Institute for Transport Studies
FACULTY OF EARTH AND ENVIRONMENT
UNIVERSITY OF LEEDS

Review of CO2 Emission Studies of High-Speed Rail in Europe

Dr Greg Marsden

ITS

Outline

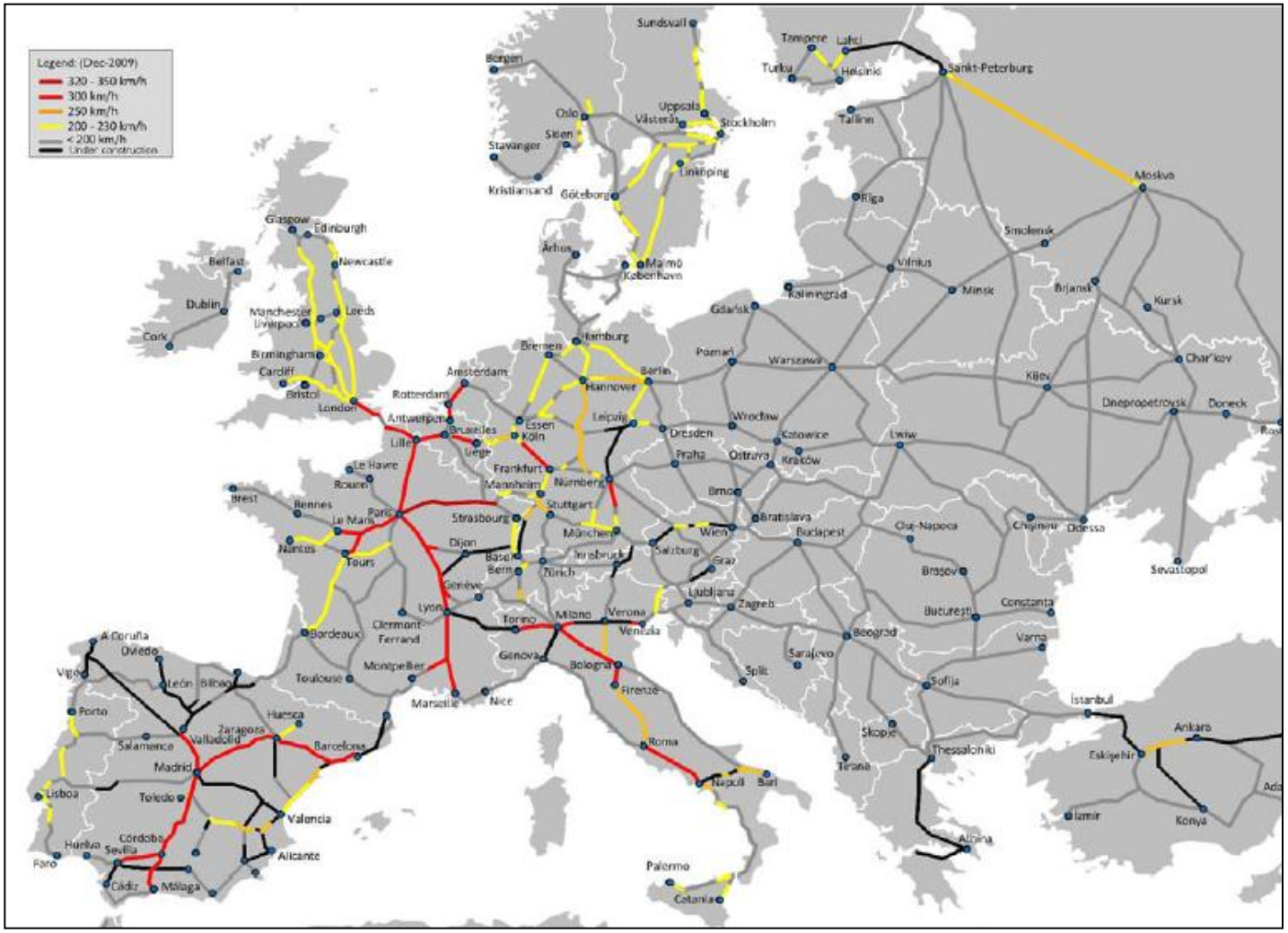
UNIVERSITY OF LEEDS

- Brief introduction to HSR in Europe
- Key factors influencing environmental performance
- Rail Fleet Technology and per-seat emissions
- Electricity Generation
- Track and Maintenance vs. Operation
- Emissions per passenger kilometre
  - Frequency, load factors, mode shift, new demand
- Some Scenarios
- Summary

ITS

HSR in Europe - 2009

UNIVERSITY OF LEEDS



Source: Wikimedia Commons' map of Europe high-speed rail 2009.

