# TAKING THE NEW ZEALAND SUBURBAN RAIL NETWORK INTO THE HYDROGEN ERA

## THE TRANSITION AND ITS RISK


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Hrail

# ABOUT US

Jacek is a qualified and highly experienced chartered transport engineer. He holds a master degree in transport (in one of the most prestigious technical universities in Europe – Warsaw University of Technology) and a doctor of philosophy degree in engineering (in Griffith University).

Helder is an accomplished railsystems engineering specialist with an extensive background of over 24 years in the field. He has a degree in Civil Engineering with a major in Environmental Engineering from QUT, and a Masters Business Administration (MBA) in Technology Management.

# CONTENT

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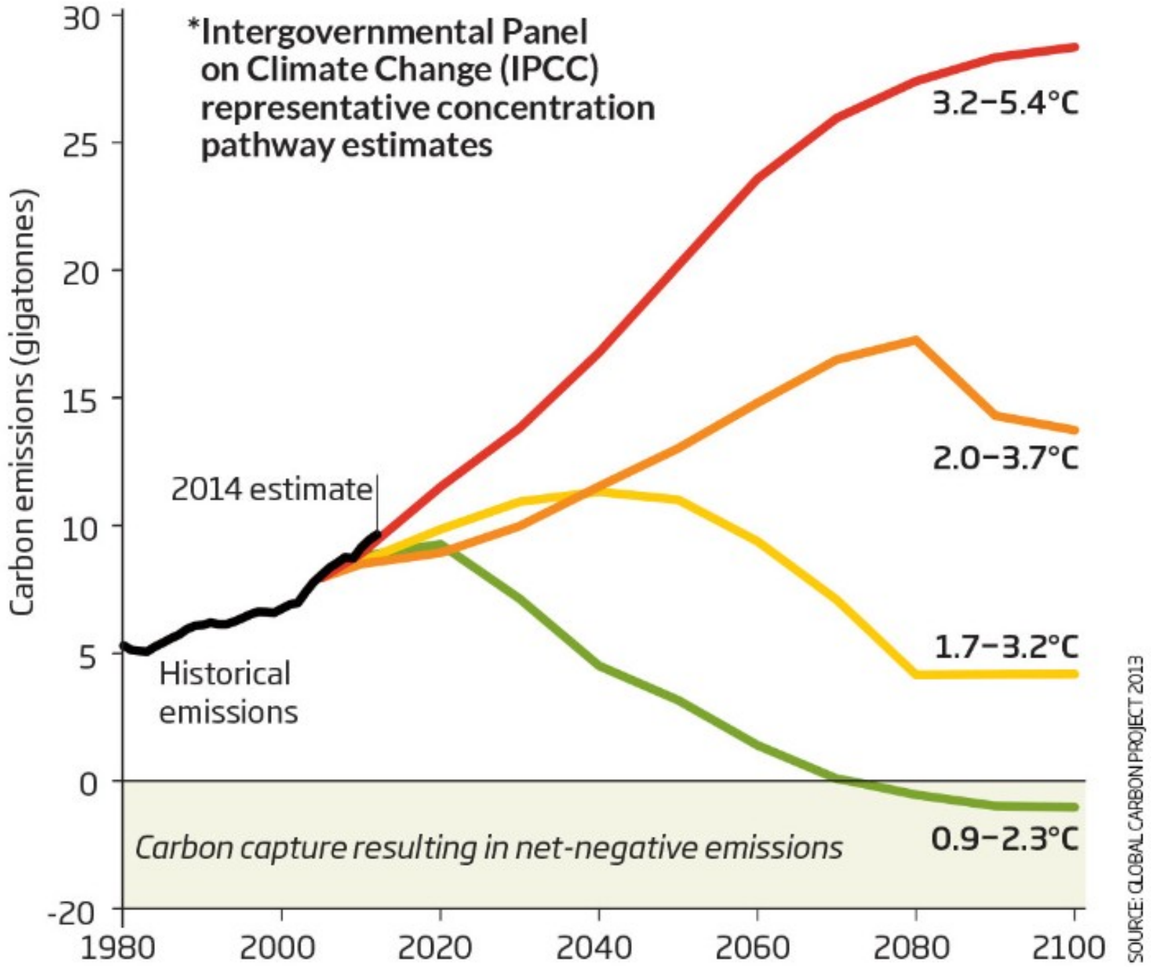
# Paris Agreement - what does it mean?

## Emissions go from bad to worse

The new report from the Global Carbon Project shows global emissions are following the course of the worst of four scenarios*. This suggests warming of at least 3°C by 2100, relative to 1850-1900




ZERO EMISSION

# CO2 EMISSIONS

560t CO2 per day, everyday...

Every Tonne of load carried by Rail saves

# 70%

of carbon emissions over road

**Carbon performance[5]**

| | 2011/12 | 2018/19 | 2019/20 | 2020/21 | 2021/22 |
|---|---|---|---|---|---|
| Rail Freight Carbon Intensity (grams $CO_2$-e per net tonne kilometre) | 32.51 | 27.06 | 27.69 | 26.72 | 26.57 |
| Carbon footprint – scope 1 and 2 (tonnes $CO_2$-e per net tonne kilometre) | 279,861 | 240,127 | 231,101 | 233,472 | 207,790 |

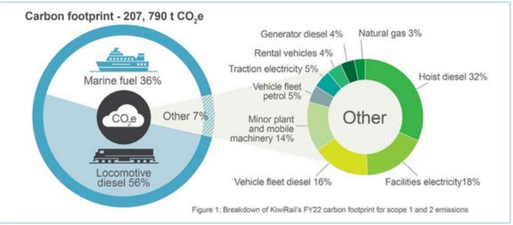



Figure 1: Breakdown of KiwiRail's FY22 carbon footprint for scope 1 and 2 emissions

Source:
KiwiRail Integrated Report 2022

**10.2 MEASURING THE ACHIEVEMENT OF OUTCOMES**

| Outcome Measures | Metric | Target |
|---|---|---|
| ADDITIONAL KIWIRAIL OUTCOMES | | |
| Grow volumes on rail | Mode share (% based on tonnes km) | Rail mode share estimated to increase from 12% in 2020 to 14% of total freight task by 2030 |
| Improved KiwiRail commercial performance | Above rail operating surplus<br>Above rail operating surplus ratio | As per KiwiRail Statement of Corporate Intent |
| Avoided emissions and harmful pollutants | Reduced emissions/harmful pollutants from rail freight | Increase from 236k $CO_2$ emissions avoided p.a. to 306k p.a. by 2030 |
| Improve the Value of Rail | Value of Rail ($) | Increase from $1.7b in 2020 to $2.1b by 2030 |

The investment in rail will contribute to the overall outcomes that the Government is aiming to achieve through the transport system.

The NZ Rail Plan sets out a draft framework of the potential indicators for measuring the achievement of rail investment against the Transport outcomes. This is expected to be refined further as the new regime is implemented. Refer to Section 3 of the NZ Rail Plan.

# HISTORY OF RAIL

First steam locomotive railway - Wales

Steam

1804

City& South London Railway - first major railway to use electric traction (3rd Rail)

Electrification

1890

World’s first diesel locomotive - Switzerland

Diesel

1912

World’s first passenger train running on Hydrogen - Germany

Hydrogen

2018

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# HISTORY OF HYDROGEN

Recognised as a unique element in 1766

by Henry Cavendish in London


The Hindenburg disaster in 1937 is still remembered well due to the live coverage of the incident. Out of 97 passengers and crew on board, 13 passengers, 22 crewmembers and one worker on the ground died. The airship was supposed to be filled with Helium (non flammable lifting gas), but the United States banned it from sale to Germany...

