Coach of the Future

Executive Summary

Introduction

Major cities are increasingly introducing urban vehicle access regulations, including for example bans on diesel vehicles, in order to tackle air quality and congestion issues. In 2016, on the occasion of the C40 meeting of urban leaders in Mexico, several major cities made the political commitment to ban diesel vehicles from their territories in the next ten years. These developments are very concerning for the coach transport sector, as commercial vehicles are often the primary victims of these bans.

Despite the willingness of coach operators to shoulder their responsibilities and make their activities as efficient and environmentally friendly as economically possible, there are simply no viable alternatives to diesel vehicles presently available on the market. In addition, the business of coach operators relies on the possibility to pick up and drop off passengers in city centres. Sudden and untimely bans, that is, by 2025-2030, in the absence of any viable alternative to diesel for the long-haul coach tourism market, would have a dramatic impact on the tourism and intercity coach services.

The purpose of this report is to identify the available alternatives to diesel in the EU coach transport sector in the short-to-medium term, to examine them from an environmental and economic perspective, to identify barriers to their use, propose solutions and to analyse what timeframe would represent a realistic and economically viable transition.

The report was commissioned by IRU and produced by ISINNOVA, based on a literature review and broad stakeholder consultation.

A number of assumptions underlie the report's results and conclusions:

- Market segment: The study focuses on the long-distance coach tourism and intercity market segments, whose average distance travelled per trip is above 500km, mainly on motorways or non-urban roads.
- Average mileage: The average mileage of a coach is 60,000 km/year.
- Driving breakdown (time/mileage): 10% urban area; 90% regional/long distance.
- Market take-up of new technologies: Market penetration of new technologies and alternative fuels is projected to start as of 2023.
- Timeline of fleet renewal: The study analyses the time frame needed to replace >50% of the existing diesel fleet (2023-2035).
- Baseline vehicle: Pollutant emissions of the alternative fuel options are compared to the Euro VI standard.


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What alternatives to diesel used on long-distance coach trips are currently technologically available or in development in the short-to-medium term?

Liquefied Natural Gas: LNG is suitable to be used over long distances due to its high energy content and density. Blended at 20% with biomethane, produced from organic or other waste material, it can improve the environmental performance of vehicles. **The study considers an LNG blend of 80% natural gas/20% biomethane a reasonable benchmark**. In addition, 20% of biomethane share is also assumed as the reference target in the NGVA Roadmap 2030 concerning the development of natural gas vehicles in Europe by 2030 (NGVA Europe, 2016). The study therefore refers to ***bio-LNG***.

Biofuels: Biodiesel (conventional or "first generation" biofuel blended with fossil fuel at 7%, also referred to as FAME) and hydrotreated vegetable oils (HVO), blended at 30% to comply with EN590 requirements, are considered the two main biofuel options. As HVO can be blended at higher levels than FAME, it offers greater emissions reduction potential. Therefore, **within the context of this study, HVO blended at 30% with diesel will be considered.** The newly revised EU Renewable Energy Directive (RED II) provides the framework for a strong demand for advanced biofuels, encouraging investment in additional production plants.

Hybrid diesel-electric: The study considers that hybrid diesel vehicles will run on diesel most of the time, while **switching into electric driving mode in urban areas**. Diesel-electric hybrids were the first hybrid powertrain to be introduced. The sharp improvement over the past years reflects the ongoing industry efforts to optimise this technology. Manufacturers are introducing new diesel hybrid concepts aimed at increasing fuel savings and electric range.

Over the long-term horizon (2035 and beyond) hydrogen fuel cells vehicles may play a role, if the cost of ownership, infrastructure provision and reliability is made affordable for transport operators. However, as stressed in previous studies (COWI, 2015), the full battery electrification of heavy-duty vehicles, including long-distance coach fleets, is unlikely to happen. **For medium-to-long distance, which is the typical range of a coach, fully electric coaches cannot be considered as a viable alternative for autonomy reasons and due to the battery weight and energy storage capacity required**. Therefore, their use in the coach sector will remain limited to short distances (200km maximum).