ITS

Factors Affecting Comparisons

UNIVERSITY OF LEEDS

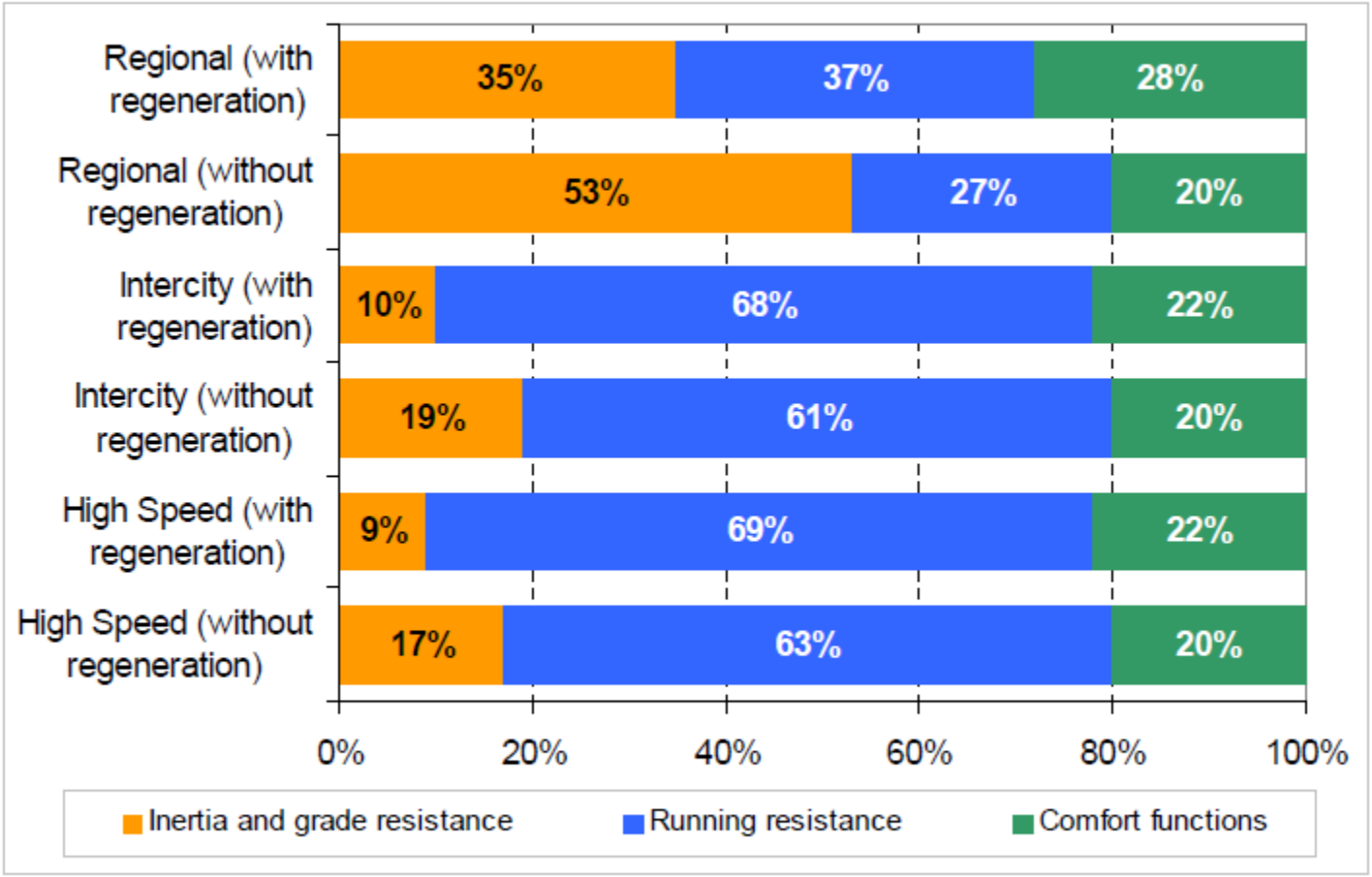
- Direct performance (energy consumption) of the rail rolling stock
- Direct and indirect greenhouse gas emissions from electricity production
- Indirect emissions resulting from the construction, maintenance and decommissioning of rolling stock
- Energy consumption/emissions resulting from construction and use of new rail infrastructure
- Seating occupancy levels and service frequency for high-speed versus conventional rail
- Energy consumption/emissions savings resulting from modal shift and factoring in demand generation

ITS

Direct Performance

UNIVERSITY OF LEEDS

Figure 2.1: Typical composition of energy demand for high-speed and conventional rail services



