Railways and Energy

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Sustainable Mobility: Energy Efficiency in Transportation (MSE 296)
May 20, 2011

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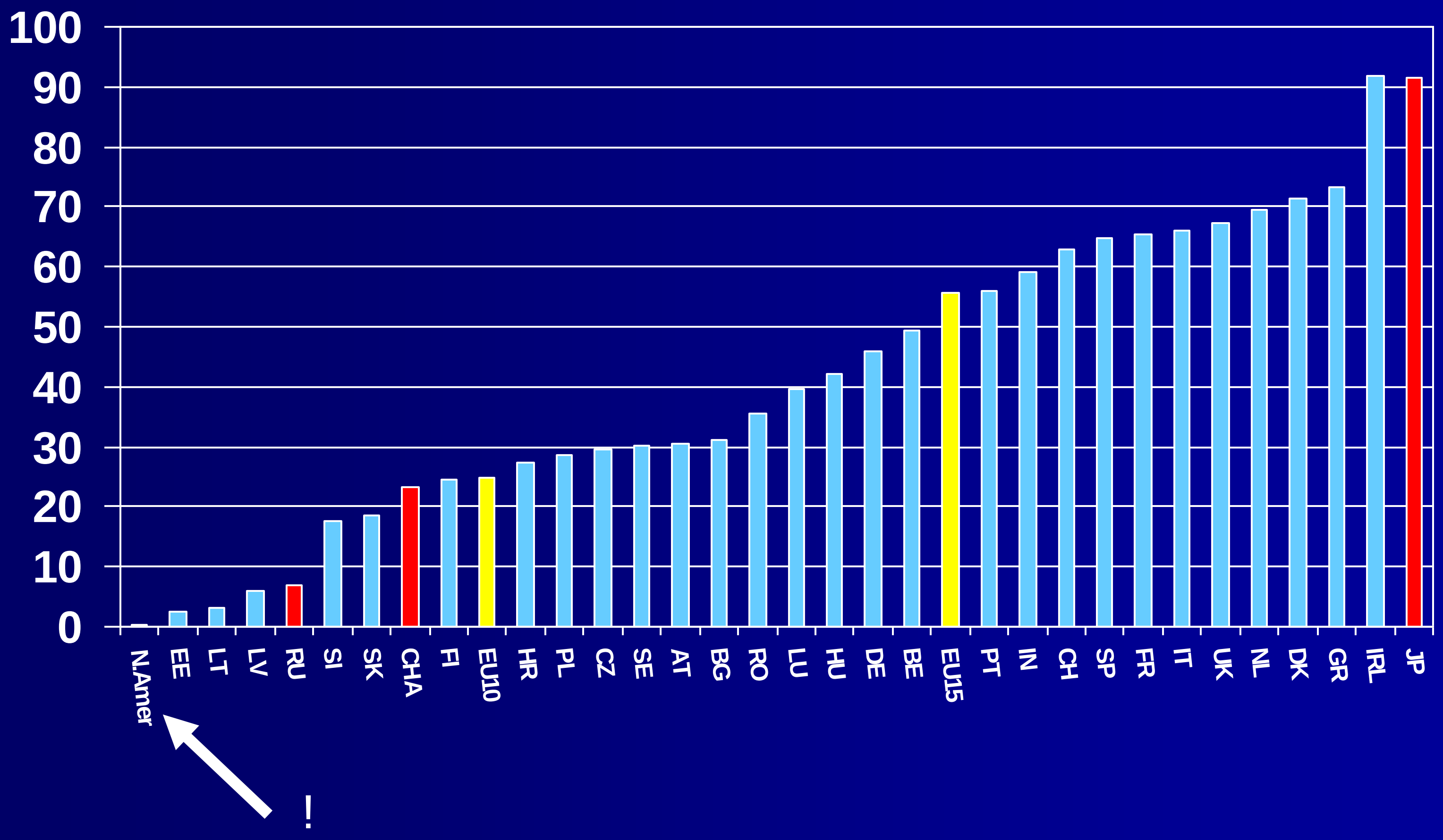
Railways and Energy