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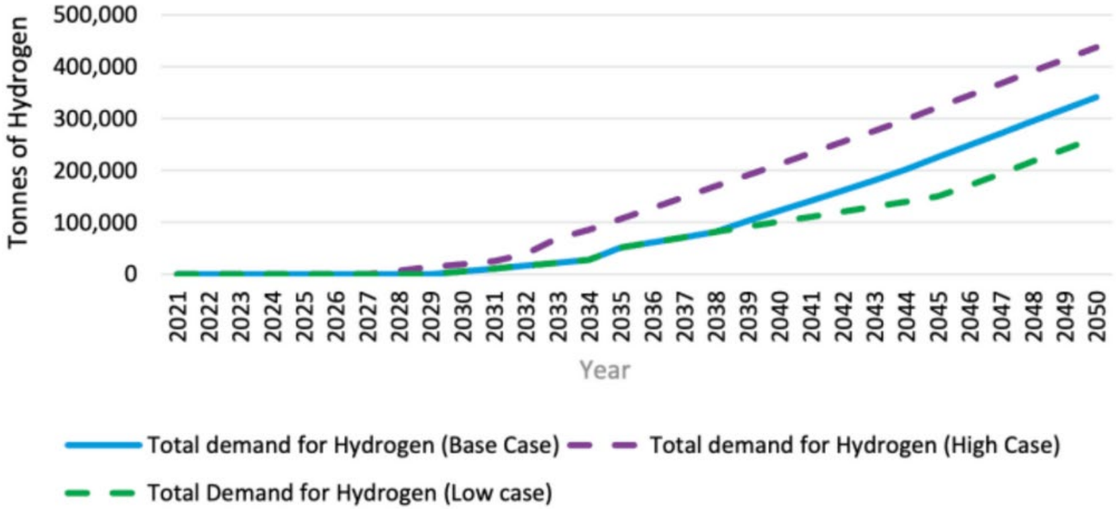
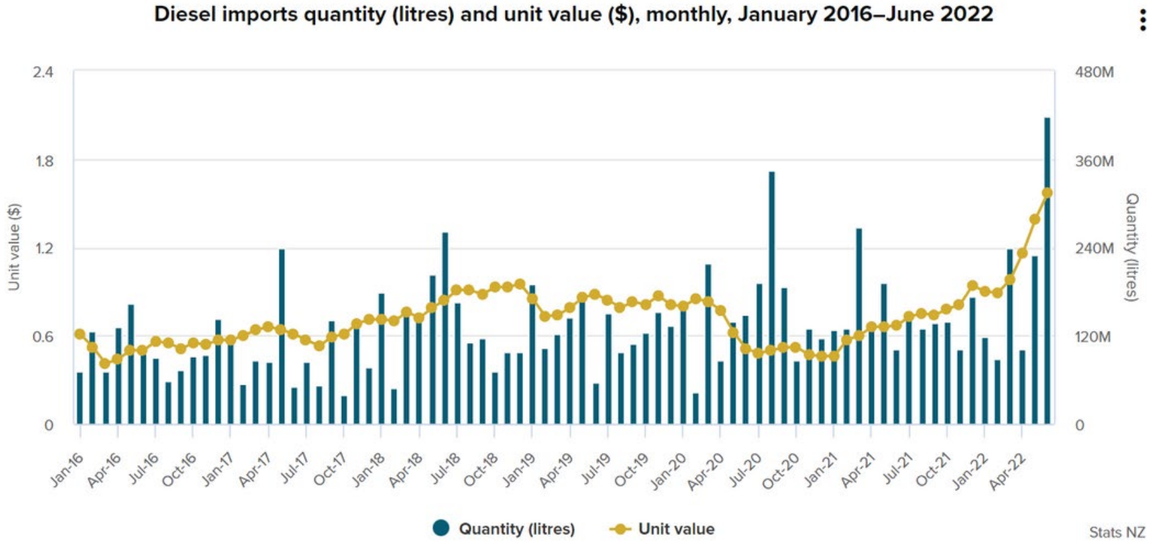



*High demand and low demand estimates for hydrogen in transport applications. Source: Castalia*



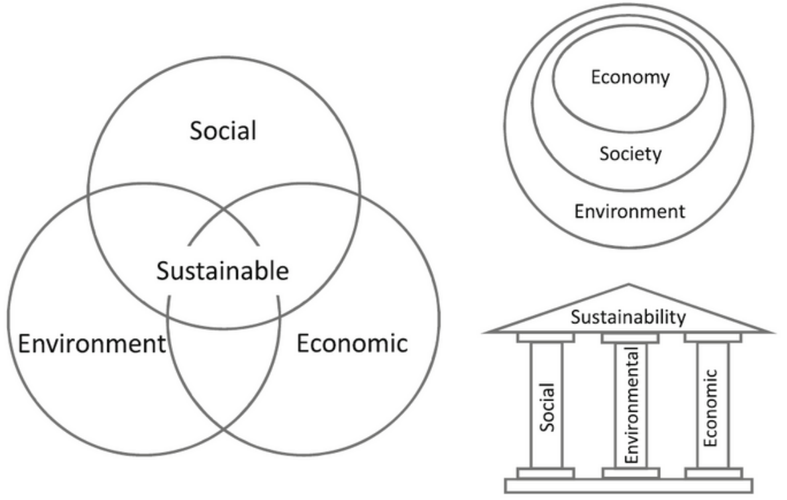




**Fig. 1** Left, typical representation of sustainability as three intersecting circles. Right, alternative depictions: literal 'pillars' and a concentric circles approach

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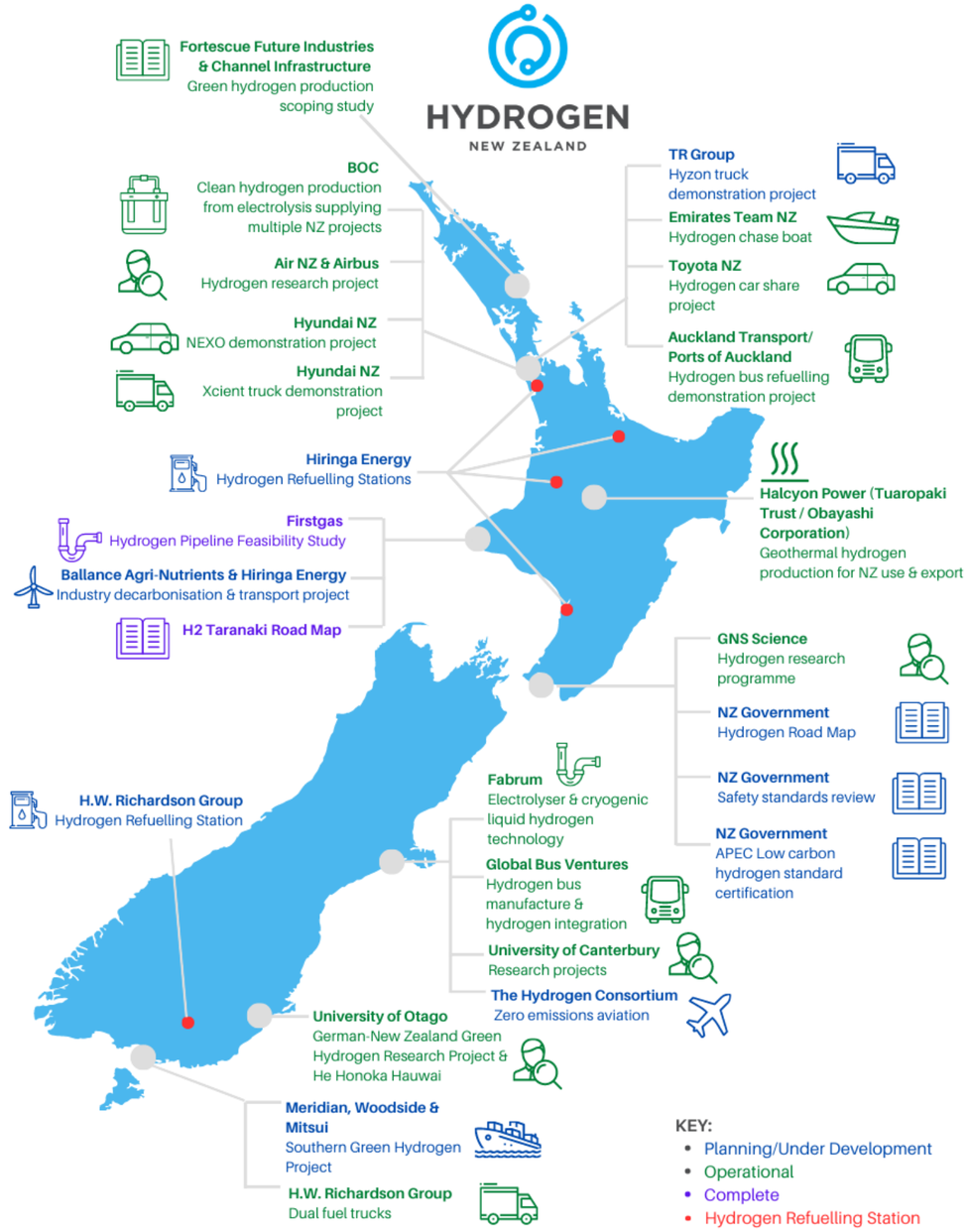




# Several H2 Options exist...

## Stadler secures second order for hydrogen trains

04.07.2023

Swiss manufacturer Stadler has been awarded the winning bid for two tenders to supply a total of 12 two-car narrow-gauge trains to the Calabria FC passenger carrier and the ARST transport company in Sardinia, as reported by the railway magazine **Railway Supply.**


Both companies have ordered 6 trains each for a total of 78 million euros. These trains will have a maximum speed of 100 km/h and can accommodate 170 passengers. The rolling stock for both orders is expected to be delivered by the end of 2026.