Notes: Reproduced from UIC EVENT (2003) Project report p27

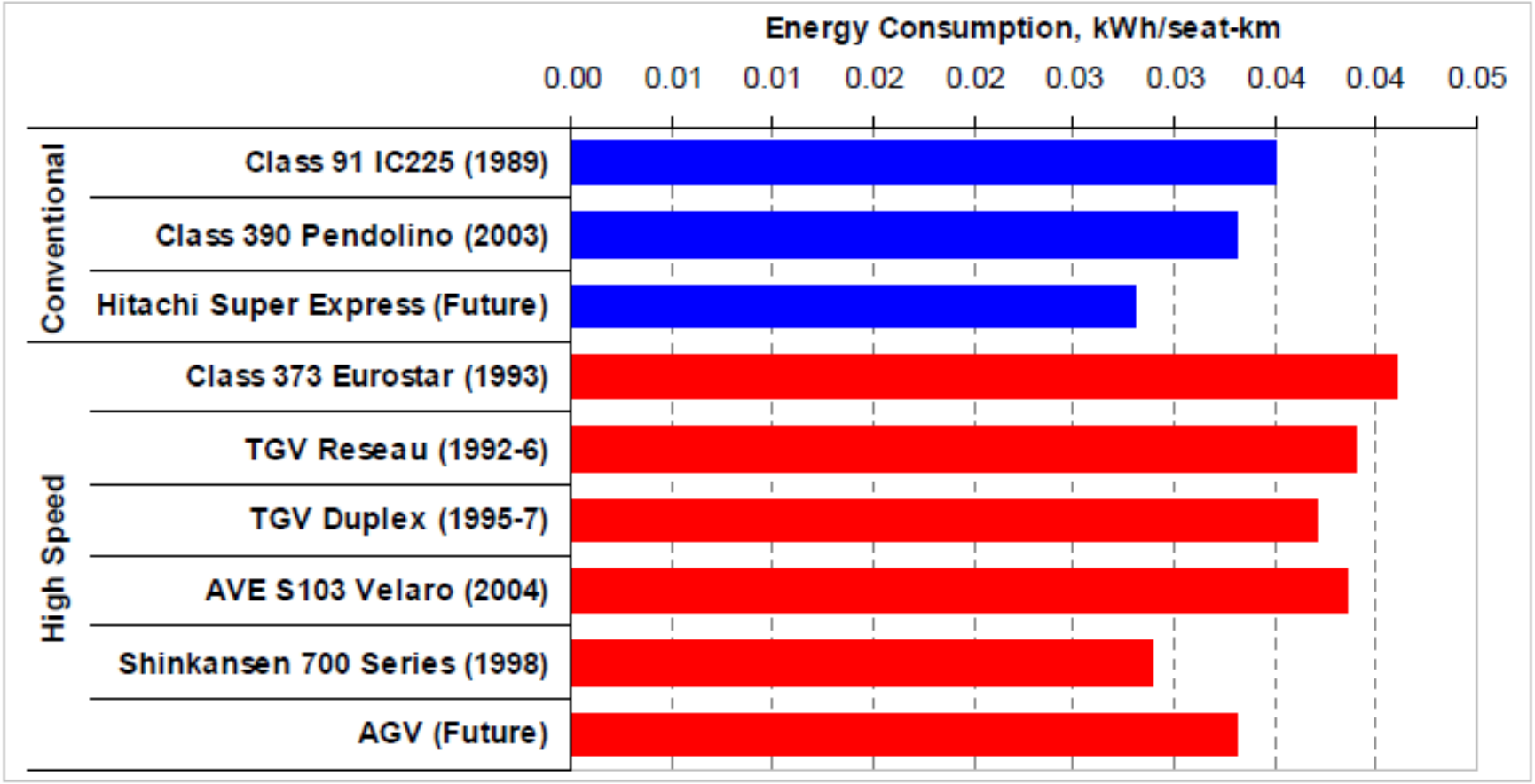
ITS

Image: Network Rail (2009)

Direct Performance

UNIVERSITY OF LEEDS

Figure 2.7: Energy consumption of current and future rolling stock (kWh per seat-km)

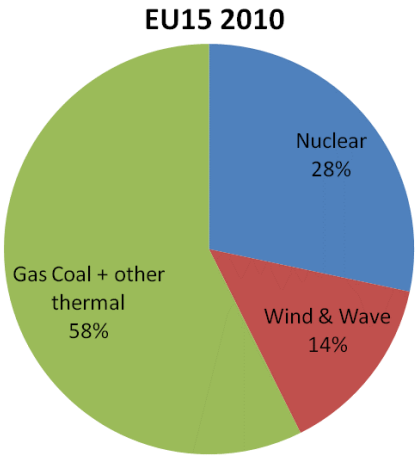


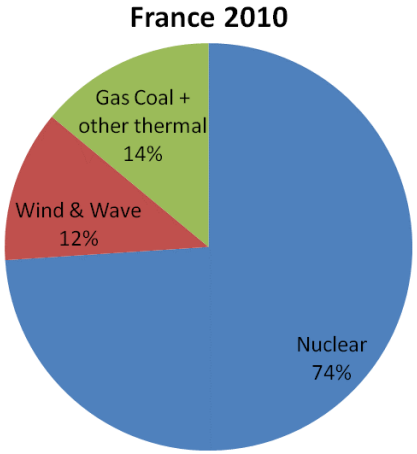
ITS

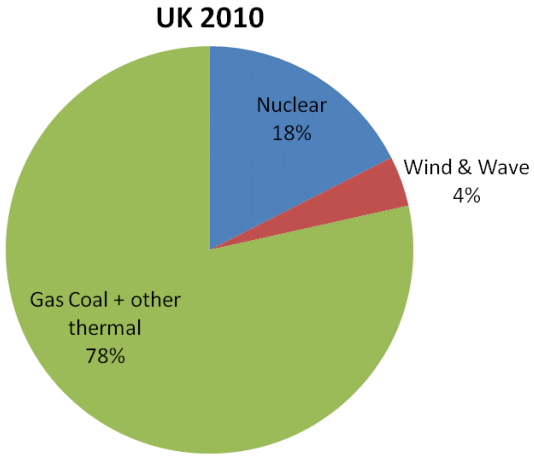
Image: Network Rail (2009)