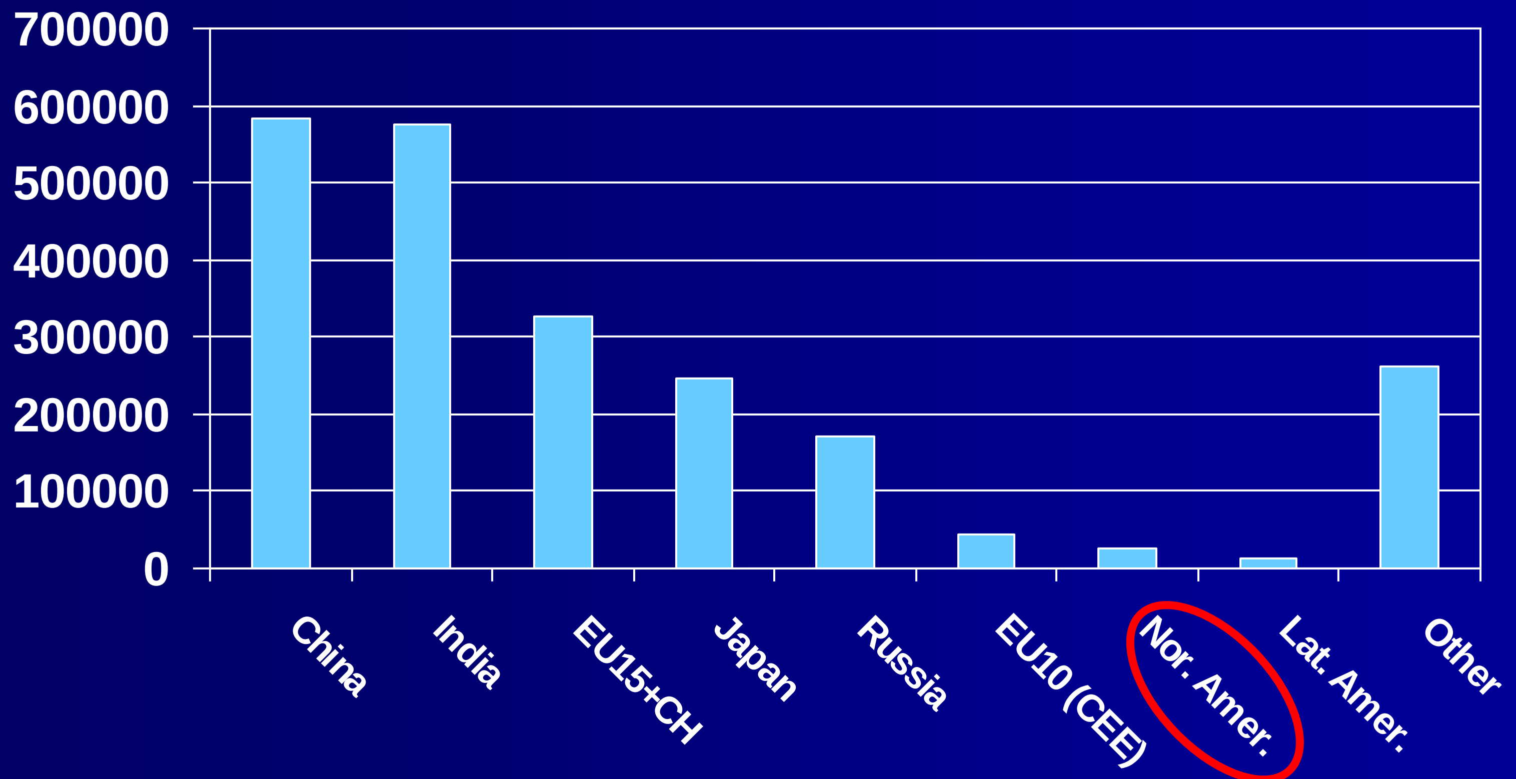
- The railway role in transport
- Railway energy intensity
- How to deploy it

Percentage of Passenger Traffic

(P-Km as % of P-Km + T-Km)



The World's Rail Passenger-Km
(2005, Millions)



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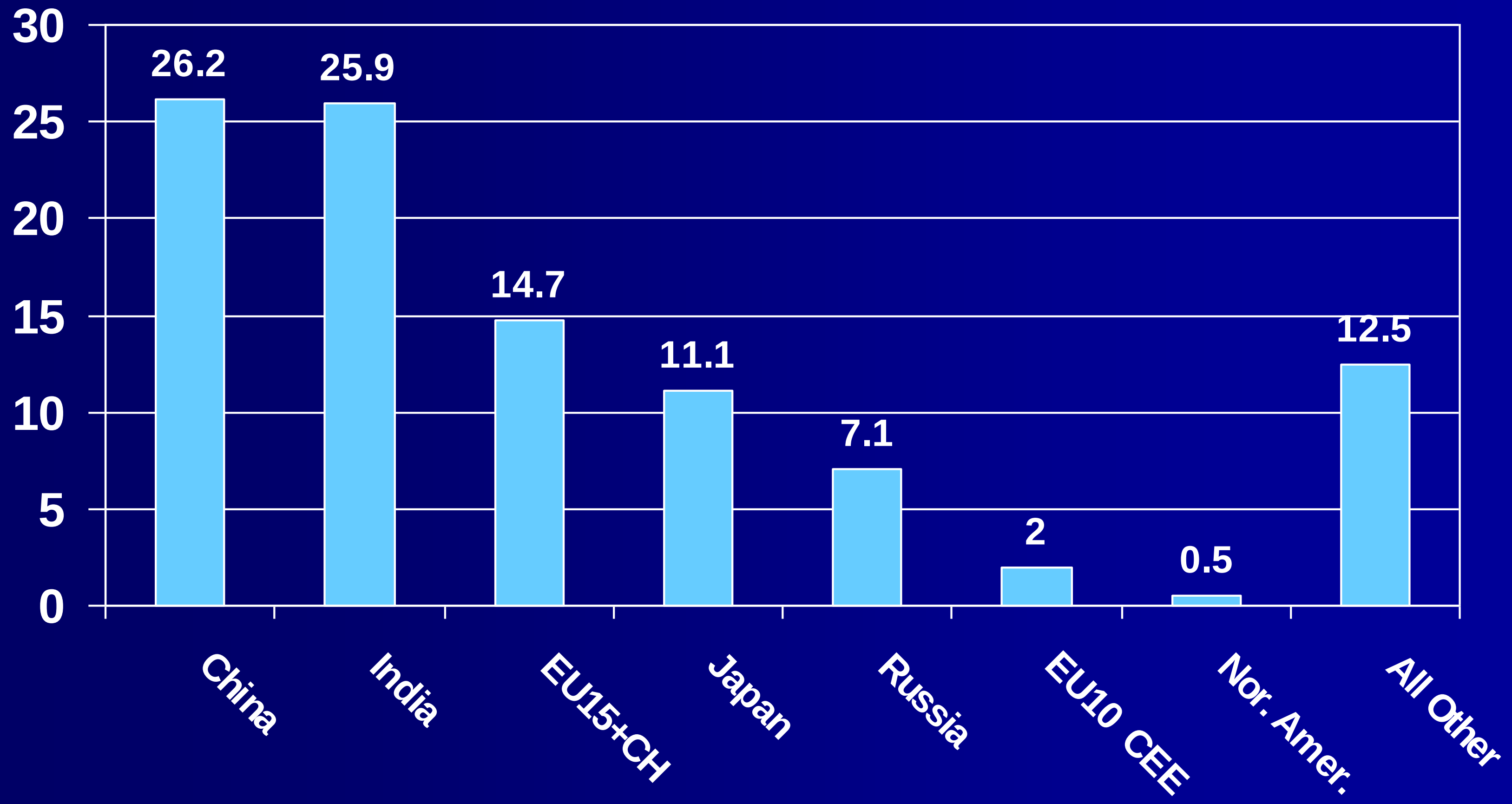
Percentages of the World's Rail Passenger-Km
(2005)



