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### Working Party on Rail Transport

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**Innovation in Rail Transport**

# The use of alternative fuels in the railways

**Note by the secretariat**

## I. Mandate

1. The Working Party may recall that at its seventy-second session a workshop was held on innovation in the railways. Continuing with this discussion, a note has been prepared by the secretariat on innovation in relation to the use of alternative fuels in the sector. This document provides summary information on the main types of alternative fuels and where they are being tested and used.

## II. Introduction

2. Technological breakthroughs are of vital importance in any sector. Historically, one of the main breakthroughs in the sector was the advent of diesel-powered engines that superseded steam-based engines. Today, rail traction is provided either by electric-based traction or diesel-based traction with electric traction covering about 56 per cent of the market and diesel 44 per cent.

3. While it is much cheaper to build a diesel only line, the whole-life costs (including societal and environmental costs) mean that the more desired option, resources permitting, is the construction of electrified lines.

4. Even though the railway is the most environmentally friendly mode of transport, there is always room for improvement and increased efficiency. As such many operators, organizations and countries are researching and financing programs focusing on future alternative fuels with the primary goal of eliminating diesel power from the sector. The main alternative fuel solution reviewed in this document are:

- Liquid Natural Gases (LNG) and Compressed Natural Gases (CNG) which represent the short-term solution, with overall less efficiency with regards to alternative solutions but are currently more economical.
- Battery Electric Multiple Units (BEMUs) which stand as a medium-term solution and do not require extensive infrastructural investments.

- Fuel Cells and Hydrogen Fuel Generation (FCH) which represent a future with zero greenhouse gas emissions but requires heavy investments both on the technological side as well as on the financial side, as this technology will require different charging/filling infrastructure.

# III. Background

5. The main innovation hubs for alternative fuels are the European Union, the United States of America, Canada and the Russian Federation. The United States of America, Canada and the Russian Federation are focusing on LNGs and CNGs given their access to gas supplies and its lower cost. This allows a huge return, as the price per gallon of oil compared to gas is much more expensive.

6. Germany and Austria are heavily focusing on BEMUs, with testing in Germany in 2018 and in Austria in 2019. The German test may lead to the introduction of this type of traction into commercial service as soon as December 2021. Other countries such as India, Australia and New Zealand, are also planning to introduce these trains.

7. New hydrogen-based technologies are being developed in Germany, the United Kingdom and France. The German railways has introduced two trains recently, while similar traction is expected to be introduced in France by 2022. The United Kingdom is also developing this technology through the national project HydroFLEX with the aim of achieving zero emissions from passenger rail in the next twenty to thirty years.

# IV. Liquid Natural Gasses – Compressed Natural Gasses

8. Recent developments in gas extraction technology have significantly reduced the price of this raw material making it more attractive to the rail sector.

9. LNG and CNG has flourished partially in the United States as a mean to avoid heavy fines or technological investment needed for meet stringent regulations on air pollution and CO2 emissions. LNG and CNG permit a reduction of carbon emissions by 30 per cent and a reduction of nitrogen oxide emissions by 60 per cent

10. The Florida East Coast Railway (FECR) started converting its fleet of locomotives to LNG in 2014 and completed deployment in 2017. Indiana Harbor Belt Railroad in Chicago has also started to convert its fleet to full CNG burning engines.

11. Russian Railways (RZD) completed test runs at the end of 2018 summer of its GTlh-002 prototype liquefied natural gas fuelled turbine-electric locomotive. The 8.3MW double-unit locomotive managed a full 636km trip carrying 7000 tonnes on the Surgut – Limbey section, reaching 100km/h. RZD plans to reach a full stock of 22 units of LNG locomotives by 2023.

12. Spain has recently carried out tests with LNG as the first operational passenger line fuelled by natural gasses in Europe. The joint venture between Spain's main train operator RENFE and Gas Natural Fenosa and Enagás, adapted a diesel train with LNG engines and is undergoing trials on the Baiña – Figaredo section. This is part of Spain's 2014-2020 strategy to develop rolling stock using alternative fuels.

13. LNG and CNG are only short-term solutions as their carbon emissions are significantly lower than diesel, but still above zero. Therefore, the cost of installing LNG/CNG equipment in depots and retrofitting old or buying new rolling stock powered by these fuels would be very high compared to the benefit in terms of emission reductions.

# V. Battery Electric Multiple Units

14. BEMUs represent a further solution for the future as an alternative diesel traction. Three main studies and manufacturers are working and testing this technology.

15. Saxony's Oberelbe Transport Authority (VVO) has commissioned a demonstration BEMU based on bus and light rail technology. The train needs 7-10 minutes to achieve a full charge through overhead electrification via a pantograph. It reaches a top speed of 160 km/h under-wires and 140 km/h catenary-free.

