Summary report

Electro-diesel locomotive transformation to H2

A prefeasibility analysis for retrofitting an electro- diesel locomotive to hydrogen fuel cell solution running in two current routes in Chile.

February 13, 2023

Analysis of the technical feasibility and the corresponding investment for the conversion of an electro-diesel locomotive to a hydrogen-based solution

Work Package 4 (WP4) Report

February 13, 2023

Programa de Energías Renovables y Eficiencia Energética en Chile

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Por encargo de:
Ministerio Federal de Medio Ambiente, Protección de la Naturaleza y Seguridad Nuclear
de la República Federal de Alemania

Ministerio de Energía
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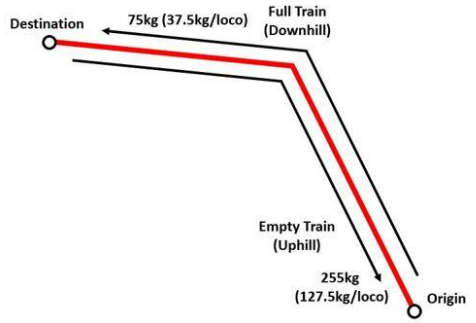
Summary report

The purpose of this report is to explore the feasibility of using hydrogen fuel cell technology to convert existing locomotives currently running on diesel gensets. Establishing the possibility of all aspects of this potentially ground-breaking endeavor would make for one of the first steps taken towards decarbonising Chile's rail network as well as a significant, and notable contribution towards the worldwide push towards global carbon neutralisation (net-zero).

The report introduces locomotives currently part of freight operator TRANSAP's fleet and two of their respective routes.

Then, a series of simulation-based studies is performed to determine the equipment required for the conversion and the amount of hydrogen required to successfully operate the routes in question.



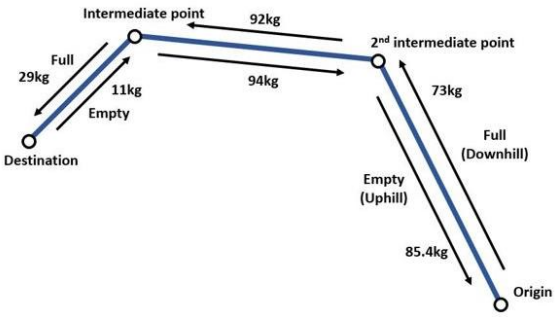
Estimated H2 demand for each section in central zone route.

As part of the main results, as it can be seen in the first image (red line), in total 330 kgH2 is needed for the whole central Chile -located route where two locomotives are needed to provide the service.

In the central south route case (blue line), about 384,4 kgH2 in total is needed for the whole route.

Additional information focused on infrastructure requirements, operations, equipment selection and packaging, homologation, health and safety considerations and financial viability is also factored into the report.

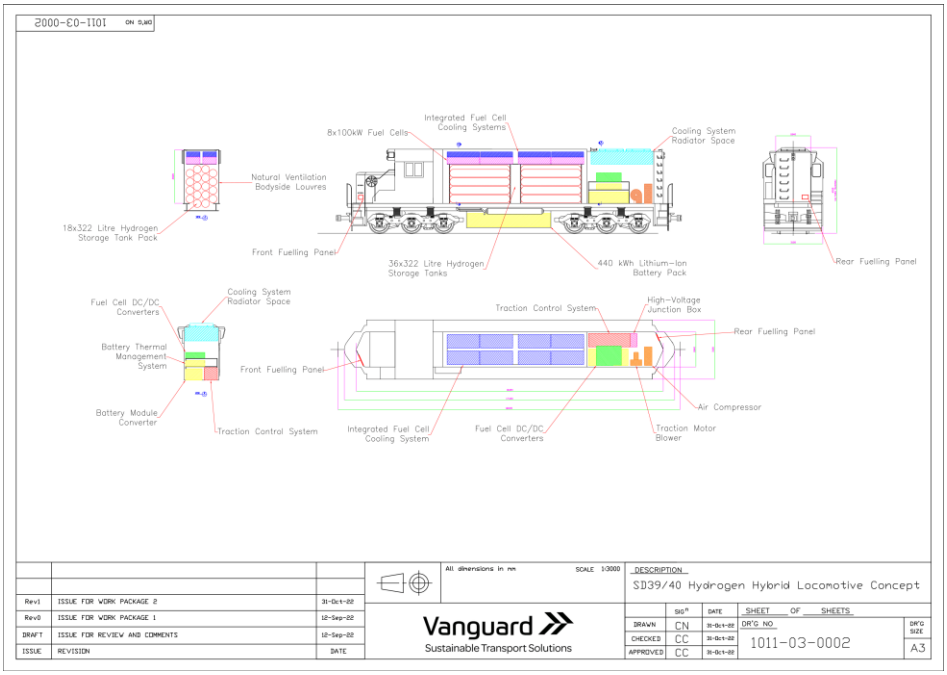
Throughout the process of writing this report, Vanguard's Single Train Simulator software was fully redeveloped following feedback received from the client; It was discovered that improved fuel cell control strategies could be able to significantly



Estimated H2 demand for each section in centra - southl zone route.

reduce the initially predicted fuel consumption. This led to the determination that a single locomotive should be able to accommodate the necessary equipment to operate a hydrogen powered service based (see image below) on the information supplied by TRANSAP.

Based on the findings of the report as laid out across the following sections, it is possible to power a SD-39 or SD-40 locomotive using hydrogen as a fuel. The SD-39 locomotive serving a Chilean central zone route is theoretically the most suitable for conversion as fewer fuel cells would be required than that of a SD -40. In addition, this locomotive would also be able to store more hydrogen per train as two locomotives are used for this route with the most readily available source of hydrogen closer to the route's fuelling point.



Notably, it was discovered that despite the limited space available within the locomotive body, between 270kg and 280kg of hydrogen could be carried onboard, of which between 255kg to 264kg would be usable whilst preserving the minimum pressure in the tanks needed to operate the fuel cells. This, crucially, could be achieved using readily available equipment already proven for use within rail vehicles (at the time of writing).

Alongside methods of integrating the new technology with existing technology within the locomotives and following closer inspection of the locomotive control systems, it has also been established that there should be minimal changes to the way in which the locomotives are operated and even potential reductions in the maintenance activities required for the locomotives (and resultant cost savings).

Finally, subject to closer inspection, the consideration of hydrogen supplies (both existing and conceptual) has been deemed sufficient for the operation of a hydrogen powered freight service across the given routes.

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