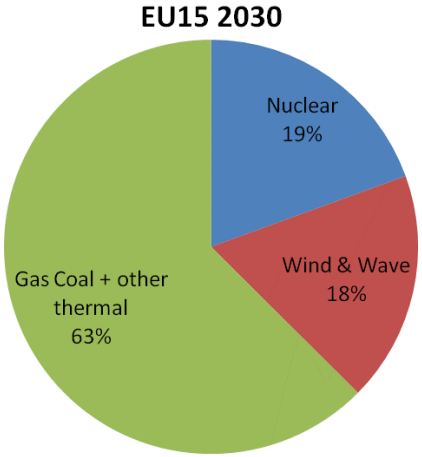
European Electricity Generation Mix

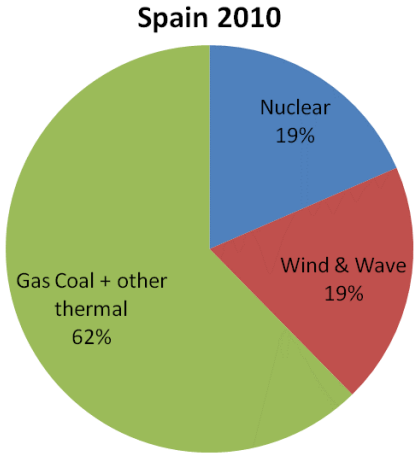
UNIVERSITY OF LEEDS

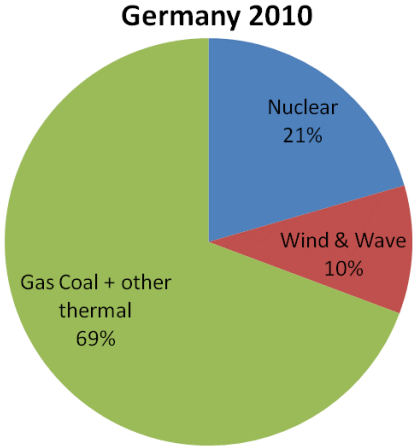








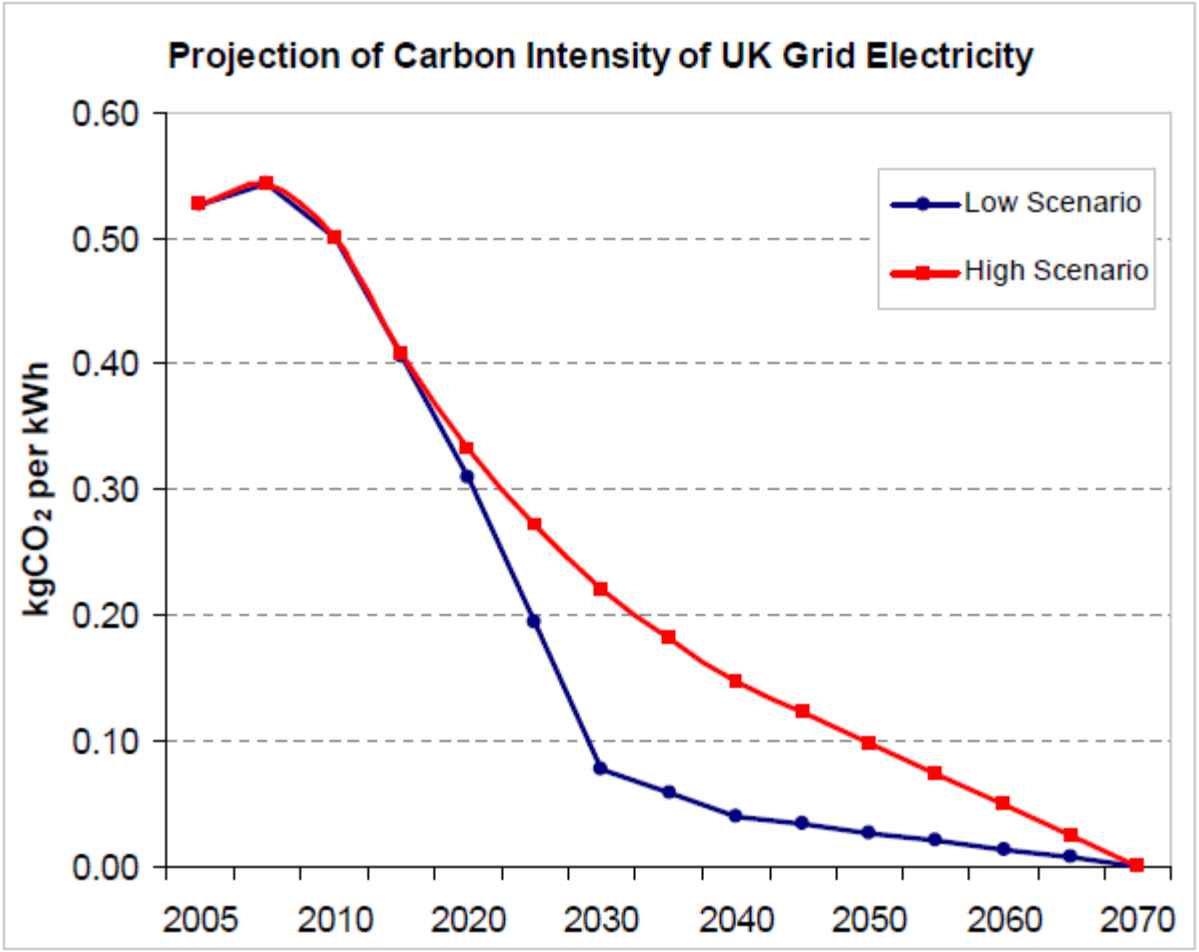




Carbon Intensity of UK Grid Electricity

UNIVERSITY OF LEEDS

Figure 2.9: Low and High Scenarios for Future Carbon Intensity of UK Grid Electricity