Top 5=85%

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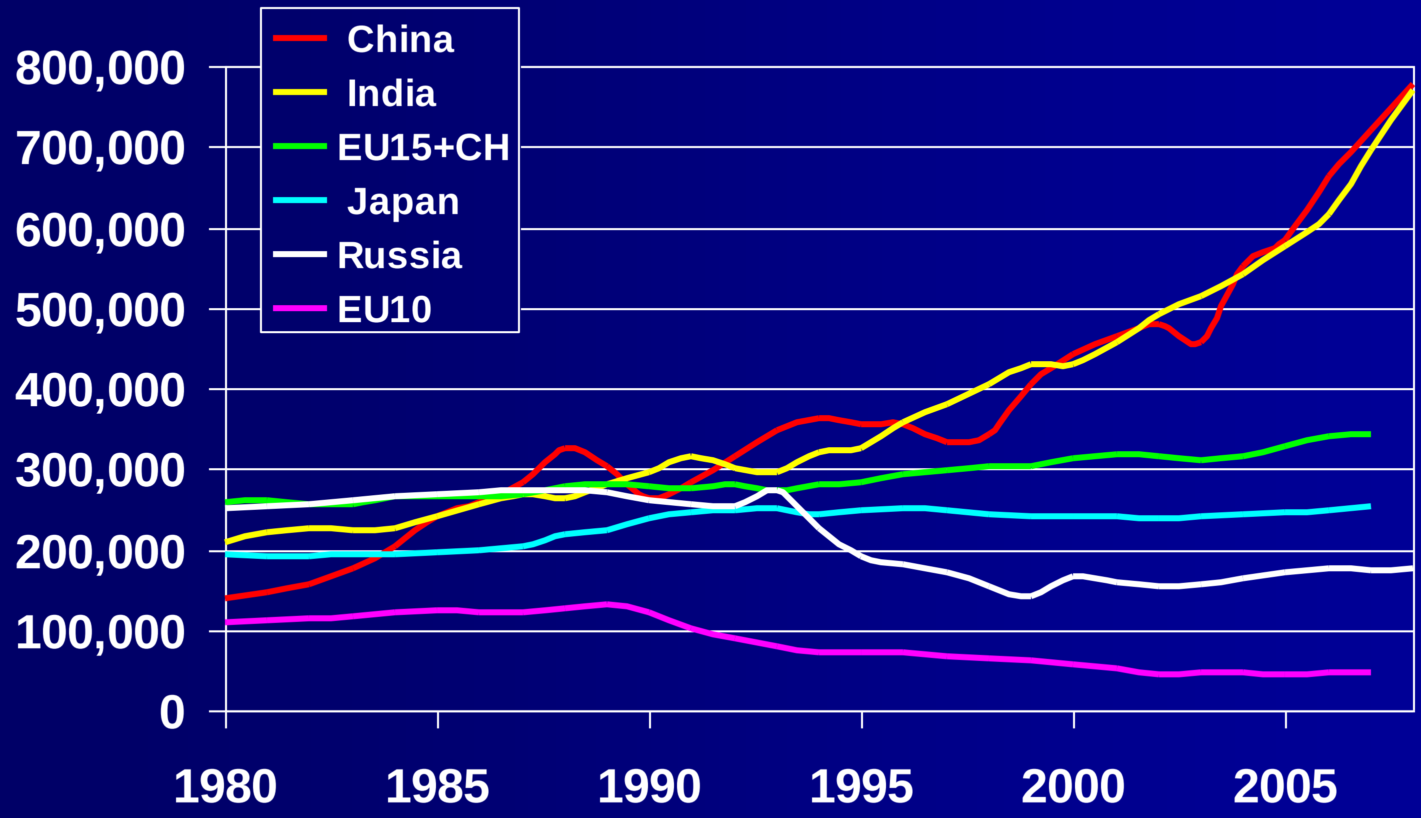
Passenger Traffic Trends