What are the barriers (technical, legal, market-related, operational) to the development and deployment of each of these alternatives?

Considering the key costs, technological, refuelling infrastructure and fuel supply barriers, it can be concluded that bio-LNG is the alternative fuel with the least barriers, aside from not having a fully developed infrastructure network and potential cross-sectoral competition for biomethane (that is, used in CHP appliances versus use as a transportation fuel).

There are very minor infrastructure or technology barriers to the deployment of HVO as this biofuel is used as a drop-in blended in a conventional diesel engine. On the other hand, biofuels and hybrids face barriers of fuel availability and economic constraints (that is, uncertainties of biofuels availability and production costs for biofuels and high vehicle acquisition costs for hybrids, respectively).

In conclusion, there is no easy fix when comparing the available alternatives to diesel in the medium-term in terms of fuel price instability (HVO) and supply infrastructure (bio-LNG).

Type of fuel and propulsion systems	Type of barriers by level of importance			
	Technological	Costs (vehicle purchase, maintenance and fuel)	Refuelling infrastructure	Fuel supply
Bio-LNG	Low (mature technology)	Low (higher vehicle acquisition costs)	Medium (not yet fully developed)	Low (natural gas supply available)
HVO	Low (mature technology)	Medium (maintenance and vehicle costs)	Low (use of existing infrastructure)	High (very limited resources)
Diesel-hybrid	Low (mature technology)	High (vehicle acquisition and maintenance costs)	n/a (based on diesel fuel distribution	Medium (accessibility to fast charging infrastructure)

How to lift these barriers and achieve deployment of the alternatives?

The analysis of the type of solutions that can be envisaged leads to the conclusion that **bio-LNG is the alternative fuel for which political and economic solutions could be most easily implemented in the short-to-medium term (2023-2035)**. Specifically, full TEN-T roll-out of LNG infrastructure by 2025 is provided for in Directive 2014/94/EU on Alternative Fuels Infrastructure. While biofuels call for solutions whose implementation may require a longer time scale, that is, feedstock availability, the July 2018 agreement on the new Renewable Energy Directive 2009/28/EC could create a stable and predictable investment-enabling environment for advanced biofuels. Diesel-electric powertrains would benefit from a clear long-term timeline and resolve to remove the technological constraints (range and corresponding weight of batteries).

In addition, energy tax policy could be a powerful instrument to support post-diesel scenarios and the decarbonisation of transport. In pursuing this, the European Commission and national policymakers will face difficulties in balancing stakeholders' needs. Tax incentives and subsidies should be designed to reflect the true costs to society (CO_2 impact and energy content), be fair for taxpayers and efficient for the industry.

What are the environmental characteristics of these alternatives (GHG and pollutant emissions)?

The transition to alternative fuels and propulsion systems will have both a local impact (air pollution reduction in urban areas) and a global one (decarbonisation of the energy and transport systems). There are two key methodologies for measuring emissions: tank-to-wheel, which assesses emissions measurable only at the tailpipe; and well-to-wheel, which also measures the emissions profile of the fuel from its production and therefore reflects the global CO2 impact of different fuels.

Therefore, **this study considers pollutant emissions (NOx and PM) and CO_2 based on a well-to-wheel (WTW) basis**. Concerning local impact, compared to a diesel Euro VI coach, the environmental performance of bio-LNG shows reductions in percentage terms of about -50% of NOx and -90% of PM. No significant reductions are observed in the case of HVO. Hybrid electric diesel vehicle performance is assumed to be proportional to the reduction of diesel consumption, which, at a rate of around 12% less, leads to 13% NOx reductions, and about 70% less for PM emissions.