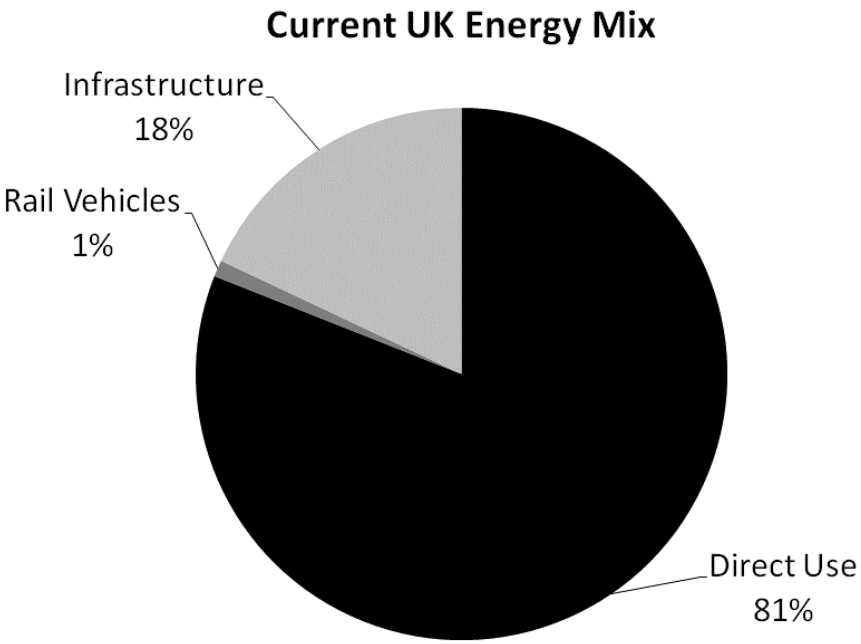
Notes: The above figure only includes the direct emissions of CO_2 from electricity generation. Resistive losses from transmission and distribution systems are included in the figures presented.

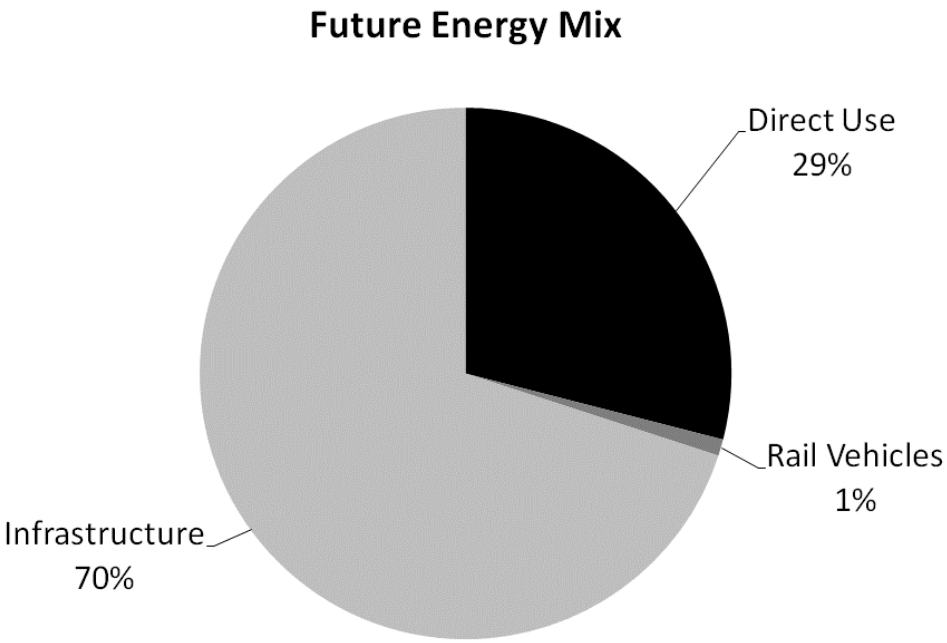
Image:
Network Rail (2009)

ITS

Vehicle and Track Construction and Maintenance

UNIVERSITY OF LEEDS





ITS

Seating Occupancy Level and Frequency

UNIVERSITY OF LEEDS

- Emission rates/passenger kilometre more relevant than emission rates/seat
- Key factors influencing load factors are:
  - Intrinsic demand
  - Length of train
  - Frequency
  - Number of stops
  - Fares

ITS

Typical Load Factors in EU

UNIVERSITY OF LEEDS

Table 2.12: Typical load factors for European high-speed rail services

Route	Country	Distance, km	Load Factor	Year	Source
London to Paris (Eurostar)	UK-France	496	64%	2009	Telegraph, 2009
Paris to Strasbourg (TGV First class)	France	487	77%	2007	ESPA, 2007
Paris to Strasbourg (TGV Second class)	France	487	88%	2007	ESPA, 2007
Paris to Marseille (TGV First Class)	France	740	60%	2003	BNET, 2003
Paris to Marseille (TGV Second Class)	France	740	76%	2003	BNET, 2003
Nurnberg to Ingolstadt (ICE)	Germany	90	42%	2006	RG, 2006
Berlin to Hamburg (ICE)	Germany	288	49%	2006	RG, 2006
ICE Average	Germany	-	50%	N/A	EEA, 2000
Madrid to Sevilla (AVE)	Spain	472	85%	1997	MEET, 1997
Malaga to Cordoba (AVE)	Spain	159	56%	2007	UIC, 2009.
AVE long distance average	Spain	-	70%	2007	UIC, 2009
AVE medium distance average	Spain	-	56%	2007	UIC, 2009

ITS

UK High Speed Rail 2 (HS2)

UNIVERSITY OF LEEDS

- 2009 modelling
- Earlier route configuration
  - London-Birmingham
    - HSR Load Factor 34%
    - Conventional LF 27%
  - London-Manchester
    - HSR Load Factor 42%
    - Conventional LF 33%