(Million Passenger-Km)



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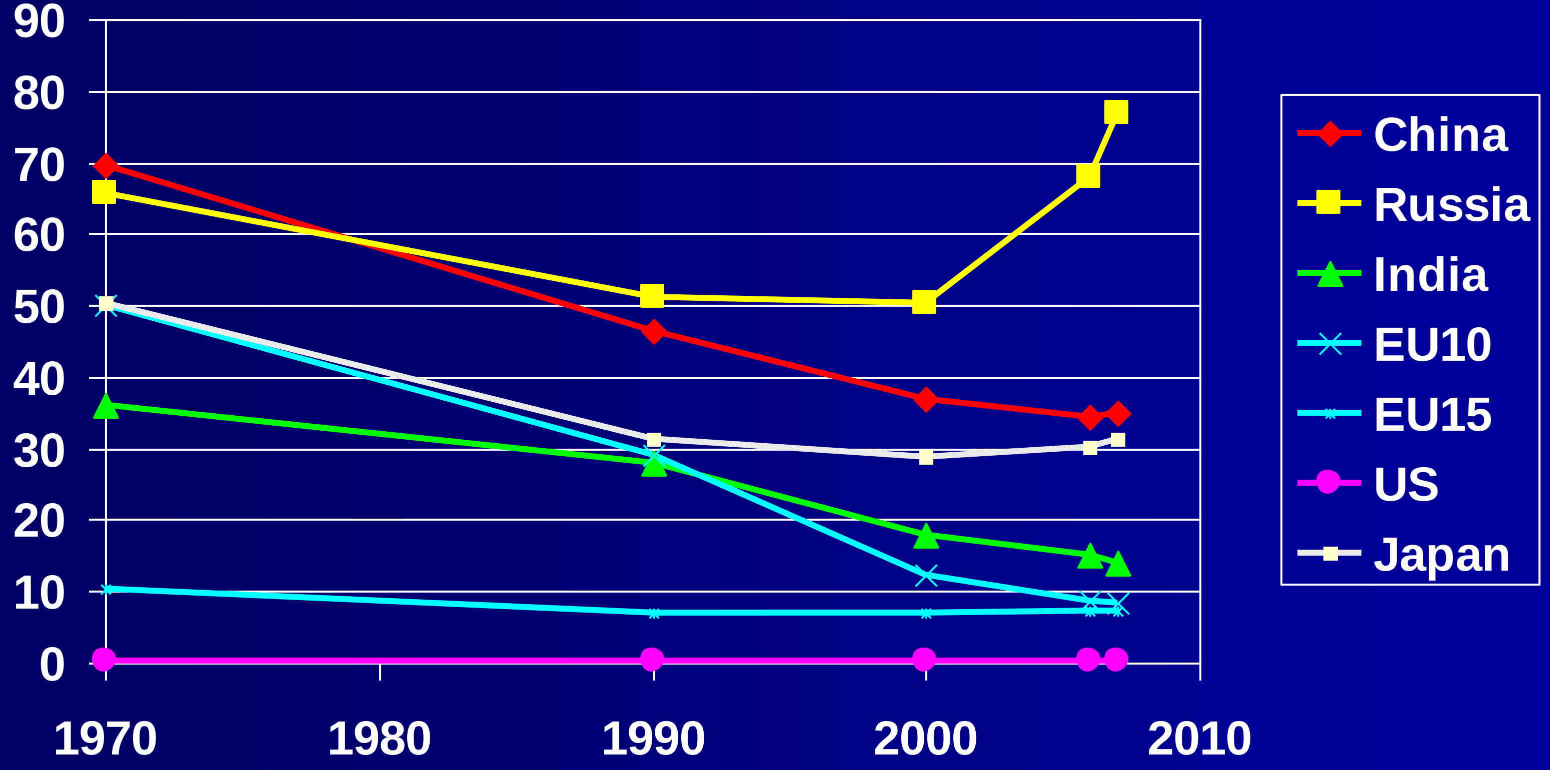
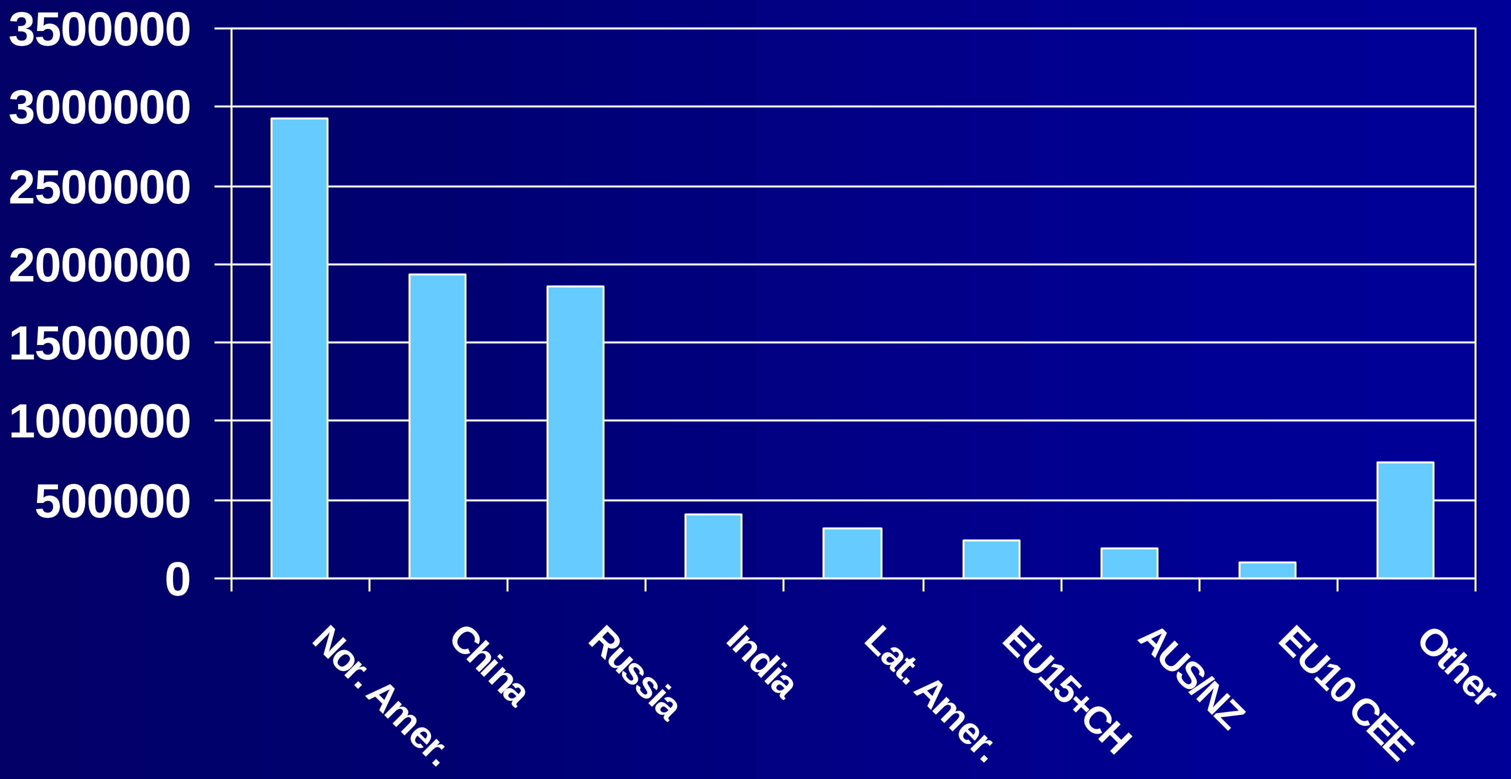
Rail Passenger Modal Share: Also Low and Falling