24.09.2021

Pesa Bydgoszcz presented its hydrogen locomotive at TRAKO. This is a modernized locomotive with installed hydrogen cells.


Picture: NaKolei.pl

## Canada's first hydrogen train is taking passengers

Runs from Quebec City to Baie-Saint-Paul until September

Emily Chung · CBC News · Posted: Jun 28, 2023 4:00 AM EDT | Last Updated: June 29


first hydrogen-powered passenger train made its deb
-Paul. (Alstom)

its

gen-powered train in North America is taking r
l Quebec this summer.

## China's first hydrogen fuel cell hybrid locomotive is put into trial operation

09.11.2021

China's first hydrogen fuel cell hybrid locomotive is put into trial operation. The experiment involved a railway line for transporting coal in the Inner Mongolia Autonomous Region in northern China.

A 627 km long line connects the Baiyinhua coal mine in inner Mongolia with the Jinzhou port in Liaoning province in northeastern China.

Compared to traditional diesel locomotives, the new hybrid locomotive will reduce carbon dioxide emissions by about 96,000 tonnes per year. This is reported by the railway magazine **Railway Supply** with reference to Xinhua.

It is specified that the design speed is 80 km/h. When fully loaded, a hydrogen locomotive can operate continuously for 24.5 hours, and its maximum traction load on straight sections of the track will exceed 5 thousand tons.

The new locomotive has broad market prospects for use in large factories and mines, as well as in ports. As previously reported, a **Polish hydrogen locomotive** was presented at the TRAKO exhibition.

## Canadian Pacific launches hydrogen locomotive

31.01.2022

On January 24 Canadian Pacific (CP) announced the first launch of its mainline freight locomotive (H2OEL), powered by hydrogen fuel cells.


y the railway magazine **Railway Supply** with reference to railwayage.

said its hydrogen locomotive program team is currently preparing for field
which stands for "Hydrogen Zero Emissions Locomotive".

ade of an existing diesel-
on generator were replac
action motors.

## Hyundai Rotem unveils hydrogen tram

04.09.2023

South Korean engineering company Hyundai Rotem showcased a prototype hydrogen-powered train at the Korea Railways & Logistics Fair in Busan, as reported by the railway portal **Railway Supply.**


It is expected that the development of a production-ready version will be completed by the end of the year. The total project cost is estimated at KRW 42.4 billion ($31.9 million), including KRW 28.2 billion ($22 million) in government funding.

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# Railway In New Zealand

## KEY FACTS

### Freight
Moves around 19 million tonnes of freight each year

### Track
Operates and maintains 3700km of track, including six million sleepers, of which 50 per cent are concrete

### Interislander
Operates four ships making 2800 sailings per year

### Property
Manages a portfolio worth $4.3 billion with more than 18,000 hectares of land

Owns more than 900 buildings

Manages 10,000+ leases, licences and grants

### Freight task
Carries 36% of the New Zealand freight task that is deemed to be available to rail

### Freight services
Operates 43,000 mainline freight departures each year

247 locomotives & shunts

### Value
The total value of rail to New Zealand's economy is approximately $1.7-$2.1 billion every year*

### Our team
4800 employees
19% female
19% under 30 years old

### Infrastructure
3100 signals
1500 public level crossings
106 tunnels
1344 bridges

### Exports and imports
Transports around 20% of New Zealand's exports and imports

### Sustainability
Reduces heavy vehicle impact by more than 1.1 million trucks per year

Every tonne of freight carried by rail delivers a 70% emissions saving over road

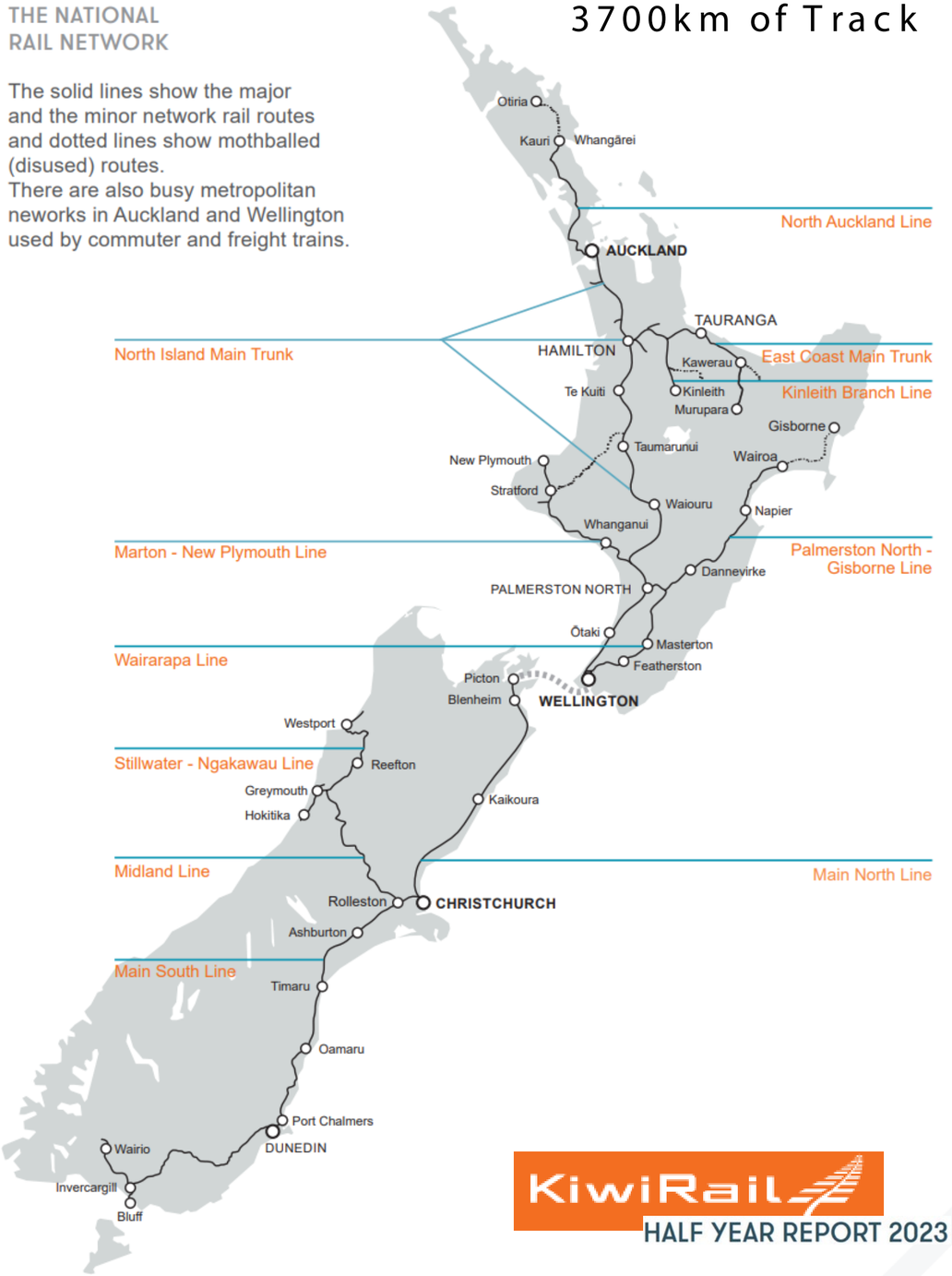
Each week, KiwiRail's National Train Control Centre (NTCC) manages the following volumes of scheduled movements across the national rail network:

- 900 freight trains
- 44 inter-city passenger trains
- 2,200 suburban passenger services in Wellington
- 3,700 suburban passenger services in Auckland

## THE NATIONAL RAIL NETWORK

The solid lines show the major and the minor network rail routes and dotted lines show mothballed (disused) routes.
There are also busy metropolitan neworks in Auckland and Wellington used by commuter and freight trains.

