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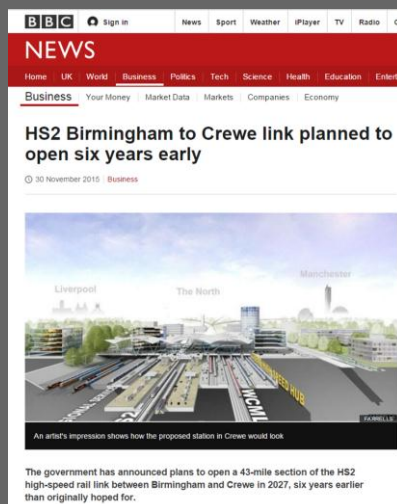
U Future Fuel for Britain's Railways B

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So what does the future look like?

- Railways are in demand:
 - new railway lines including HS2, HS3, Crossrail ...
 - more trains needed, with a 57% growth in capacity required by 2034
 - more stations & depots
 - much higher operating speeds (HS2 built for 250mph)
- This requires substantially more power than the railways currently use, despite advances in technology



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Where's the power going to come from?

- Not from diesel:
 - global climate change concerns
 - increasing local pollution concerns (i.e. NOx and particulates)
 - advances in after-treatment help, but are not a solution
 - stability of supply
 - security of supply
 - train leasing companies wont buy new diesel fleets



Source: Top Gear Magazine - 2015

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So we're going to electrify everywhere?

- No – it's too expensive
- There are also challenges in relation to the grid:
 - railways currently consume about 0.5% of grid capacity
 - but capacity to increase dramatically, more electrification & higher speeds
 - conceivable that electricity demand could double to 1% by 2034
 - there's not a lot of spare generating capacity and it's likely to get worse



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So what can be done about it?

- Reduce consumption:
 - improve train aerodynamics
 - reduced train mass
 - increased use of regeneration
 - limit maximum speeds
 - improve the energy efficiency of our buildings, stations, depots



Source: Rail Technology Magazine website - 2015

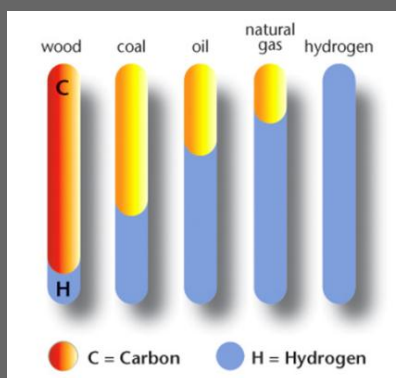
- But there's a limit to what can be achieved, so will still need to examine the alternatives

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So what are the alternatives?

- Generate our own electricity (ideally local to rail infrastructure), and
- Find an alternative to diesel for autonomous power that is:
 - ideally not reliant on fossil fuels, or at least which produces less CO₂
 - produces no NO_x and particulate pollution
 - is suitable for both urban and non-urban environments



Source: Based on data from SustainabilityNow website - 2003

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How do we generate our own electricity?

- Could build our own power stations, but we don't need that sort of power at a single location
- Smaller distributed power generation might be better:
 - solar can't provide the sorts of power we need
 - on-shore wind would require huge energy storage capacity
 - could use natural gas, particularly if fracking happens
 - could also use biogas



Source: Reuters website - 2013

Source: The Lincolnie website - 2015



Source: The Guardian website - 2012



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So how can we use natural gas / biogas?

- Could use CHP plants as per New Street which has a 1.5MW installation on the roof with excess heat feeding the local district heating system
- But this still produces NOx and particulates
- One alternative is to use Direct Fuel Cells (DFCs):
 - 59MW installation in S.Korea
 - constructed in 14 months by Fuel Cell Energy Inc.



Source: NewStreetNewStart website - 2015



Source: Fuel Cell Energy Inc. website - 2015

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What's a DFC and why is it a good idea?

- Natural gas (or biogas) reformed within a high temperature fuel cell:
 - generates electricity at 47% efficiency (gas turbines \approx 40%)
 - zero NOx and particulates
 - lower CO2 emissions
 - virtually silent
 - high grade “waste” heat 350-400°C used to heat/cool buildings or boost electrical efficiency to over 60%
 - provides a plentiful supply of high-grade hydrogen, which could be useful



Source: Fuel Cell Energy Inc. website - 2015

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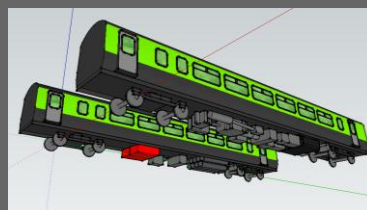
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Alternatives for autonomous traction?

- IPEMUs (i.e. EMU + battery) wherever trains run mainly under the wires, but hop off to go short distances:
 - through tunnels
 - to cover non-electrified “end of the line” stations
 - to hop between electrified routes
- But there is still a need for trains that never need to “recharge” from the overhead
- UoB is keen on fuel-cells



Source: Rail Technology Magazine website - 2015



Source: Fuel Cell Systems Limited - 2015

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So why do fuel cells make sense?

- Hydrogen can be generated from wide variety of sources
- Large quantities of energy can be stored
- Trains have known duty cycles and return to base every
- 100kW to 200kW fuel-cells available, suitable for 75mph regional services or light rail
- UoB looking at retro-fitting mid-life DMUs such as Class 150/3/6 to construct Britain's first FCEMU



Source: Author - 2015



Source: Author - 2015

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Any final thoughts?

- Could FCEMUs provide low cost alternative to electrification?
- Could a combination of DFCs, electrolysers & FCEMUs enable the Britain's railways to run on only natural gas and off-peak electricity?
- Could railway stations become the "hydrogen hubs" of the future?

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