(Russia is suspect)

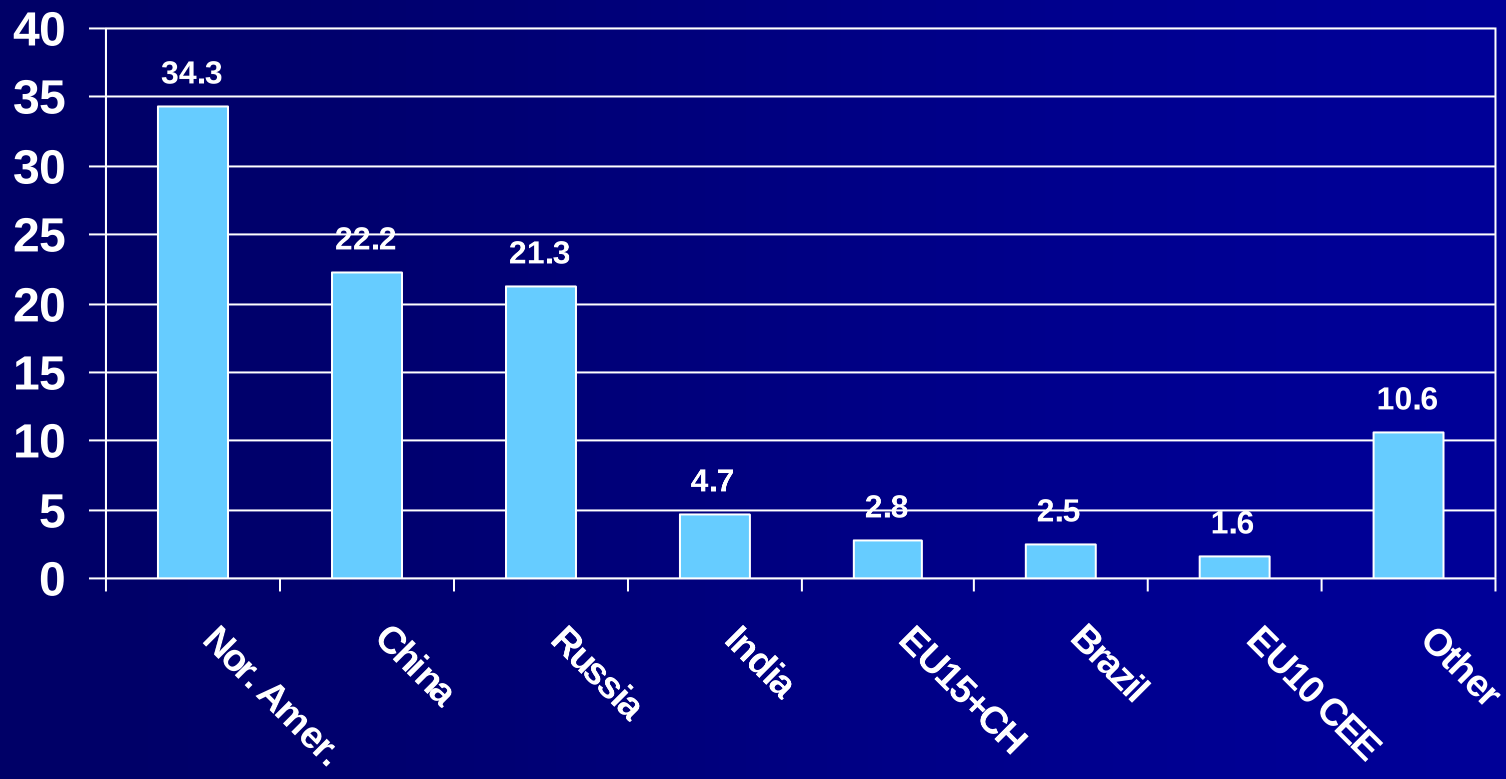
(% Passenger-Km)