3700km of Track

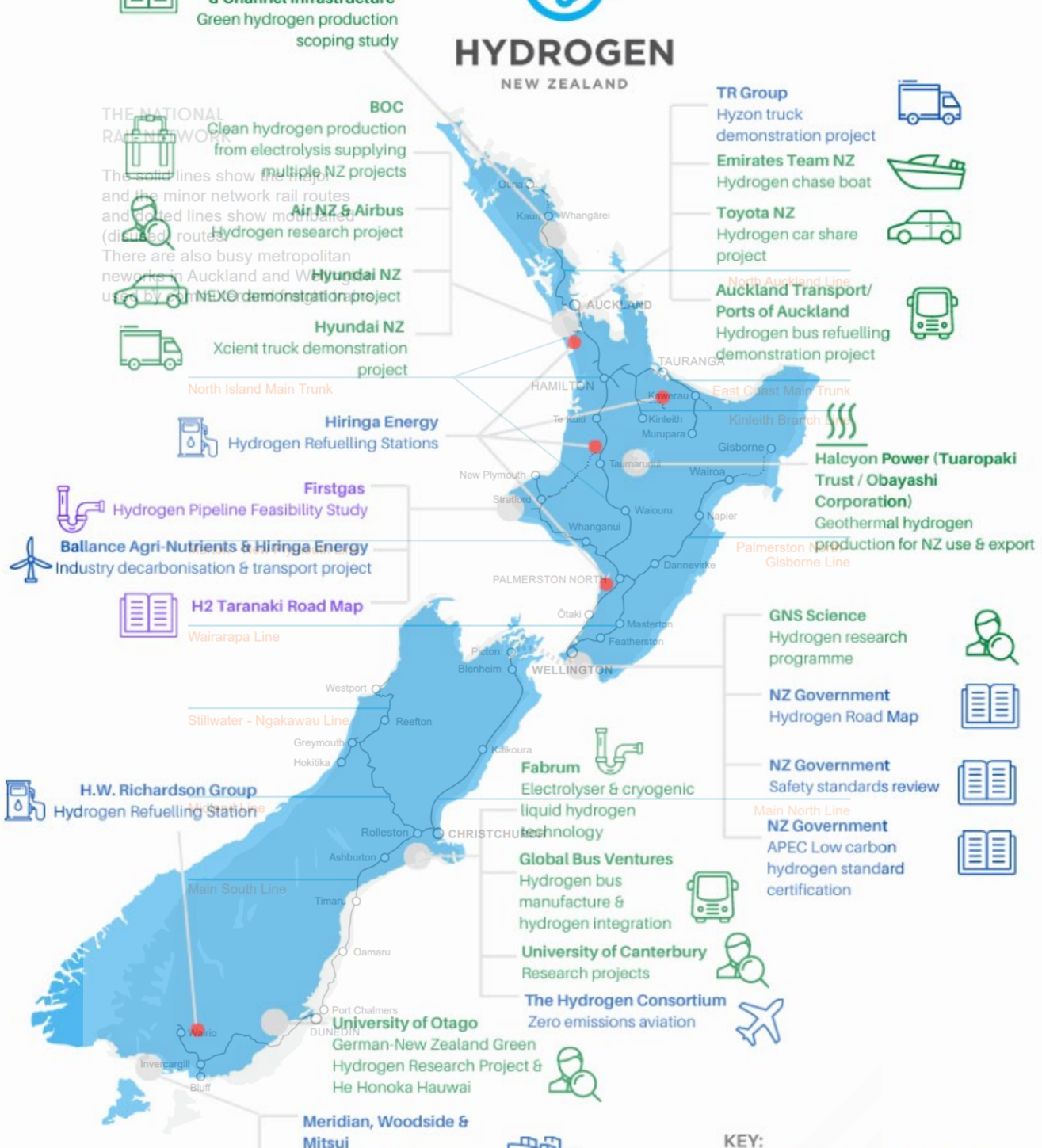



KiwiRail
HALF YEAR REPORT 2023

# Railway x Hydrogen

## Opportunity on North Island

## Production & Refueling Sites close to Rail line



# So where would be a good place to test hydrogen trains in NZ?

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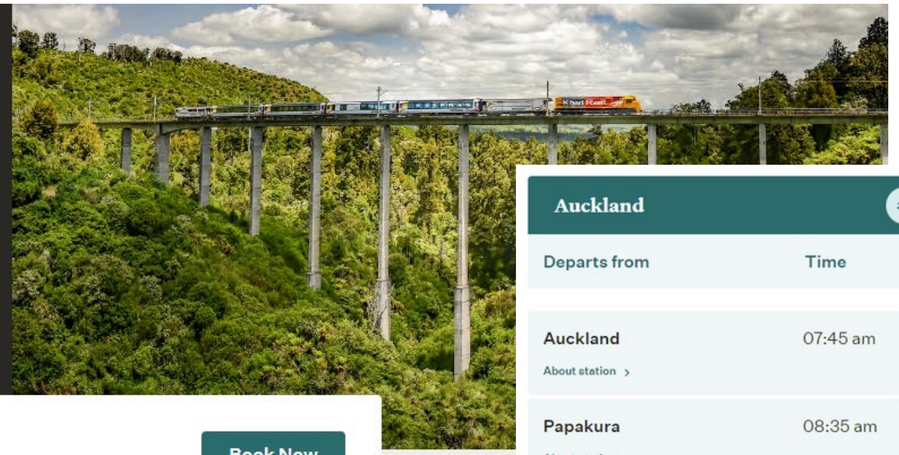
# Northern Explorer Train

Auckland to Wellington train



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Trains | 1 days | From: NZ$189 | Departure: Wellington | Destination: Auckland

Book Now

Explore the rural heart of New Zealand's North Island on this epic 648km journey from Auckland to Wellington by train.

Our Northern Explorer train connects multi-cultural Auckland with our bustling capital, Wellington. With unique blends of international prestige and local culture, both are excellent places to start or finish your adventure.

See the scenic wonders of Middle Earth, soar over towering viaducts, across the high plains of the volcanic plateau, and beneath three mighty volcanoes.

Book a journey like no other by travelling in either direction from Auckland to Wellington or Wellington to Auckland.

Destinations include:

Auckland • Hamilton • Otorohanga (Waitomo Caves) • Taumarunui • Tongariro National Park • Ohakune • Palmerston North • Wellington

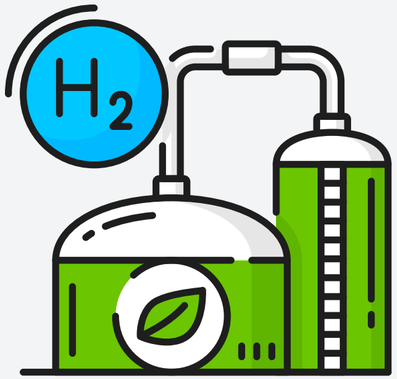
GREAT JOURNEYS NEW ZEALAND


| Auckland | | Wellington | |
|---|---|---|---|
| Departs from | Time | Arrives at | Time |
| Auckland<br>About station | 07:45 am | Papakura | 08:35 am |
| Papakura<br>About station | 08:35 am | Hamilton | 10:15 am |
| Hamilton<br>About station | 10:15 am | Otorohanga | 10:50 am |
| Otorohanga<br>About station | 10:50 am | Taumarunui | 12:25 pm |
| Taumarunui<br>About station | 12:25 pm | National Park | 01:15 pm |
| National Park<br>About station | 01:15 pm | Ohakune | 01:45 pm |
| Ohakune<br>About station | 01:45 pm | Palmerston North | 04:20 pm |
| Palmerston North<br>About station | 04:20 pm | Paraparaumu | 05:30 pm |
| Paraparaumu<br>About station | 05:30 pm | Wellington<br>About station | 06:25 pm |

