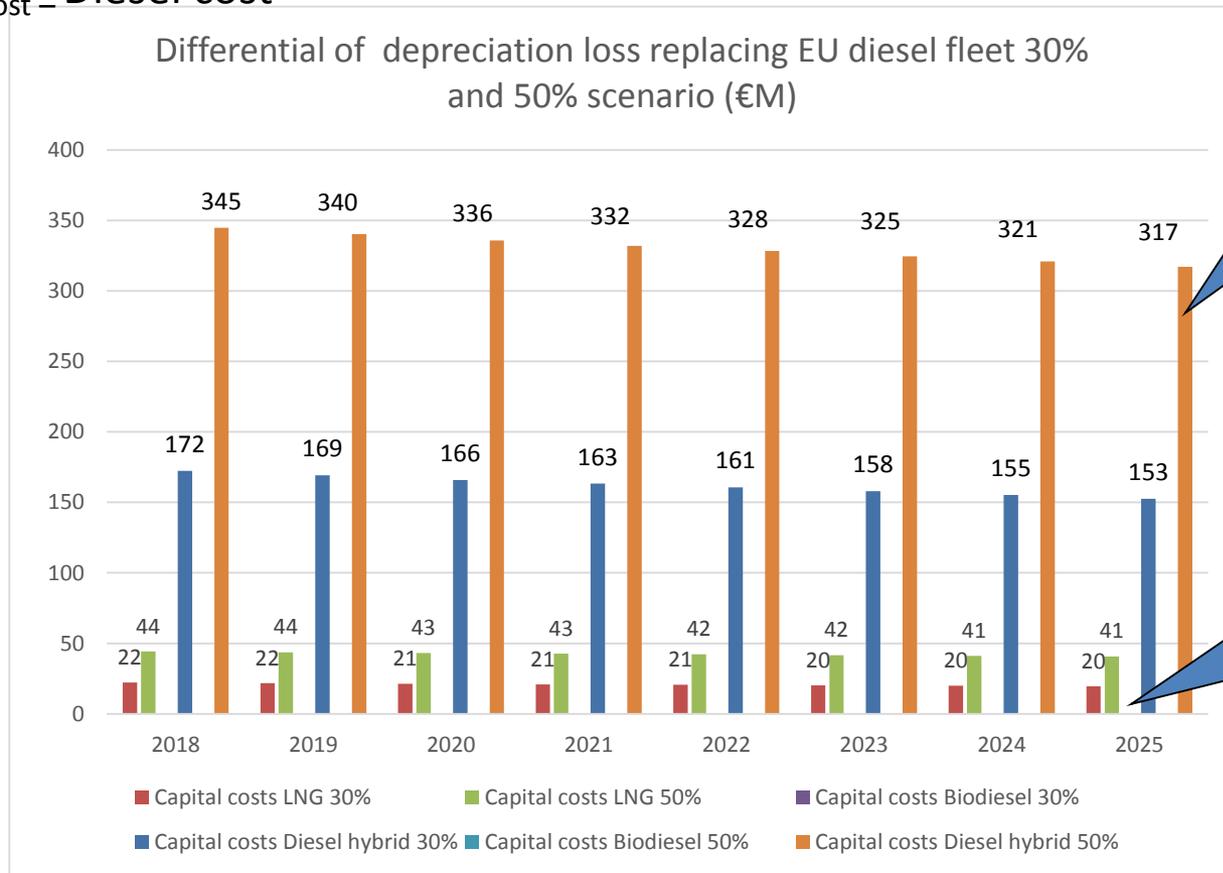
Impacts

Assumptions (costs):

- I is the investment required to ensure the transition: vehicle acquisition costs (interest rate 5%). It also includes the stranded investment corresponding to the not fully depreciated vehicles due to the transition
- The number of vehicles not depreciated correspond to +5% annual (30% scenario) and + 7% annual (50% scenario). No residual value is calculated.