The World's Rail Freight Ton-Km
(2005, Millions)



Percentages of the World's Rail Freight Ton-Km
(2005)



Top 4=82.5%

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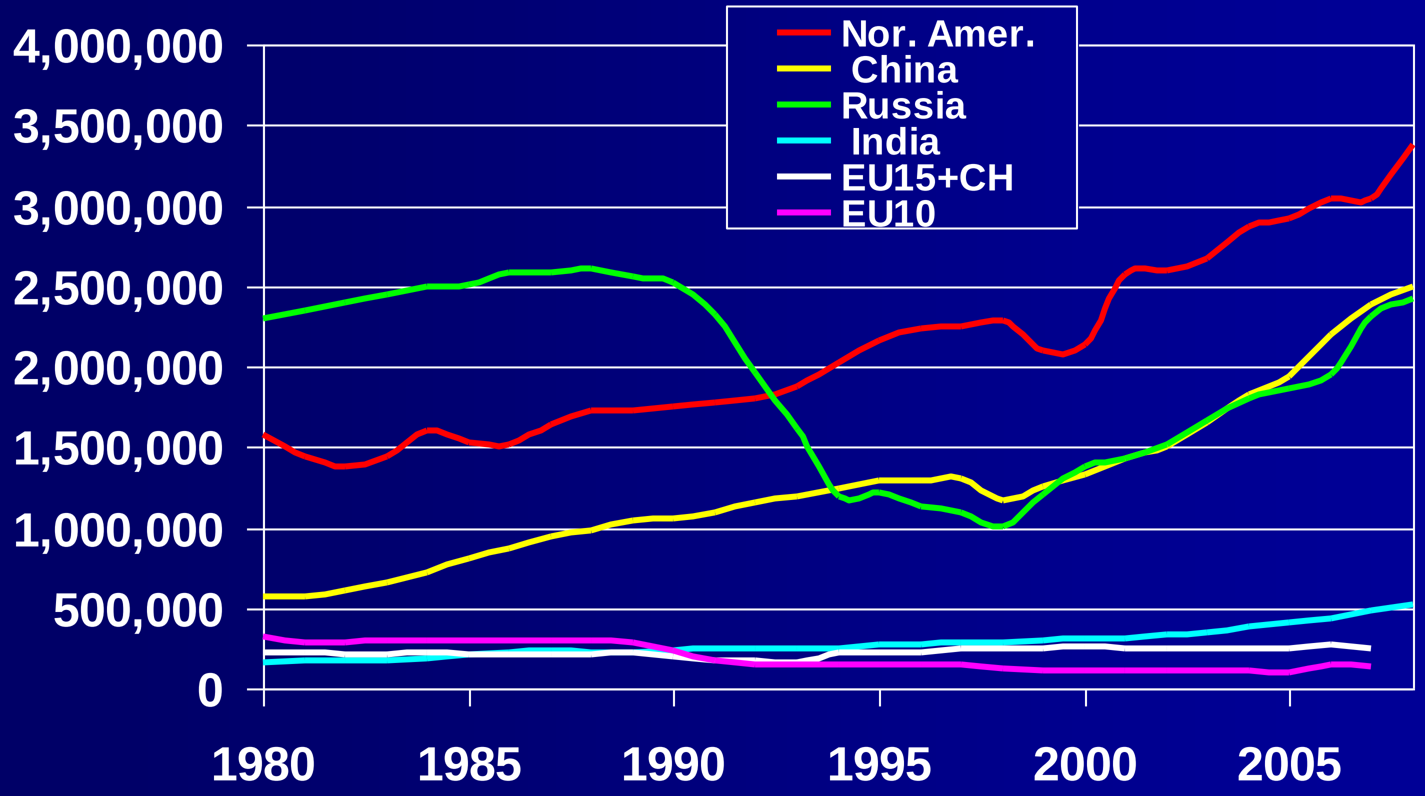
Rail Freight Traffic Trends

(Million Ton-Km)