	Emissions	Average values compared to a Euro VI coach	
Bio-LNG	NOx PM	-50% -80/90%	↓
HVO	NOx PM	-0/1% -0/1%	→
Diesel-hybrid	NOx PM	-13% -70%	↓

Concerning the global impact, the assessment of CO_2-emissions equivalent, CO_2, CH4, and N_2O of fuel lifecycle emissions is complex and depends on how and where fuels are produced. For example, well-to-tank (WTT) biofuel emissions from indirect land use change (ILUC) may increase abatement costs per tonne of CO_2e, depending on the feedstock used. In this study, ILUC effects are not considered, as most of the material (waste and residuals) used to produce advanced biofuels (HVO) pose a low risk of indirect emissions from land conversion. In summary, the following CO_2e WTW emissions have been considered:

CO_2 g/km	WTT	TTW	WTW	Average values versus Euro VI coach
Euro VI	247	827	1074	
Bio-LNG*	198	554	752 (-30%)	↓
HVO**	124	802	926 (15%)	↓
Diesel-hybrid***	222	719	941 (10%)	↓

Sources: Thinkstep (2017); ADEME (2017); Nylund (2011)
* 80% natural gas; 20% biomethane
** 70% diesel; 30% synthetic biofuel
*** 90% diesel (motorway); 10% electric (urban)

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?

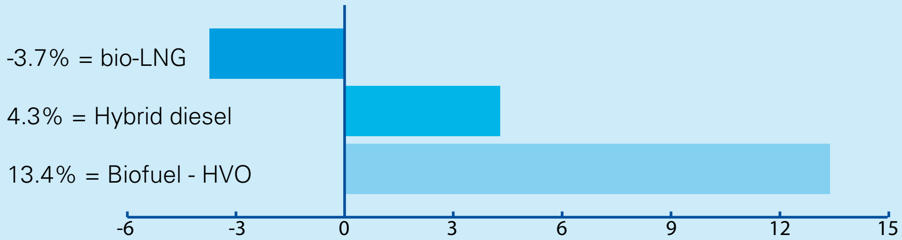
The possibility of implementing a successful transition from diesel to alternative fuels relies on sound business cases for operators. The technological availability of alternative fuels (for example, adequate market supply) may not in itself be enough to ensure the transition, that is, if there are no economically viable business cases.

The conclusion of the study is that, over the average lifetime of a coach (that is, 13 years), the shift from diesel to alternative fuels will incur higher annual costs (including capital, maintenance and fuel costs), with the exception of bio-LNG vehicles. All other operating and fuel costs remaining equal over the lifetime of a coach, bio-LNG vehicles may lead to -3.7% lower annual costs compared to a Euro VI diesel vehicle thanks to lower fuel prices and despite higher vehicle purchase costs.

While vehicles running on HVO require no additional capital costs, overall costs exceed those of diesel vehicles by about 14% due to higher fuel costs. In the case of hybrid diesel-electric vehicles, the cost increase compared to diesel vehicles is +4.3% due to higher capital and maintenance costs.

In absolute values, the shift from diesel to bio-LNG vehicles would reduce costs for operators by about EUR 3,100 per vehicle per year. For the other alternative fuels and powertrains, higher costs amount on average to EUR 3,600 for hybrid diesel-electric and EUR 11,300 for HVO vehicles.

Difference of annual capital and operating costs by alternative fuels and powertrains compared to a Euro VI diesel coach (baseline year: 2018)



What is the emissions abatement cost of these alternatives compared to the current situation, taking into consideration emission reductions and purchase and operational costs?