Impacts

Alter_fuelc_{ost} - Diesel cost



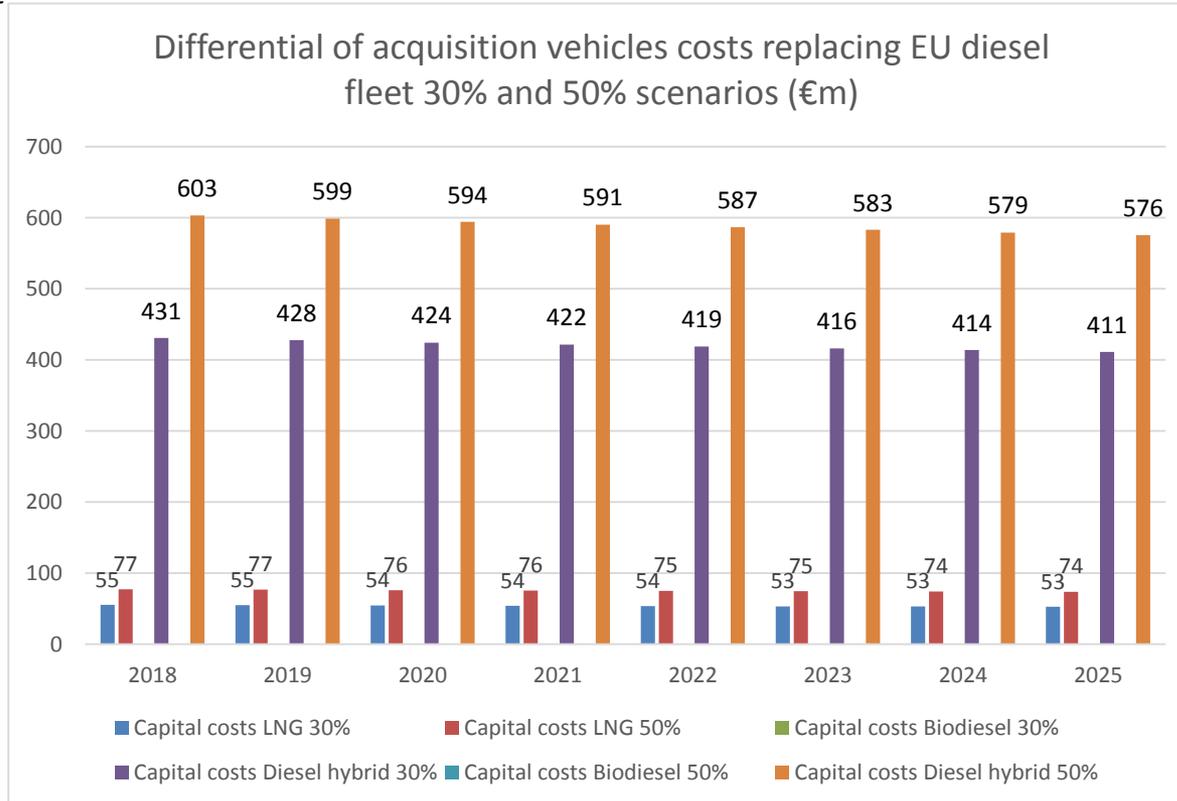
The more vehicles replaced, the higher the costs from not fully depreciated vehicles

Biofuels vehicles have the same acquisition and depreciation prices

Comparison between LNG/biofuels vehicles and diesel Hybrid fuelled vehicles

Impacts

Alter_fuel_{ost} - Diesel cost



Comparison between LNG/biofuels vehicles and diesel Hybrid fuelled vehicles

Assumptions (costs):

- Δ Infra costs include the direct costs of fuelling (equipment on site, costs of gas/electric grid), and the indirect costs of fuelling (costs for building structures, land, or provisions for automatic payment).