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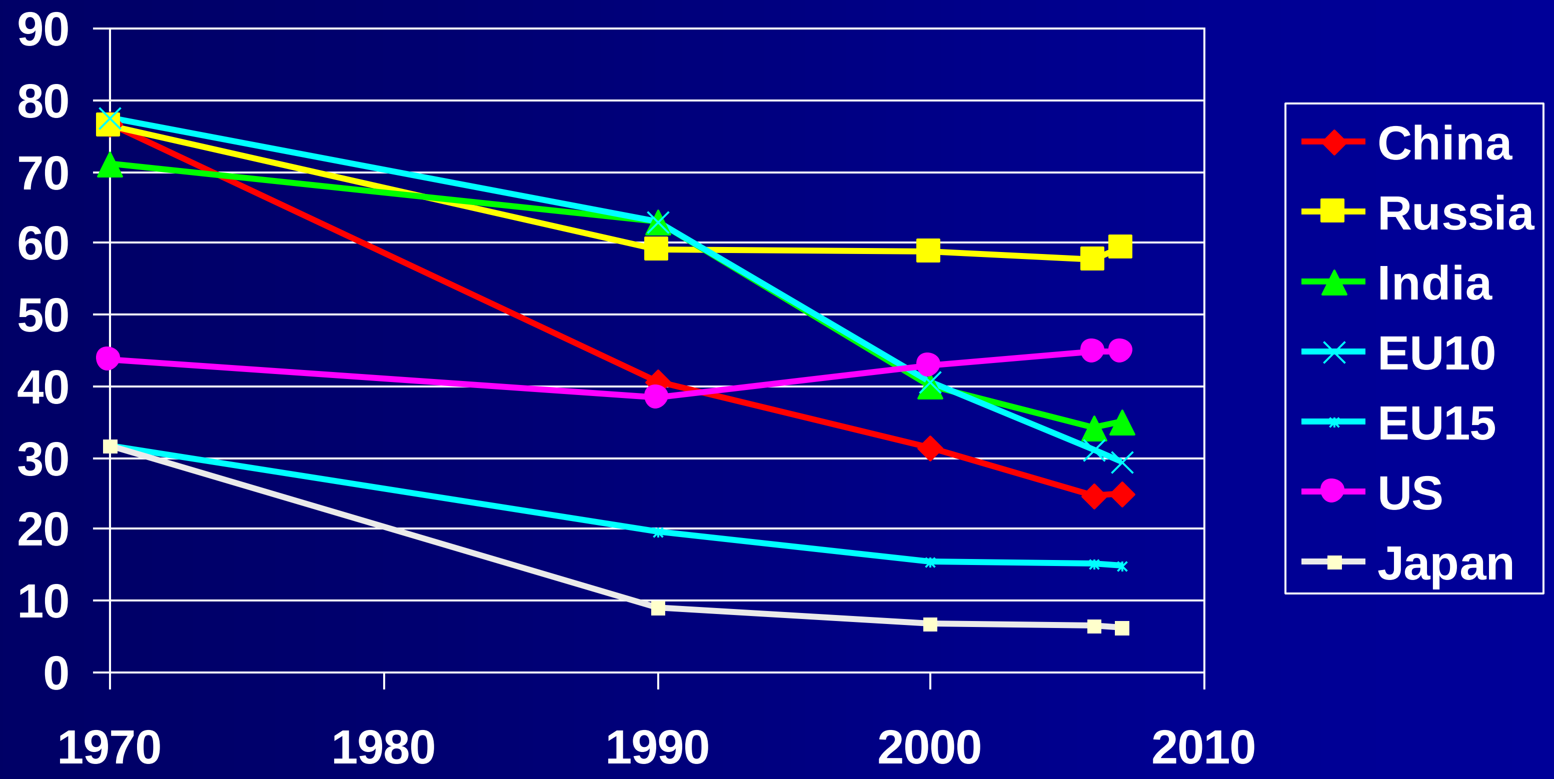
Rail Freight Modal Share: Low and/or Falling (U.S. & Russia)

(% Net Tonne-Km)



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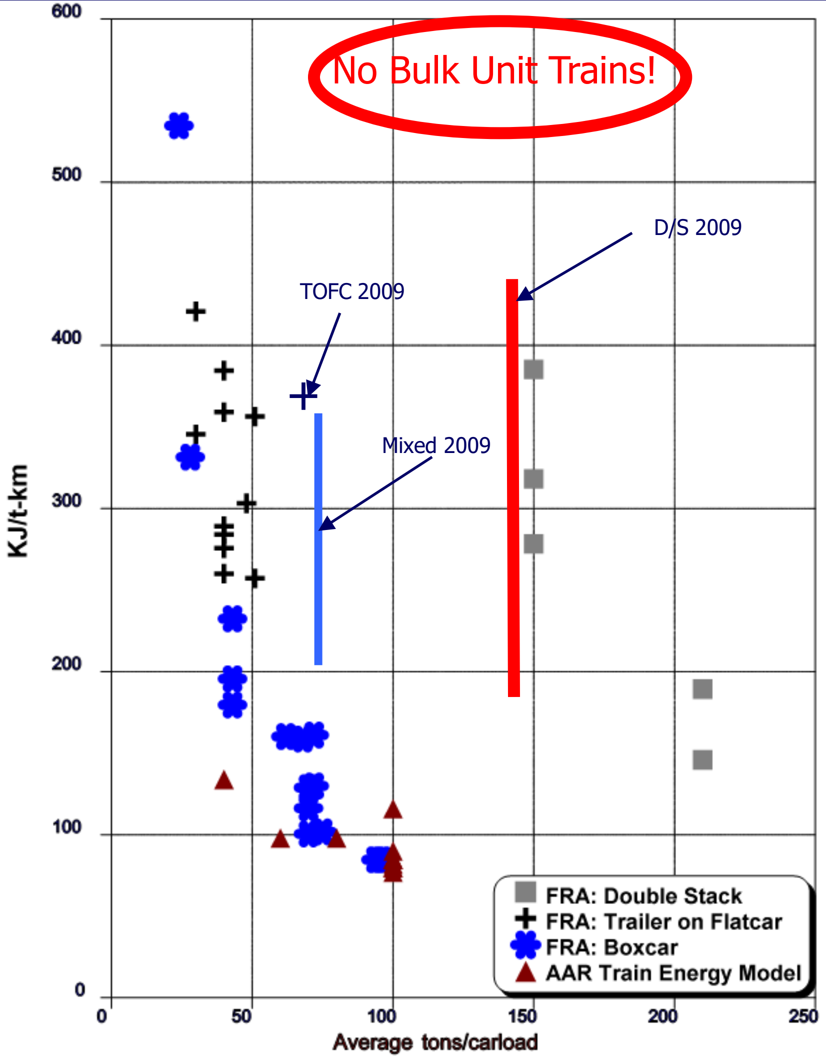
Rail Freight Energy Intensity Examples