By assessing the abatement costs, the **study compares the costs entailed in shifting to alternative fuels or propulsion systems relating to the CO_2 and pollutant emissions gains, thereby highlighting which options are the most economically viable and desirable from an environmental perspective**. Abatement costs are calculated as the differential between capital, fuel costs and maintenance costs of alternative fuels and powertrains compared to Euro VI diesel vehicles, divided by annual CO_2 and pollutant emissions saved. Negative differentials mean lower costs for CO_2 and pollutant savings compared to Euro VI vehicles. Abatement costs have also been calculated for NOx and PM. The results are as follows:

- A shift from diesel to bio-LNG has the most cost-effective abatement costs per tonne of CO_2, that is, about EUR -81 per tonne emitted.
- Concerning NOx, bio-LNG exhibits the lowest abatement cost, equalling about EUR 0.10 per gram of NOx compared to a Euro VI vehicle. Hybrid diesel-electric vehicles follow closely, with NOx abatement costs of about EUR +0.50. HVO has higher abatement costs of about EUR +1.90 per gram of NOx).
- Concerning PM emissions, bio-LNG vehicles have the lowest abatement costs per gram of PM (EUR -0.90) compared to a Euro VI vehicle. HVO vehicles follow with abatement costs of about EUR +5 per gram of PM reduced. Hybrid vehicles have higher abatement costs of about EUR +7 per gram of PM).

Overview of the most viable options in the short-to-medium term.

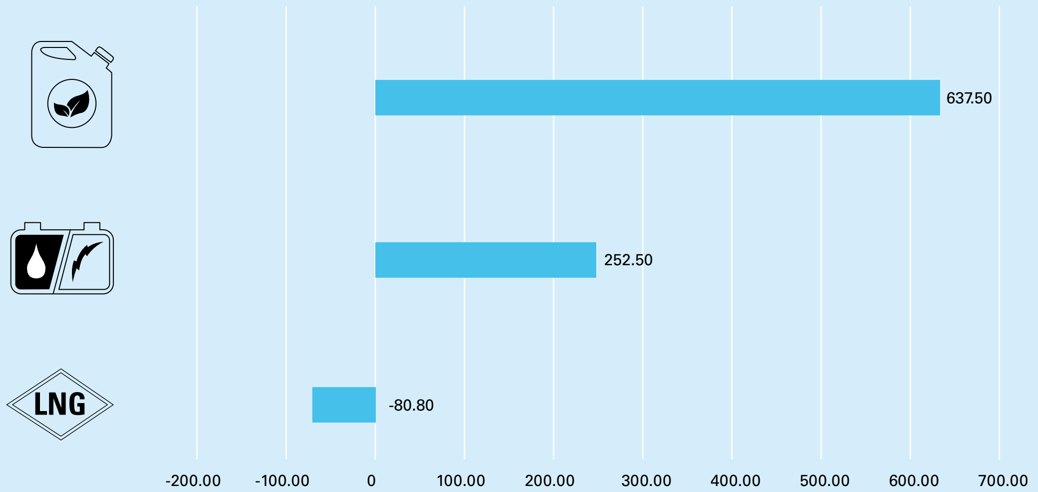
Building upon the insights regarding CO_2 and pollutants abatement costs and weighing the pros and cons of the alternative fuels and propulsion systems available in the short-to-medium term (2023-2035), the potential alternative fuels to diesel are identified in three categories, in order of importance:

- **Bio-LNG**: This fuel has the lowest abatement costs and manageable barriers in the short-to-medium term (full roll-out of LNG infrastructure is the main barrier). No serious technical or economic barriers have been identified and limited biomethane supply is projected to become less of an issue in the medium-to-long term.
- **HVO**: This biofuel has, on average, higher abatement costs. The resource availability barrier (feedstock availability) could be overcome in the short-to-medium term because advanced biofuels are mainly waste-based, with low supply constraints.
- **Alternative propulsion systems (hybrid diesel-electric vehicles)**: These vehicles benefit from increased fuel economy and low abatement costs for NOx. High vehicle acquisition costs and necessary technical improvement in batteries could be overcome in the medium term.