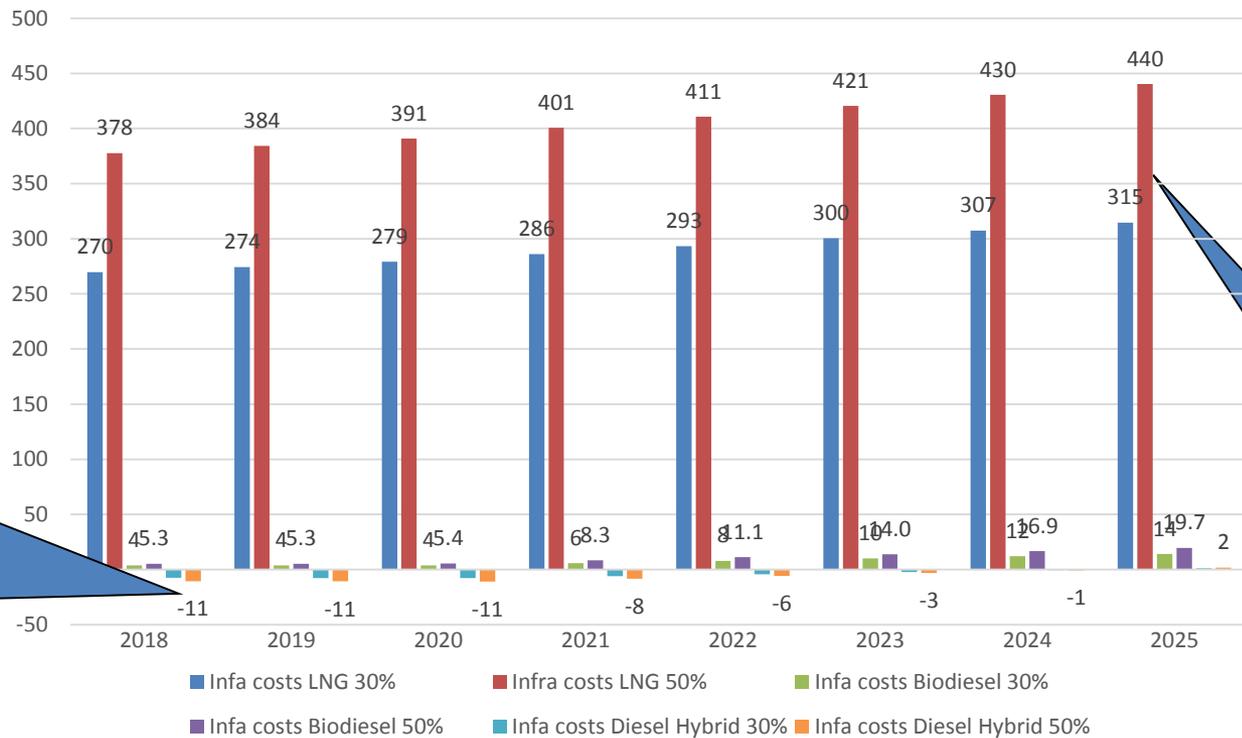


Impacts

Alter_fuelc_{ost} - Diesel cost

Differential of infrastructure costs replacing EU diesel fleet 30% and 50% scenarios (€M)

€/litre



Year	diesel	CNG
2011	0,060	0,230
2018	0,069	0,264
2020	0,072	0,275
2025	0,079	0,303

Saving of resources shifting to Diesel Hybrid, due to lower fuel consumption

High differential costs in LNG vehicles due to higher infra costs per litre and fuel consumption

Impacts

Assumptions (costs):

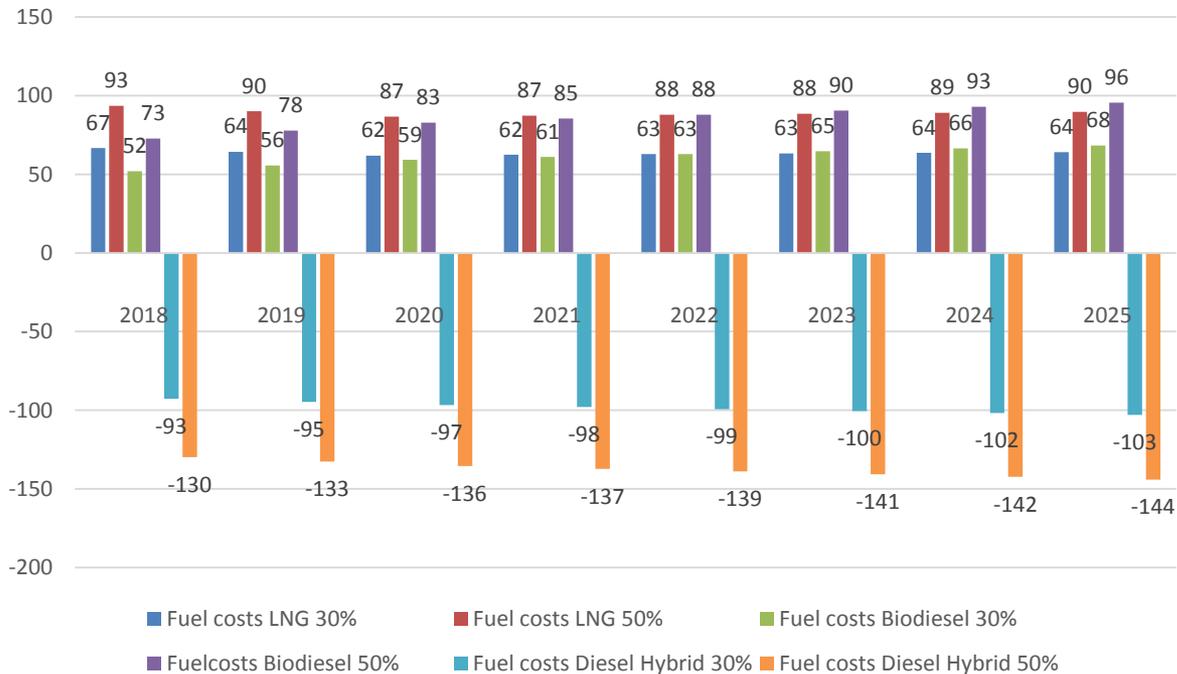
- Δ fuel costs is the difference in retail fuel prices of gas, biodiesel and diesel hybrid fuelled vehicles compared to diesel.
- Given the extreme variability of national fuel prices, we have considered retail prices of diesel costs per liter, i.e. including taxes, whose average price is available at EU level (EU weighted average taxation), scaling up to other fuel prices through stakeholders' consultation, e.g.