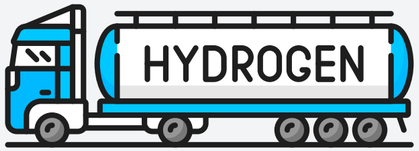
# Conceptual Case Study

# What the future might look like for rail transport ...

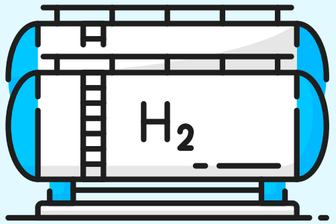
Rolling stock

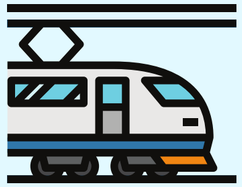

Production




Transportation




Storage





Operations & Maintenance


Energy Supplier

Railway Operator

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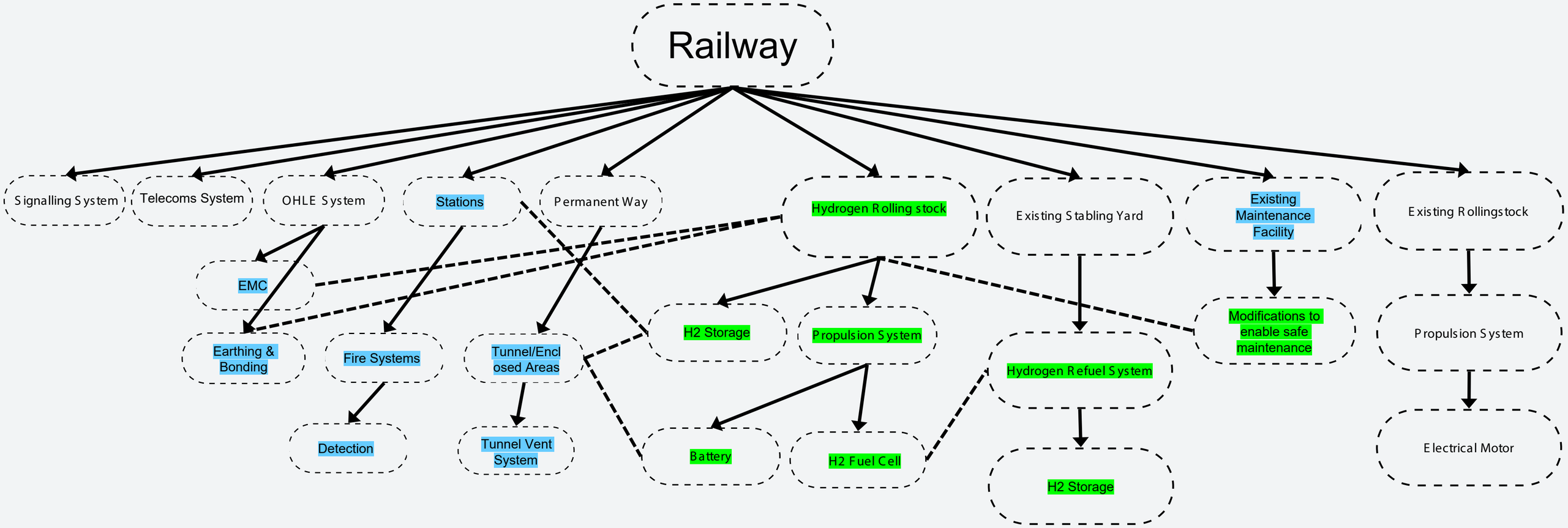
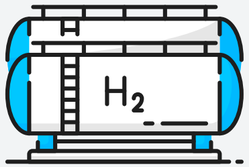
# Railway System



# Mitigation of Key Risks

## Storage

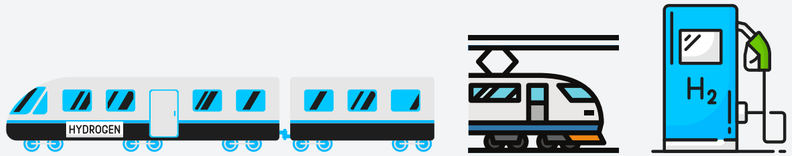



- Inappropriate Handling of H2
- Metal Degradation of tanks leading to leaks
- Cyber Attack
- Physical Security

SA - TS 5359:2022


NIST Cybersecurity Framework/Iso 27000

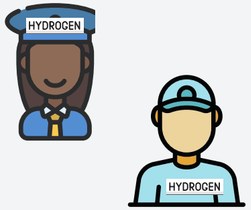
## Rollingstock



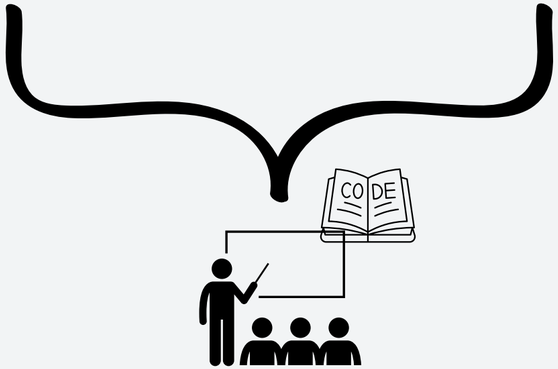

- Fuel Cell Damaged during transit and creates an electrical hazard
- H2 Storage tanks damaged during transit and cause a release of H2
- H2 Storage tanks damaged due to OHLE strike / arc
- Risk of fire on train in tunnel (battery and/or h2 tanks)
- Venting of H2 into enclosed area/tunnel
- Derailment causing damage to H2 Storage tanks
- Also similar risks to storage

Limited or no standards in Rail. Therefore need to have explicit risk estimation.

## Operations & Maintenance




- Poor Training on new H2 equipment
- Maintenance Facilities not designed to maintain H2 equipment
- Incorrect refueling releases H2 into atmosphere



# Safety Devices used in Hydrogen

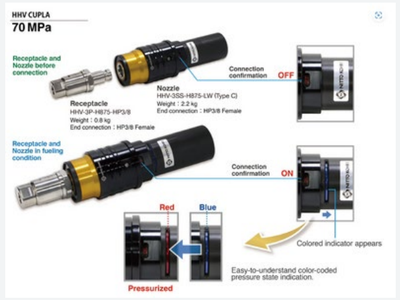
This thermal pressure relief device (TPRD) is designed to clear up tanks and vessels when overheating. A glass ampoule is destroyed when the reaction temperature (typically 110° C) is reached, thus releasing the hydrogen from the tank out through a safety vent in a very short time. Usually used on composite tanks due to composite tanks deteriorating from heat.

This pressure relief device (PRD) is designed to clear up tanks and vessels when a pre-determined pressure is achieved. A spring mechanical lever opens and when pressure returns to the safe level, it closes. They are designed to operate multiple times. Usually used on Steel Tanks as they are more robust in fire situation.

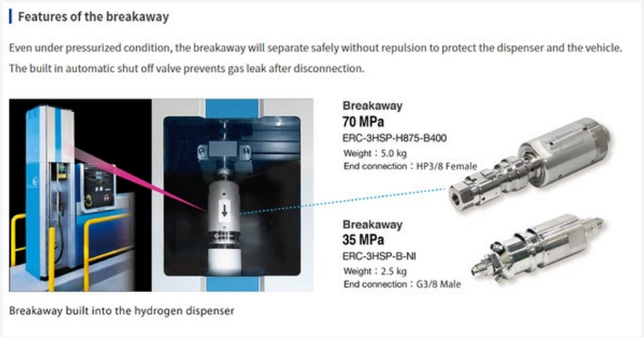

Emergency Stop - Stops the flow of Hydrogen

Hydrogen Sensor - if detection hits a certain level, triggers alarms or shutdown of equipment

Thermal Camera - detection of fire




Coupler for refueling - internal interlocking triggered by pressure - so it can only disperse if safely locked. Visual Indicator to show operater status.