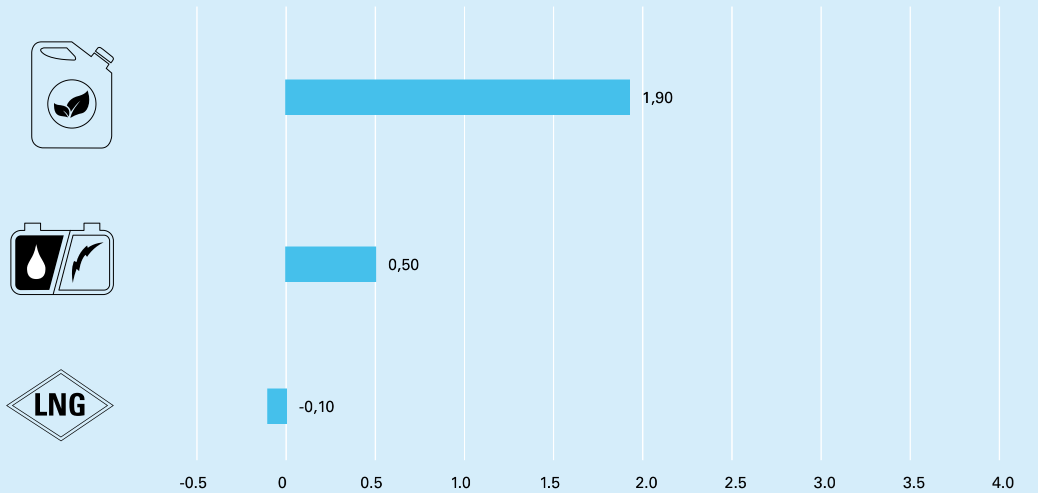
	Infrastructure costs	Vehicle costs	Fuel costs	Pollutant emissions	CO_2 WTW
Bio-LNG*	High	Medium	Saving	-50% NOx -90% PM	-30%
HVO**	n/a	n/a	Higher	-0/1% NOx and PM	-15%
Diesel-hybrid***	n/a	High	Saving	-15% NOx -70% PM	-10%

* 80% natural gas; 20% biomethane
** 70% diesel; 30% synthetic biofuel
*** 90% diesel (motorway); 10% electric (urban)

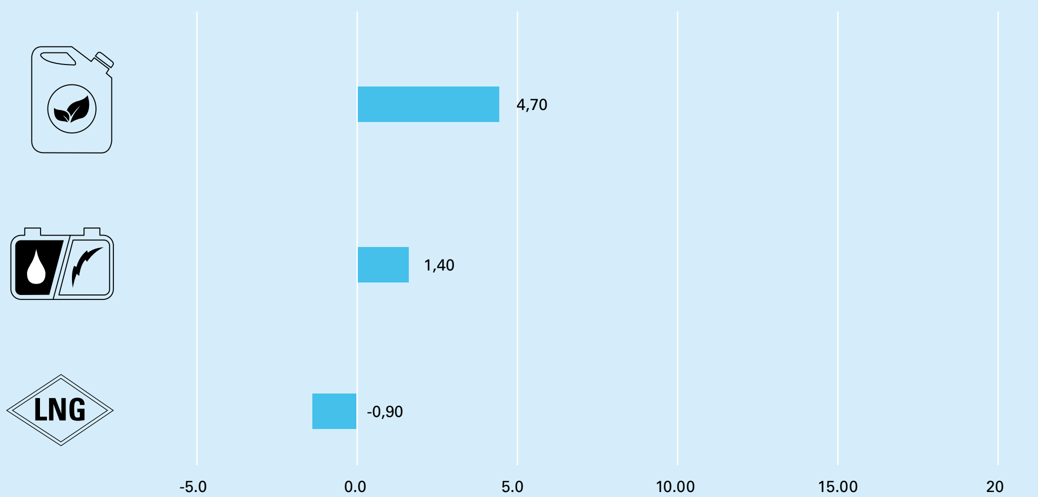
C0_2 abatement costs (€/tonne)



NOx abatement costs (€/g)



PM abatement costs (€/g)



Over what timescale could a reasonable amount of the fleet transition to alternative fuels?