	Diesel EU VI*	CNG/ LNG	Bio- diesel
Energy Cost	100	118	114

Impacts

Alter_fuelcost - Diesel cost

Differential of fuel costs replacing EU diesel fleet
30% and 50% scenarios (€M)



Saving of resources shifting to Diesel Hybrid, due to lower fuel consumption

Assumptions (costs):

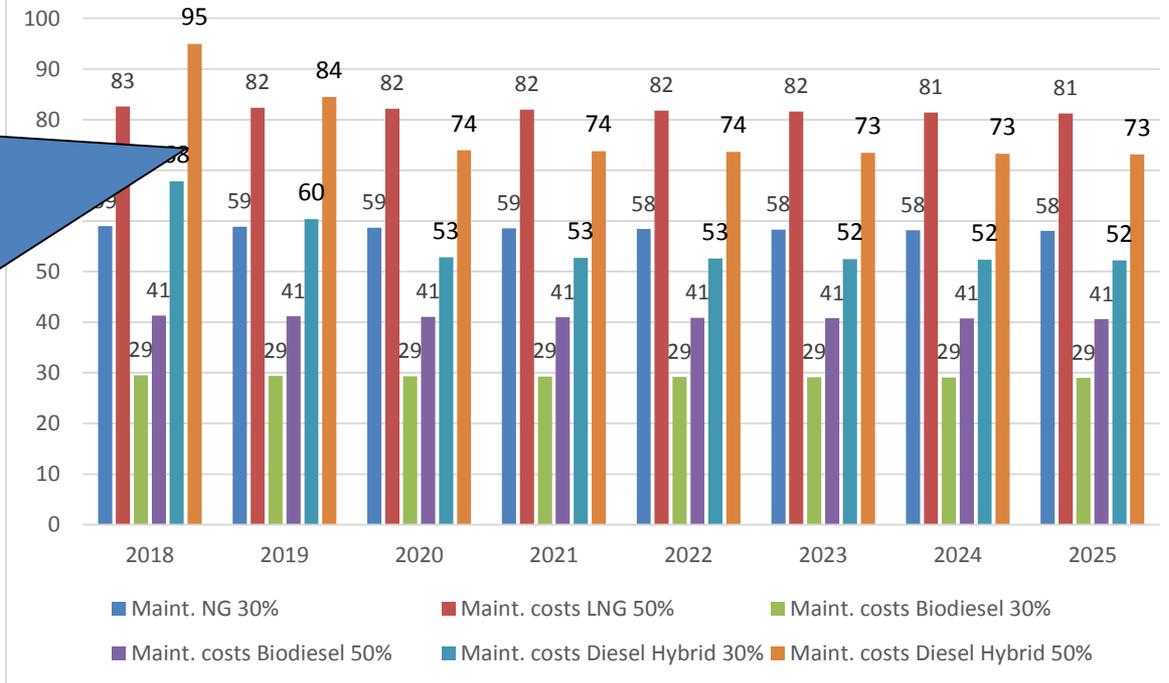
- Δ OC costs is the difference in maintenance and operating costs of gas and biodiesel fueled vehicles compared to diesel.
- Average maintenance and operating costs from literature for a diesel costs per km (€ 0,15). Then, we have applied the following index:

	Diesel EU VI*	CNG/ LNG	Bio- diesel
Operating Cost	100	120	110

Impacts

Alter_fuelcost - Diesel cost

Differential of maintenance costs replacing EU diesel fleet 30% and 50% scenarios (€m)



High differential costs in 50% scenario . Hybrid shows higher differential in maintenance costs compared to natural gas vehicles, diminishing over time, due to reducing costs of batteries