Breakaway - built in automatic shut off valve prevents gas leak after disconnection

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# Hydrogen Opportunities

## A railway without Overhead Power

...based on the information from the UK risk model, that electric shock risks associated with traction power contribute up to 6 fwi (fatalities and weighted injuries) out of 132 fwi per year across UK mainline railway operation (excluding suicides)

Source - Acmena have reviewed the data within RSSB UK

Data from the Office of the National Rail Safety Regulator (ONRSR) in Australia shows that in the 12 months from March 2019 to February 2020, there were over 1,200 reported signals passed at danger (SPADs)... Did the overhead system contribute towards some of the SPADS?

# Other Factors to Consider in NZ

# Railway Resilience

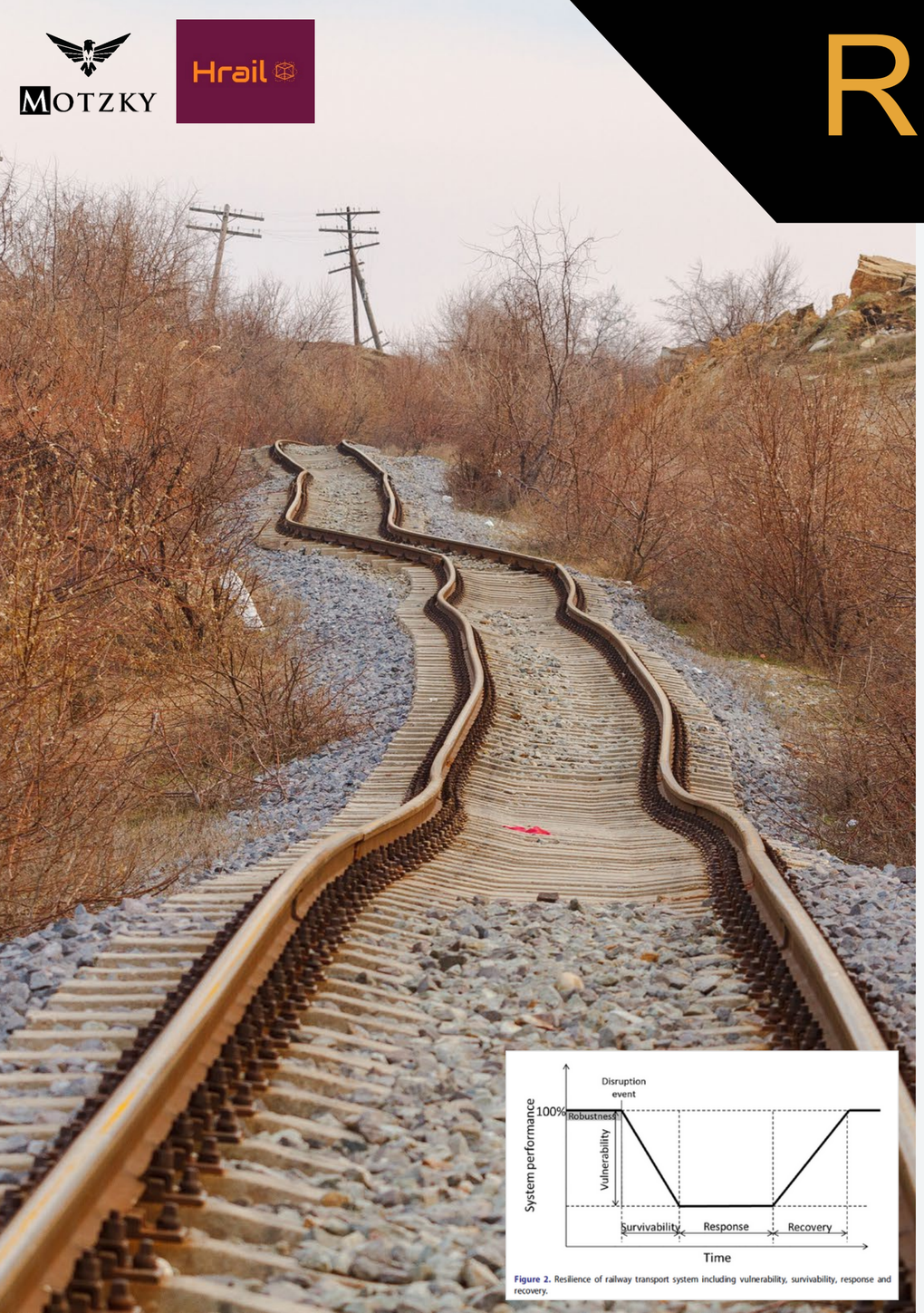
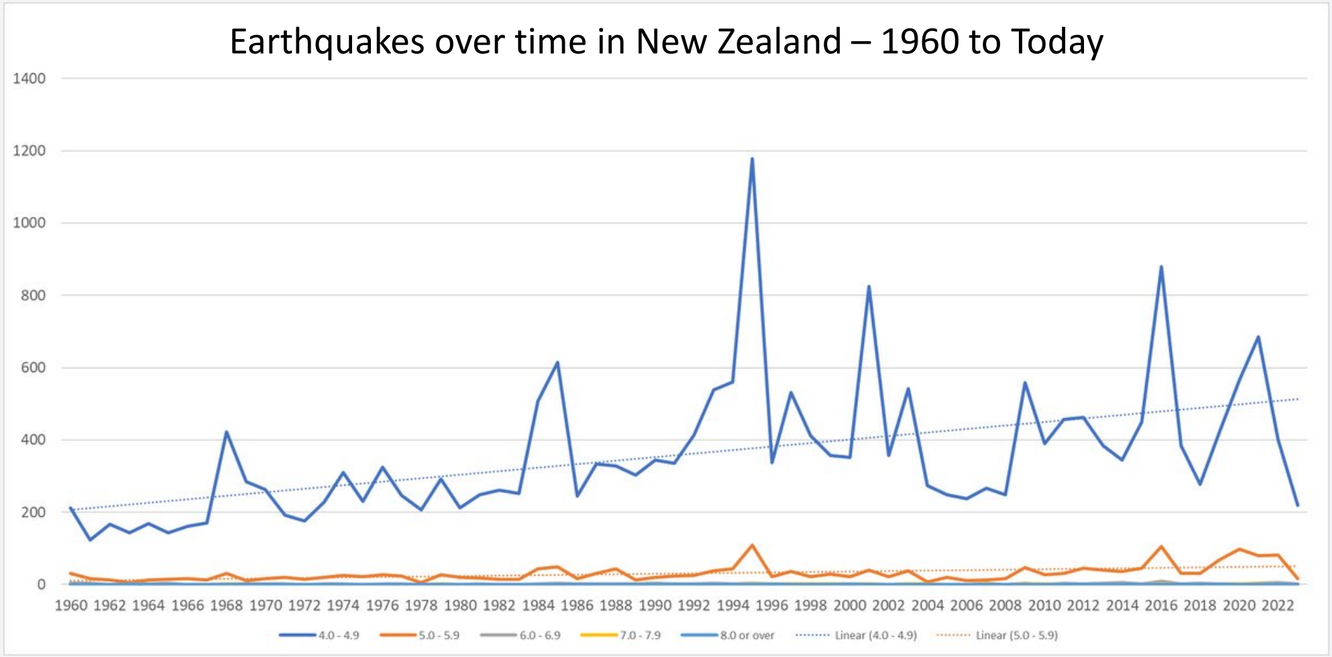



Figure 2. Resilience of railway transport system including vulnerability, survivability, response and recovery.

NZ is prone to seismic activity which affects railway operations directly

- Track needs to be rebuilt/retamped
- An overhead system will further delay in recovery works




Source Data

# Back to the Concept

**New Zealand DF / DFT class (General Motors)**

DFT7295 departing the Ashburton yard, 20 February 2013. Note the enlarged driver's side windscreen.

