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THE PENETRATION AND UTILISATION OF HYDROGEN TO POWER RAILWAY VEHICLES

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University of Birmingham

Railway Research (since 1968)

- Aerodynamics
- Asset management
- Condition monitoring
- Environment
- Geotechnical engineering
- Materials and metallurgy
- Modelling and computation
- Network capacity
- Non-destructive testing
- Power and traction
- Risk and safety
- Signalling and train control
- Systems engineering

Hydrogen Field

- Hydrogen Generation
- Hydrogen Storage
- Hydrogen Applications

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OUTLINE

- PhD Scope,
- Work Done,
  - Review of prototypes ,
  - Well-to-Wheel Analysis,
- Future Direction.

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PHD SCOPE 1

Hypothesis:

Hydrogen powered railway vehicles (hydrail) offer a suitable, economic alternative to diesel and electric traction for different railway services such as, freight, commuter, long distance.

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PHD SCOPE 2

- Hydrail vehicles are technically possible,
- The overall impact on the climate and energy security will be investigated,
- Economic considerations analysed i.e. Business case,
- The most suitable service for commercial introduction of hydrail vehicles will be shown.

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WORK DONE - PROTOTYPES

There are four hydrogen powered railway vehicles to date. Two of them in North America and two in Japan,

USA

Mining Locomotive – Vehicle Projects,
Switcher Locomotive – Vehicle Projects

Japan

Single Railcar – JR East,
Two Railcars – RTRI.

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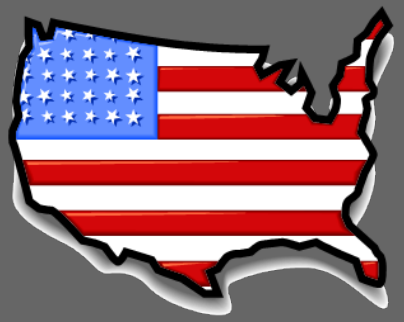
USA



1 Mining Vehicle

- In 2002 Vehicle Projects created a hydrogen powered railway vehicle which replaced a battery powered one in a mine in Canada,
- The hydrogen vehicle outperformed the battery powered one.

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2 Hydrogen Switcher

- In November 2009 vehicle projects switcher locomotive entered operational testing in the Los Angeles Basin (LA),
- The hydrogen is supplied by Air Products.

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FUELLING ARRANGEMENTS

- Hydrogen Trailer, then pumped to locomotive tanks,
- New full trailer delivered when necessary,
- Equipment mobile as the locomotive is in the area only for about three month,
- Based on energy content, hydrogen fuel cost today is equivalent to diesel fuel ($2-3/gal) in LA supplied by Air Products.

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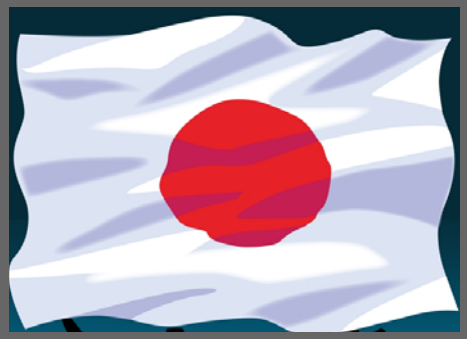
JAPAN



1 East Japan Railway Company (JR East) Railcar

www.hydrail.net 2010

- In 2002 JR East started the development of the New Energy Train,
- First diesel hybrid, in commercial operation since 2004,
- In 2006 hydrogen railcar was finished,
- In 2007 test runs conducted on commercial lines.

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2 RAILWAY TECHNICAL RESEARCH INSTITUTE (RTRI) RAILCARS

- From 2001 the RTRI conducted tests with fuel cells,
- In 2003 hydrogen powered bogie,
- In 2006 single fuel cell powered railcar, auxiliaries powered from catenary, no regenerative braking,
- In 2008 two car hydrogen hybrid train.

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EUROPE

- Hydrogen vehicle development is focused on road transport,

- Some countries have projects with hydrogen trains, e.g. Denmark,
- No full hydrogen prototype exists,
- France is testing a hybrid locomotive with a 235 kW diesel engine and a 50 kW fuel cell.

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WELL-TO-WHEEL ANALYSIS 1

Hydrogen traction has been compared to diesel and electric traction, several production pathways have been considered.

www.linde-engineering.com 2010

1) Current Situation (2008) for the UK, USA and California.
   - Hydrogen produced from natural gas via steam methane reforming,
   - Diesel produced from petroleum oil,
   - Electricity produced, from various source, mix includes coal, nuclear, natural gas and renewables.
2) Vehicle efficiencies are for electric (76%), diesel (30%) and hydrail (49%).
3) Future situations have been analysed, here presented hydrogen from thermolysis compared to electricity form solar power plant.

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WELL-TO-WHEEL ANALYSIS 2

Current Situation (2008), well-to-wheel efficiencies and CO2 emissions per kWh energy used at the railway wheel

Electric

UK	(24%, 0.86kg CO2/kWh)
USA	(22%, 0.95kg CO2/kWh)
CA	(26%, 0.60kg CO2/kWh)

Diesel (26%, 1.02kg CO2/kWh)

Hydrogen

Fuel Cell hydrogen gas	(29%, 0.71kg CO2/kWh)
Fuel Cell hydrogen liquid	(23%, 0.87kgCO2/kWh)
Internal combustion engine hydrogen gas	(18%, 1.16kg CO2/kWh)

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WELL-TO-WHEEL ANALYSIS 3

Solar well-to-wheel efficiencies, energy transport over long distance using hydrogen pipeline and High Voltage Direct Current (HVDC) for electricity, starting with sun radiation (100%)

www.savingenergy.ie 2010

Electric (solar power station) (12%)

Hydrogen (produced by thermolysis)

Fuel Cell hydrogen gas (18%)

Fuel Cell hydrogen liquid (14%)

www.psi.ch 2010

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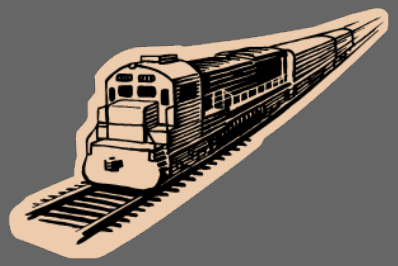
FUTURE DIRECTION - SUMMARY

1. Hydrogen as a power carrier has been demonstrated in several rail applications,
2. All projects concluded that hydrogen is a feasible power carrier for railway applications,
3. Hydrogen can have well-to-wheel efficiency benefits and lower CO2 emissions.



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FUTURE DIRECTION PHD PROJECT

- Include the cost of GHG to society and other stakeholders and show then adapted cost for hydrogen vehicles,
- Establish the suitability of hydrogen for different services e.g. freight, commuter, high speed etc.,
- Conduct commercial assessments (business case) for the implementation of this technology,
- Analyse the impact under different ‘states of the world’,

- Show the risk to the rail industry for different scenarios e.g. not participating in the development, being pro-active etc.,
- Provide the rail industry with recommendations how to respond to hydrail vehicle development.

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THANK YOU!

Further Information at:

http://postgrad.eee.bham.ac.uk/hoffrichtera/website/index.htm

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