ITS

Passengers using HS2

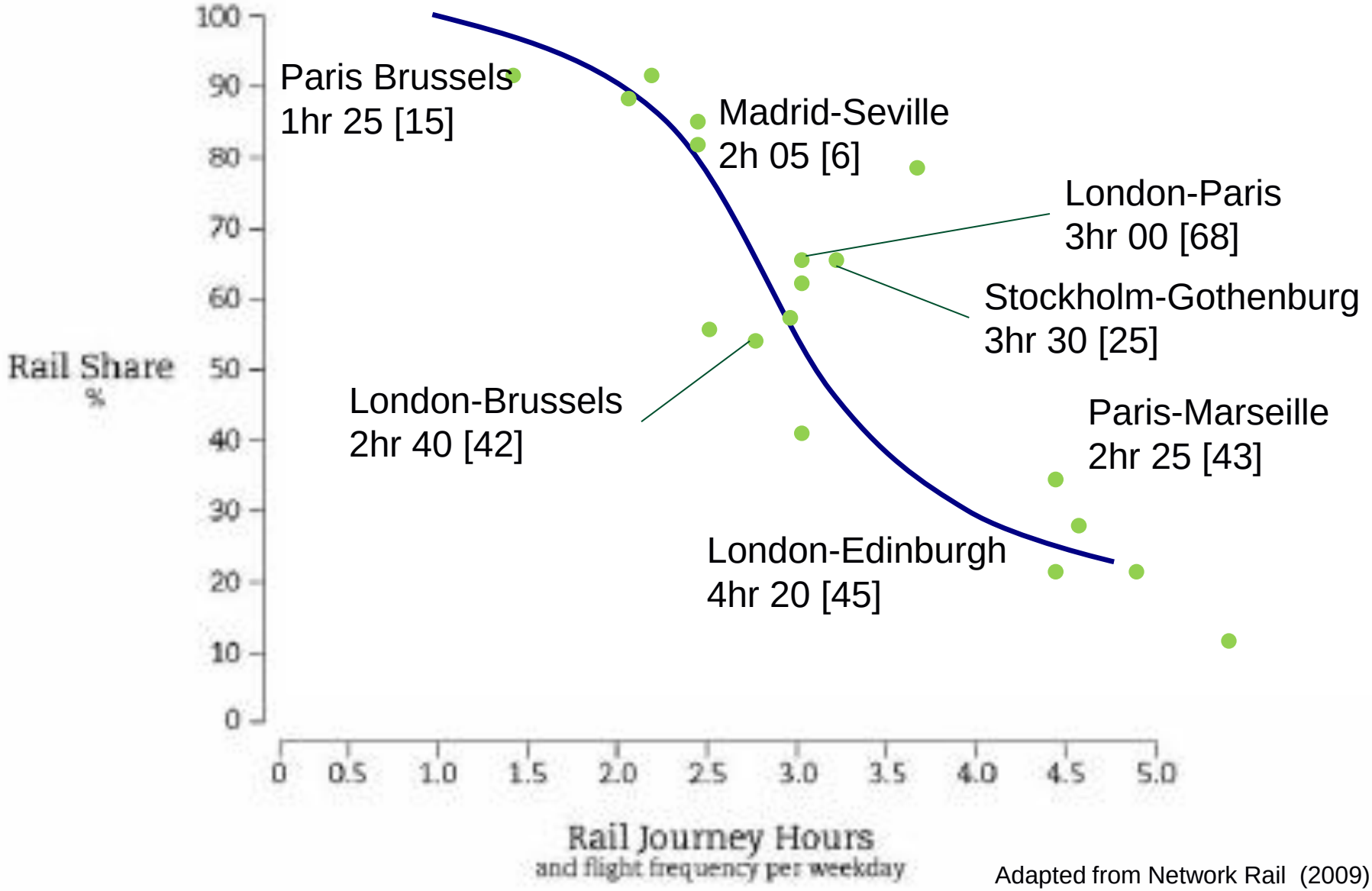
UNIVERSITY OF LEEDS

Switch from classic rail	57%
New Trips	27%
Modal Shift from Air	8%
Modal Shift from Car	8%

ITS

Mode Share by Journey Length

UNIVERSITY OF LEEDS



Adapted from Network Rail (2009)