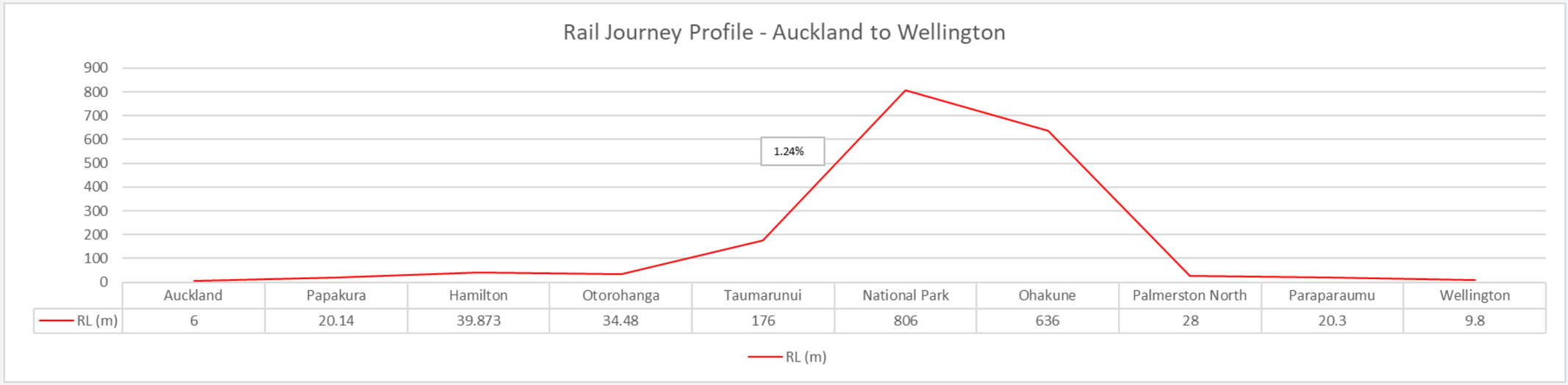
| Type and origin [hide] | |
|---|---|
| Power type | Diesel-electric |
| Builder | General Motors Diesel (GMD), Canada |
| Model | DF EMD GL22MC<br>DFT EMD GT22MC |
| Build date | 1979 - 1981 |
| Rebuilder | Tranz Rail (Hutt Workshops) |
| Rebuild date | 1992 - 1997[1] |
| Number rebuilt | 30 (rebuilt as the DFT class) |

| Specifications [hide] | |
|---|---|
| Configuration: | |
| • UIC | Co'Co' |
| • Commonwealth | Co-Co |
| Gauge | 3 ft 6 in (1,067 mm) |
| Length | 16.7 metres (54 ft 9 in) |
| Adhesive weight | 86.4 tonnes (85.0 long tons; 95.2 short tons) (DF)<br>87.6 tonnes (86.2 long tons; 96.6 short tons) (DFT) |
| Loco weight | 86.4 tonnes (85.0 long tons; 95.2 short tons) (DF)<br>87.6 tonnes (86.2 long tons; 96.6 short tons) (DFT) |
| Prime mover | GM 12-645E (DF)<br>GM 12-645E3C (DFT) |
| RPM range | 900 rpm |
| Engine type | V12 Diesel engine |
| Aspiration | Roots-type supercharger (DF)<br>Turbocharger (DFT) |
| Displacement | 126.84 litres (7,740 cu in) |
| Generator | AR6-D14 |
| Traction motors | Six D29CCT |
| Cylinders | 12 |
| Cylinder size | 230 mm × 254 mm (9.1 in × 10.0 in) |

| Performance figures [hide] | |
|---|---|
| Maximum speed | 113 km/h (70 mph) |
| Power output | 1,230 kW (1,650 hp) DF<br>1,800 kW (2,400 hp) DFT |
| Tractive effort | 198 kN (45,000 lbf) |

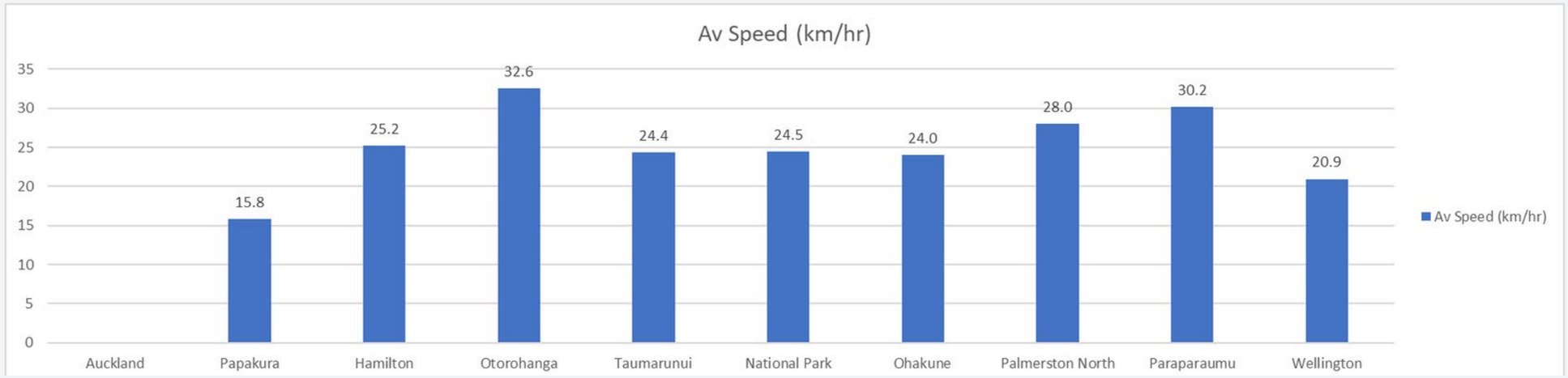
| Career [hide] | |
|---|---|
| Number in class | 30 (20 DFBs and 10 DFTs) |
| Numbers | 1651 - 1670[n 1][2] (original DF)<br>6006 - 6317 (TMS DF)<br>7008 - 7348 (DFT) |
| Locale | All of New Zealand |
| First run | 1979 |
| Disposition | 22 DFBs in service<br>6 DFTs in service<br>1 DFT undergoing overhaul to |

Source - Wikipedia




# Total Distance - Auckland to Wellington - 680 km

# Existing Travel Time - 10 Hours 40 min

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# Available Now

## Supplier 1

TECHNICAL DETAILS (FLAGSHIP PROJECT: FLIRT H2 VEHICLE FOR SBCTA)

| | |
|---|---|
| Range | > 286 miles (460 km) |
| Maximum Speed | 79 mph (127 km/h) |
| Refuelling time | < 30 mins. |
| Seats | 116 |

USA

## Supplier 2


**Fuel cells for long operating ranges**

Due to their high power density, hydrogen trains typically require one tank stop at the depot per day, especially for ranges over 120 km. Two train lengths are available: two-car units for ranges up to 600 km and three-car units for ranges between 800 and 1,000 km.

**Your benefits with Mireo Plus H:**

- EMU performance
- Extremely energy-efficient and power-saving thanks to SiC (silicon carbide) technology
- Maximum speed of 160 km/h
- Low lifecycle costs
- Highly efficient fuel cell enabling long ranges
- Long-lasting batteries thanks to LTO technology
- Smart system for fast refueling

Germany

## Supplier 3

- Trains are capable of 1000 km of travel before refueling *
- *Bremervorde Germany has a refueling station - 64 x 500 bar tanks - total capacity 1800 kg
- 1 kg of hydrogen replaces 4.5litres of diesel
- Supports 14 hydrogen powered trains (Alstom Trains, LINDE designed Hydrogen Refueling Yard)
- *Uses 1.6t of hydrogen per day
- Refuel 15mins per train
- Has been in operation for since 2018

Germany

## Supplier 4


The vehicles consist of two passenger cars, whose lightweight aluminium construction helps to increase the train's energy efficiency, and a power pack to house the fuel cells and hydrogen tanks, as well as other technical equipment.

With an overall length of around 50 metres, the new trains have 89 seats per vehicle for a total of 155 passengers transported and are fully accessible for people with reduced mobility.
Furthermore, the new vehicles offer specific areas for wheelchairs, pushchairs and bicycles positioned near the access and exit doors, as well as a PRM toilet compliant with TSI standards.