16. The Austrian railway operator, ÖBB, has developed a three-car BEMU called Cityjet eco, also powered by an overhead catenary. It can reach a maximum speed of 140 km/h on catenary free lines. A total of 25 of these units to be made.

17. Finally, the California Air Resources Board through its Zero and Near Zero-Emission Freight Facilities programme, in the United States of America, is the first entity to cover the freight network with its battery-electric charged systems. With a 22.6 million USD grant the project consists in a hybrid version of both battery and diesel in order to allow the transport of heavy goods.

# VI. Fuel Cells and Hydrogen Fuel Generation

18. Hydrogen technology currently has the most potential for increasing the long-term sustainability and efficiency of railway industry. Trains powered by hydrogen technology acquire their energy through fuel cells. In these cells, hydrogen molecules and oxygen molecules are combined to produce electricity. The energy produced is then either used to power the train or, if in excess, it is stored in batteries. The only emission it creates is in the form of steam vapour and water.

19. Europe stands as the main hub both in terms of the research and implementation of this technology. Currently research in this technology is being fostered in Europe by the Shift2Rail Joint Undertaking (S2R JU) and Fuel Cells and Hydrogen Joint Undertaking (FCH JU). Additionally, three European states have already either started a related project or signed related contracts (the United Kingdom, Germany, France).

20. Shif2Rail JU is an entity born in 2009 by the cooperation of the European rail industry, coordinated by UNIFE with the aim of creating a smart, green and integrated transport system. It is financed through the Horizon 2020 Programme and its main objectives are: reducing rail transport lifecycle cost by 50 per cent, doubling the capacity of the system and increasing reliability and punctuality by 50 per cent.

21. The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) is specialized in the accelerated development and introduction of hydrogen-based technology into the market. This is also funded by the Horizon 2020 Programme. The work undertaken under the framework of these two entities has shown that in diesel-stock replacement, FCH is extremely cost-competitive (in the long-run) and has zero emissions (if the electrolysis is made from renewable resources). Three scenarios have been studied: low, base and high. Estimates say that by 2030, 11 per cent, 20 per cent, or 40 per cent (based on scenarios) of the market share will be serviced by hydrogen trains. This will replace the current diesel-stock which accounts for 20 per cent of the traffic in Europe and 40 per cent of its networks. The studies have underlined how this will bring to a total decarbonisation of railways, without the need of a full electrification of the network, reducing the visual impact of the railways and its related costs. Hydrogen trains will have a competitive advantage mostly in non-electrified corridors of more than 100 km (where there is a cost of less than 50 euro/MWh), preferably of high density, reaching rural or mountainous areas. Compared to diesel, hydrogen trains will have a higher initial cost, or higher total cost of ownership (TCO) but, on the other hand, their maintenance cost will be exponentially lower.

22. These estimates however are limited to the passenger sector. A switch to the freight sector will be more difficult. According to the previous studies there could be an alternative: flexible hybridisation. Hybrid (Diesel/FCH) freight trains will be able to carry more than 5000 tonnes of capacity, to reach speed limits over 180 km/h and to cover distances of more than 700 km.

23. Germany was the first country to officially test and engage in the hydrogen market. In September 2018, Germany deployed two FCH-trains on a network between Cuxhaven and Buxtehude (100 km). This rolling stock is equipped with fuel cells in which the chemicals

(hydrogen and oxygen) combine to create energy, used to power the train and stored in specific lithium-ion batteries present on board, and steam and water by-product is then released into the atmosphere, causing no greenhouse gas emissions. The train has a capacity of 300 passengers and can reach a maximum speed of 140 km/h. It can run up to 1000 km with a single tank of hydrogen, similar to the range of a diesel unit. The state of Lower Saxony has commissioned 14 additional trains for delivery by 2021.

24. SNCF, the main French railway company has recently unveiled its 2035 commitments regarding both cost-reductions and gas-reductions. The long awaited TGV2020 will be, as defined by the Sustainable Development Director of SNCF, 20 per cent cheaper to procure and operate and 20 per cent more energy efficient as well as being 99 per cent recyclable. Besides these commitments, SNCF plans to reach 0 per cent in their diesel-stock by 2035 to be achieved through the use of FCH technology.

25. Similar schemes are also available in other countries including the United Kingdom as mentioned above.

# VII. Summary and next steps

26. This note has provided an introduction to the various forms of alternative fuels that are currently available for the railways. The Working Party may wish to consider next steps in relation to this and to other aspects of innovation in the railways.