Outcomes

UNIVERSITY OF LEEDS

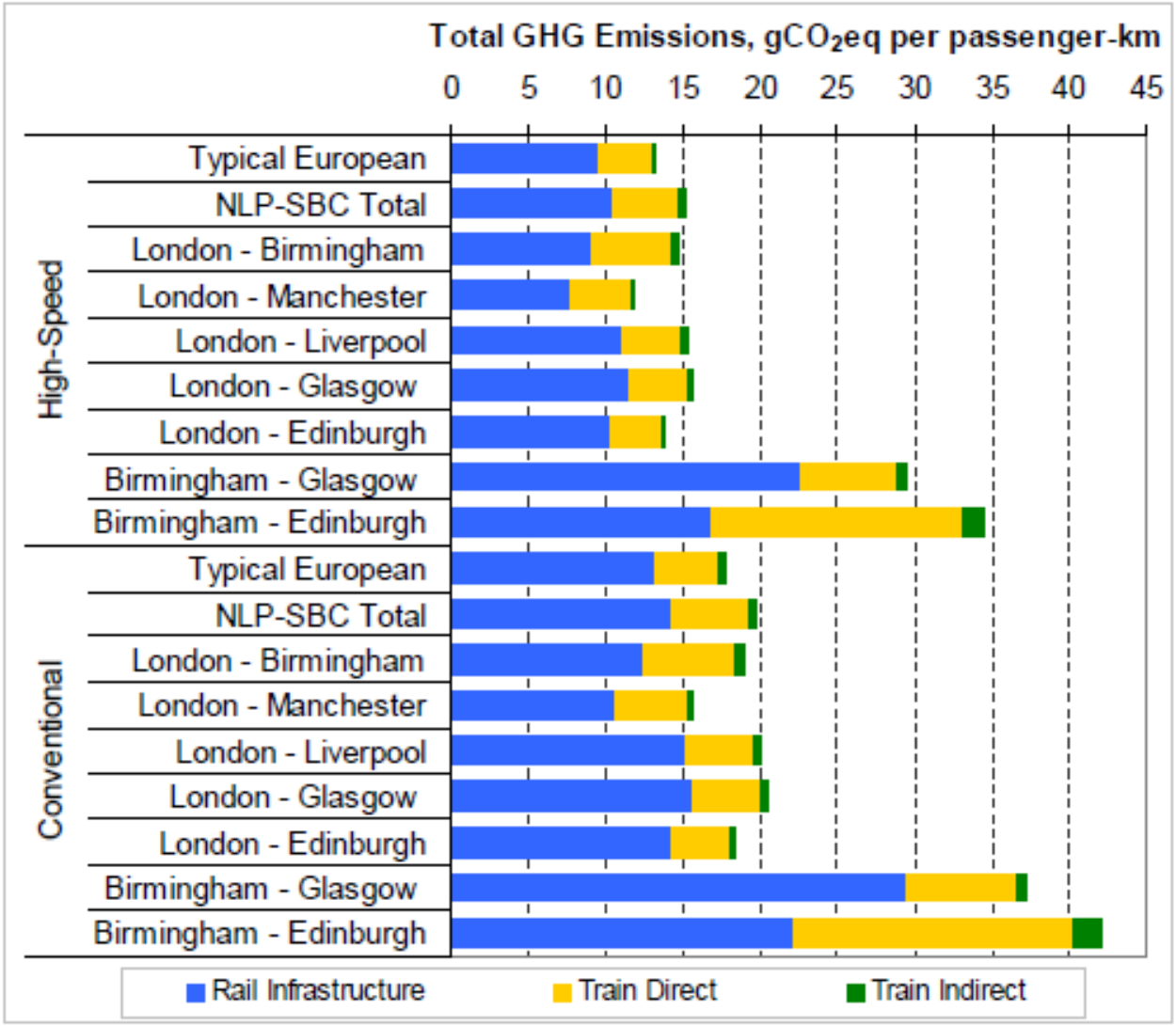


Image: Network Rail (2009)

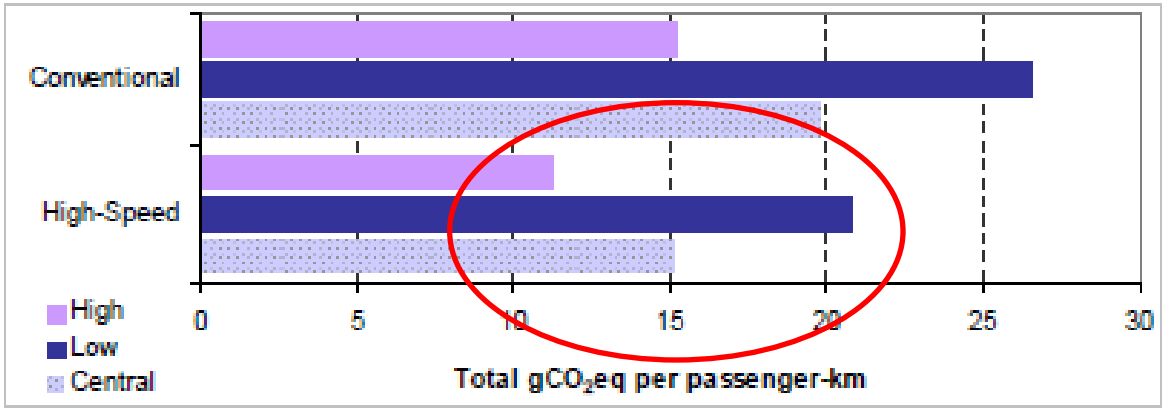
ITS

20% sensitivity analysis

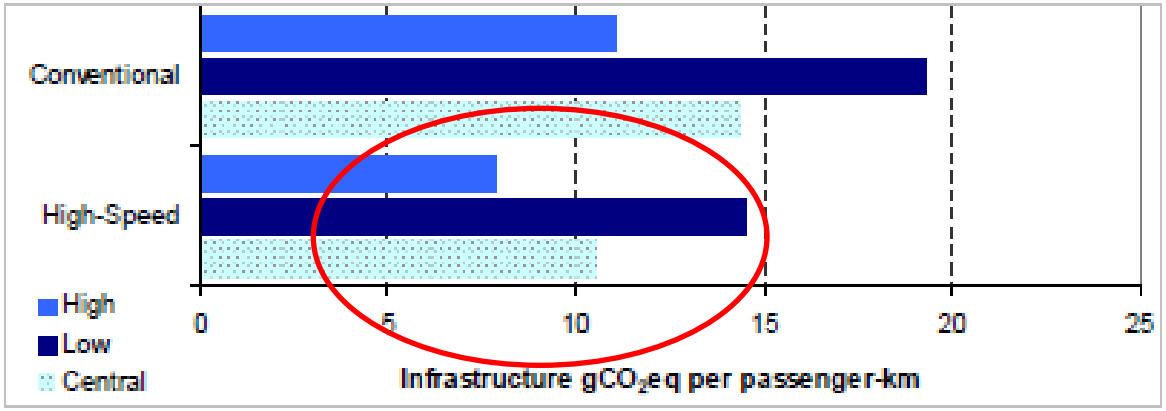
UNIVERSITY OF LEEDS

Figure 3.6: Sensitivity analysis breakdown on the impact of varying occupancy levels and passenger numbers on the comparison of total GHG emissions from conventional and high-speed rail

Total:



Infrastructure:

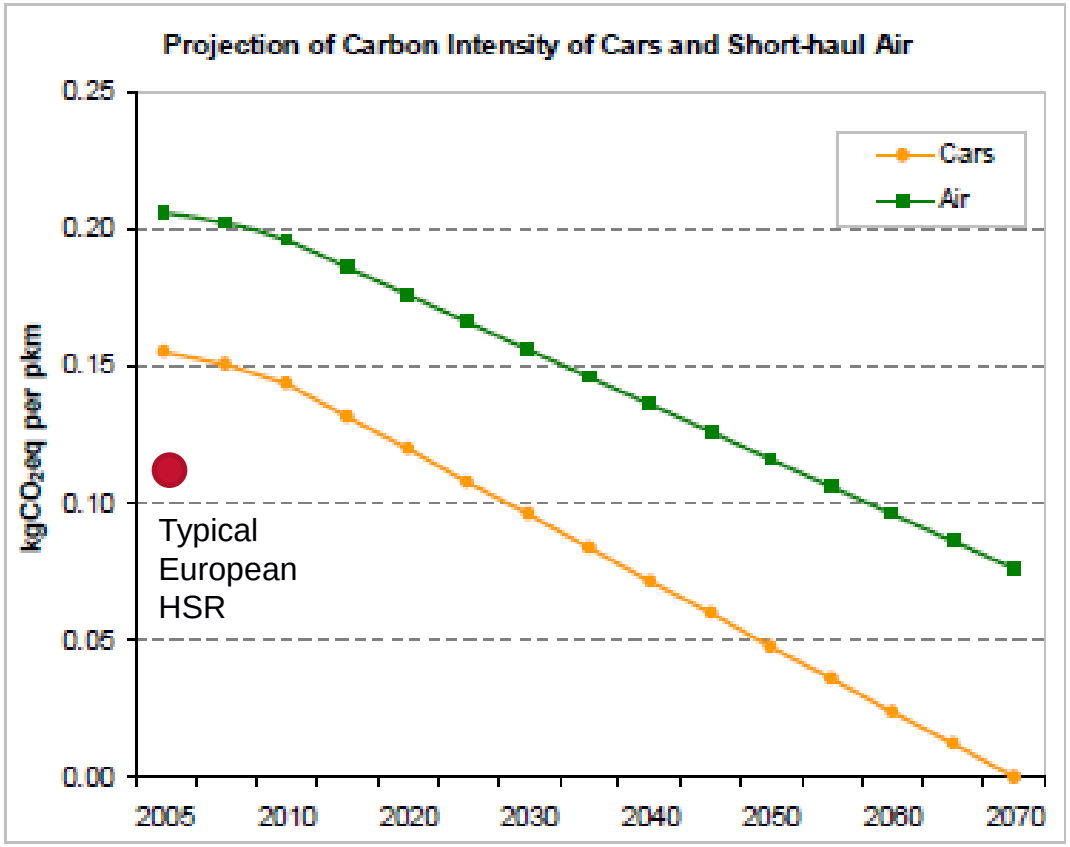


ITS

Image: Network Rail (2009)

Comparative advantage of mode shift reduces

UNIVERSITY OF LEEDS



Adapted from Network Rail (2009)

ITS

Energy consumption by mode (MJ per pass km)

UNIVERSITY OF LEEDS

Inter city train at 44% load	0.5
High speed train at 49% load	1.08
High speed train at 70% load	0.76
Air (500km flight) at 70% load	2.57
Diesel car on motorway at 36% load	0.94
	Source: CE Delft (2003)

TGV (France)	0.68 (4g CO_2/pass km)
ICE (Germany)	0.79 (27g CO_2/pass km)
Aircraft (Europe Short-Haul)	1.4-3.5 (100 – 150g/pkm)
	Source: Janic (2003)

ITS

Some points in summary

UNIVERSITY OF LEEDS

- Case varies country to country
  - Environmental Benefits are typically only 2-4% of benefits
- Specifics of the proposal are critical to relative benefits
- Other modes are improving their efficiency also
- This is a tool for economic rather than environmental policy in UK context
  - Domestic air emissions in UK < 2% of total transport CO_2
  - May still feature as cost effective CO_2 policy due to co-benefits
  - Significant environmental mitigation costs for routes

ITS

References

UNIVERSITY OF LEEDS

CE Delft (2003) To shift or not to shift, that‘s the question. The environmental performance of the principal modes of freight and passenger transport in the policymaking context. Delft.

Janic, M. (2003) High-speed rail and air passenger transport: a comparison of the operational environmental performance, *Proc. Instn Mech. Engrs*, **217** Part F, 259-269

Campos, J. and De Rus, G. (2009) Some stylized facts about high-speed rail:A review of HSR experiences around the world, *Transport Policy*, **16**, 19-28

Nash, C.A. (2009) When to Invest in High-Speed Rail Links and Networks? Discussion Paper No. 2009-16, ITF-OECD Joint Transport Research Centre

Network Rail (2009) Comparing environmental impact of conventional and high speed rail, New Lines Programme, http://www.networkrail.co.uk/aspx/5892.aspx

Gonzalez Gonzalez, E., Marsden, G. and Smith, A.E. (2010) How important are environmental factors in the case for High Speed Rail? A comparison of the United Kingdom and Spain, Presented at the 12th World Conference on Transport Research, Lisbon, 11-14th July

ITS

Contact

UNIVERSITY OF LEEDS

Dr Greg Marsden

Institute for Transport Studies

University of Leeds

United Kingdom

G.R.Marsden@its.leeds.ac.uk

Tel: +44 (0)113 3435358

Web: www.its.leeds.ac.uk

ITS