Italy

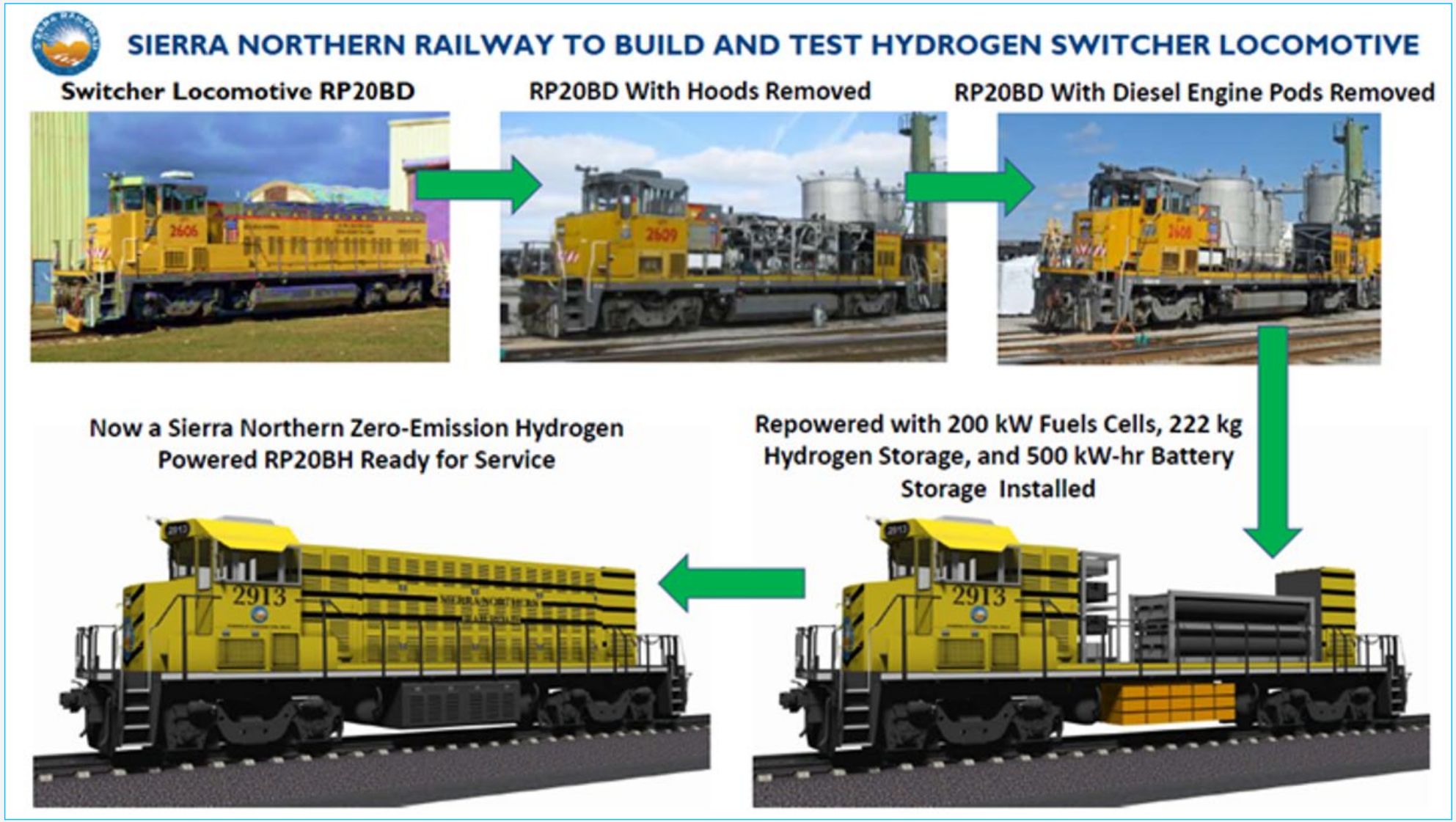
# Coming soon...

## Loco 1


## Loco 2


## Loco 3


## Loco 4

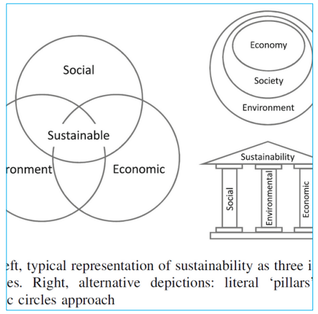


Toward sustainability and resilence

# Conclusions

Bringing road to rail is a way forward in the strategy of de-carbonisation, however we also need to de-carbonise the railway.

New Zealand has so many natural advantages to become a leader in hydrogen production and application in transport.




ft, typical representation of sustainability as three i
es. Right, alternative depictions: literal 'pillars'
c circles approach

New Zealand transport can become emission free sooner if the sustainability economic pillar is activated toward implementation of hydrogen, both in supply and in use.

From a safety perspective, the key area to review for the New Zealand railways, are the existing tunnels and whether they are adequate to support the running of hydrogen tunnels in their current state..

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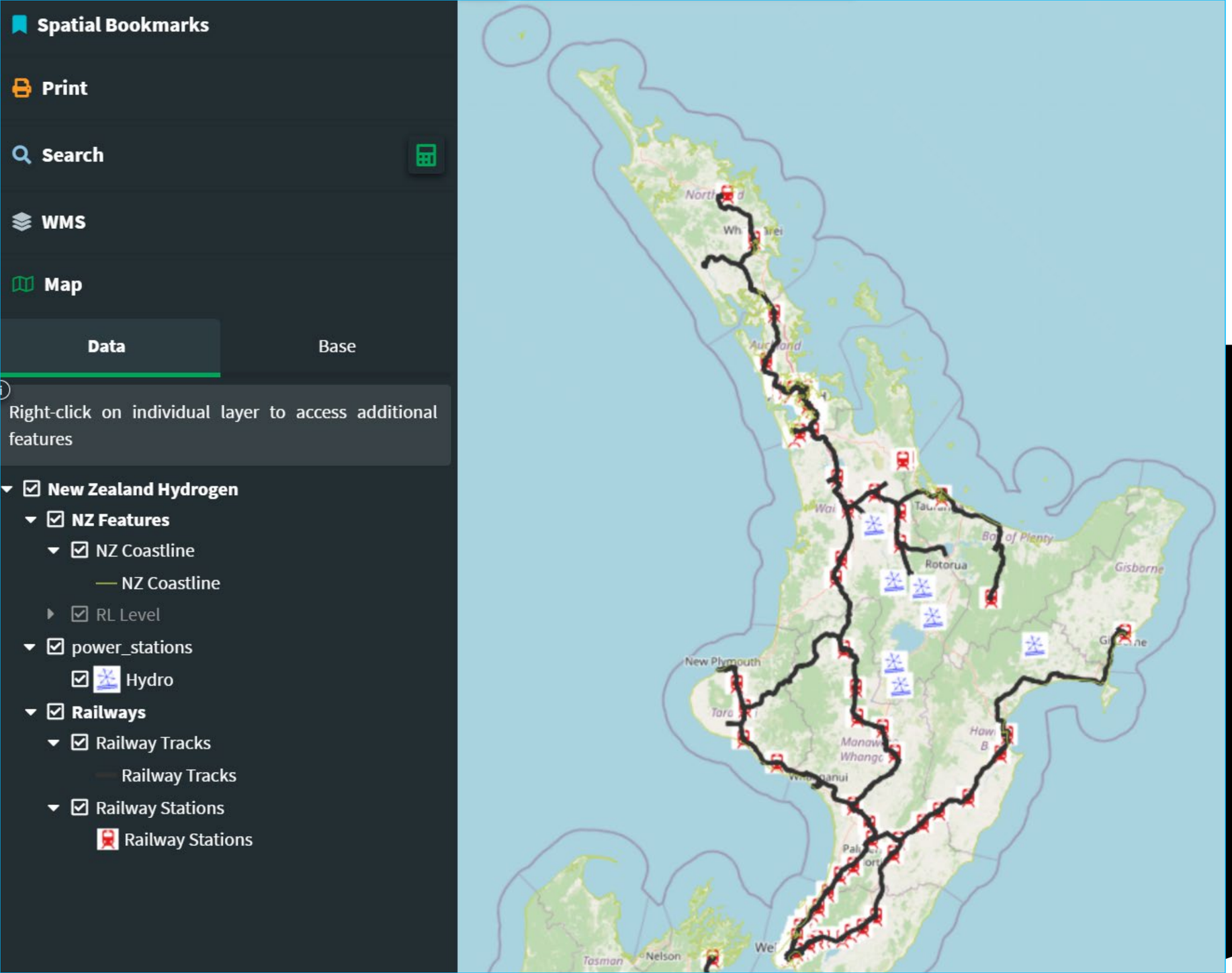
Hrail




Building and maintaining an integrated map that includes hydrogen related assets support hydrogen implementation in Transport industry and promotes opportunities which may not be visible

Toward sustainability and resilence

# Conclusions

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