Examining the timeframe for the shift to alternative fuels is important for assessing the feasibility of the timeline of diesel bans. Several assumptions need to be made in order to estimate the timeframe for the renewal of the EU coach fleet and a transition from diesel vehicles to alternatively fuelled vehicles:

- The average renewal rate of the EU coach fleet is 5% per year, in line with averages from the last 15 years.
- The fleet renewal assumed in this report starts in 2023, to take account of vehicle manufacturers' production cycles and consequent availability of alternatively fuelled vehicles.
- As of 2023, all new vehicles purchased would either be running on bio-LNG, HVO or diesel-electric hybrids – provided that these options are commercially available, and incentives are in place to support their deployment.

If these conditions are met, the assumption is that by 2035, more than 50% of the EU coach fleet may have been replaced with alternatively fuelled vehicles, leaving about half of the EU coach fleet still running on diesel. It is assumed that from when there is a fleet share of 50% alternative fuels, diesel bans would be feasible for the coach transport sector's perspective.

This optimistic projection confirms the assessment of the European Commission that diesel is projected to maintain its significant share in total final energy demand in transport until 2030 and notably that "diesel continues to be the primary fuel for heavy-duty vehicles" (European Commission, 2016).

In this scenario, potential bans on diesel vehicles before 2035 would still leave almost half of the EU coach fleet without the possibility to complete their natural renewal cycle and to fully depreciate, thus exposing coach transport operators to significant financial losses for minimal environmental benefits as compared to Euro VI vehicles.

It is therefore important that **potential future bans leave enough time for industry and operators to accommodate production timelines and business models for renewal and that local authorities provide a reasonable timeframe for the definition of ad-hoc policies supporting fleet renewal**, for example, taxation and incentives, allowing for fine-tuning with stakeholders before implementation of diesel bans.

Without such an enabling policy framework, operators would still, to a certain extent, continue to purchase diesel vehicles beyond 2023, thereby threatening the viability of diesel bans. A shift to alternatively fuelled vehicles as of 2023 will need strong legislative support.

Conclusions

When assessing the different alternatives to diesel, bio-LNG emerges as the option with the lowest abatement costs and most manageable barriers, with the infrastructure being the key remaining issue. HVO has medium abatement costs due to higher fuel costs but is still a promising option considering the high level of technology readiness and infrastructure availability. Resource availability is one of the key barriers to its increased usage but can be overcome as advanced biofuels are mainly produced with wastes and residues, with low supply constraints. Finally, alternative propulsion systems offer significant benefits but uptake in the short-term is hampered by high vehicle acquisition costs and lack of sufficient battery technology.

bio-LNG emerges as the option with the lowest abatement costs and most manageable barriers.

Under ideal circumstances, the coach sector will have renewed 50% of its vehicle stock by 2035, therefore replacing 50% of existing diesel vehicles with bio-LNG, HVO and diesel-hybrid vehicles.

If the uptake is imposed artificially and without an enabling policy framework, for example by imposing premature diesel bans which would not allow for economies of scale, scenarios show that there will be overall negative costs for society and transport operators. For society at large, the environmental benefits from less air pollution and CO_2 emissions would be lower than the resources spent in investment (capital, maintenance and fuel costs). The reason that costs outweigh benefits lies in the fact that environmental benefits compared to an already highly efficient Euro VI coach are relatively small.

If diesel bans for coaches are implemented from 2035 onwards and communicated from an early point, they may act as an incentive for a market uptake of alternatively fuelled coaches.

In the long-term horizon (after 2035) and respecting natural investment cycles, the transition to post-diesel coaches may start to pay off as economies of scale and CO_2 emissions savings (especially in the case of a higher share of bio-LNG vehicles) may lead to higher benefits than costs.

If diesel bans for coaches are implemented from 2035 onwards and communicated from an early point, they may act as an incentive for a market uptake of alternatively fuelled coaches and speed up fleet renewal, provided that alternative options are commercially available and other incentives are in place to support uptake of alternative fuels.

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