Source: FRA Studies, 1991 and 2009

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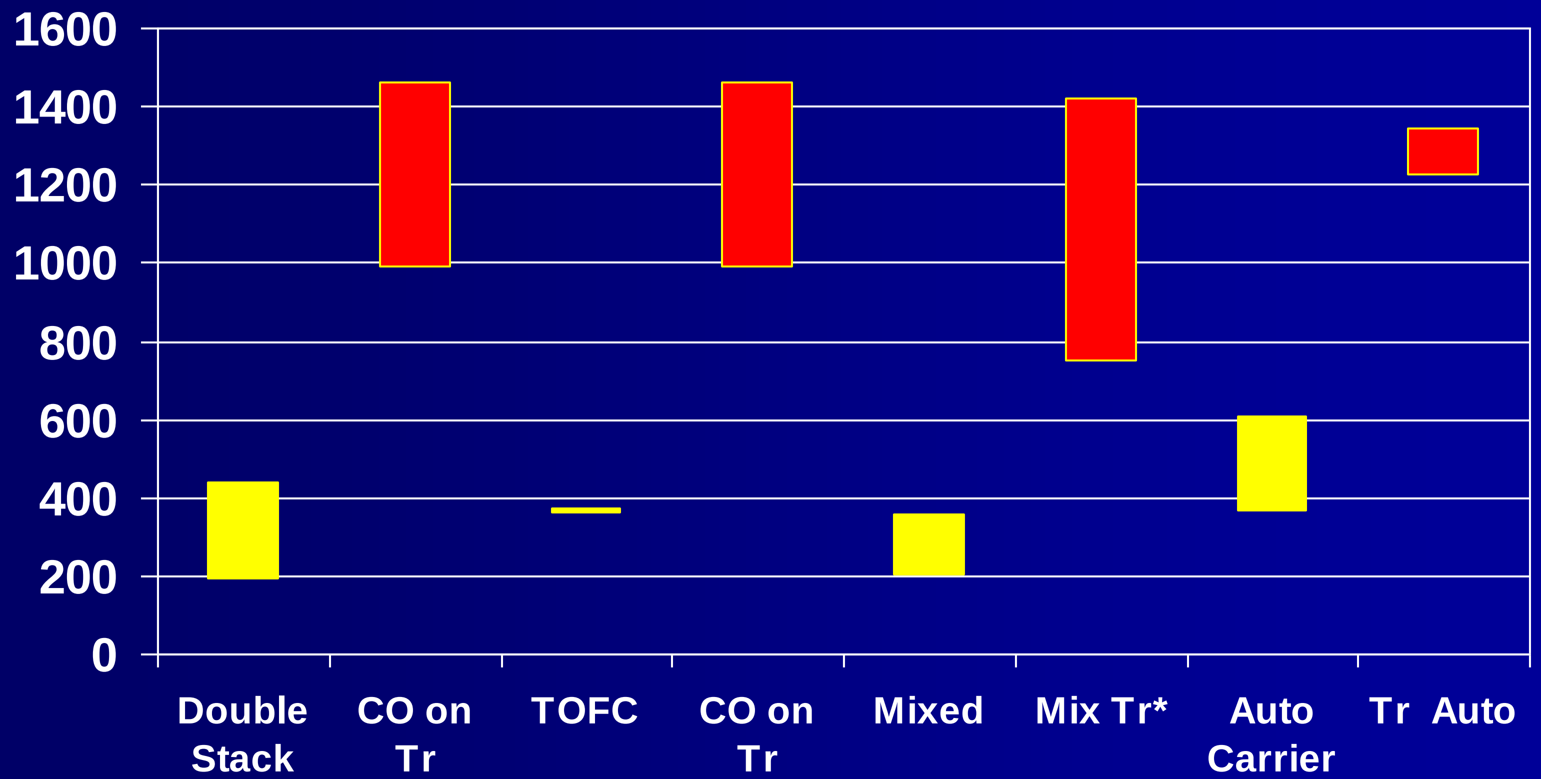
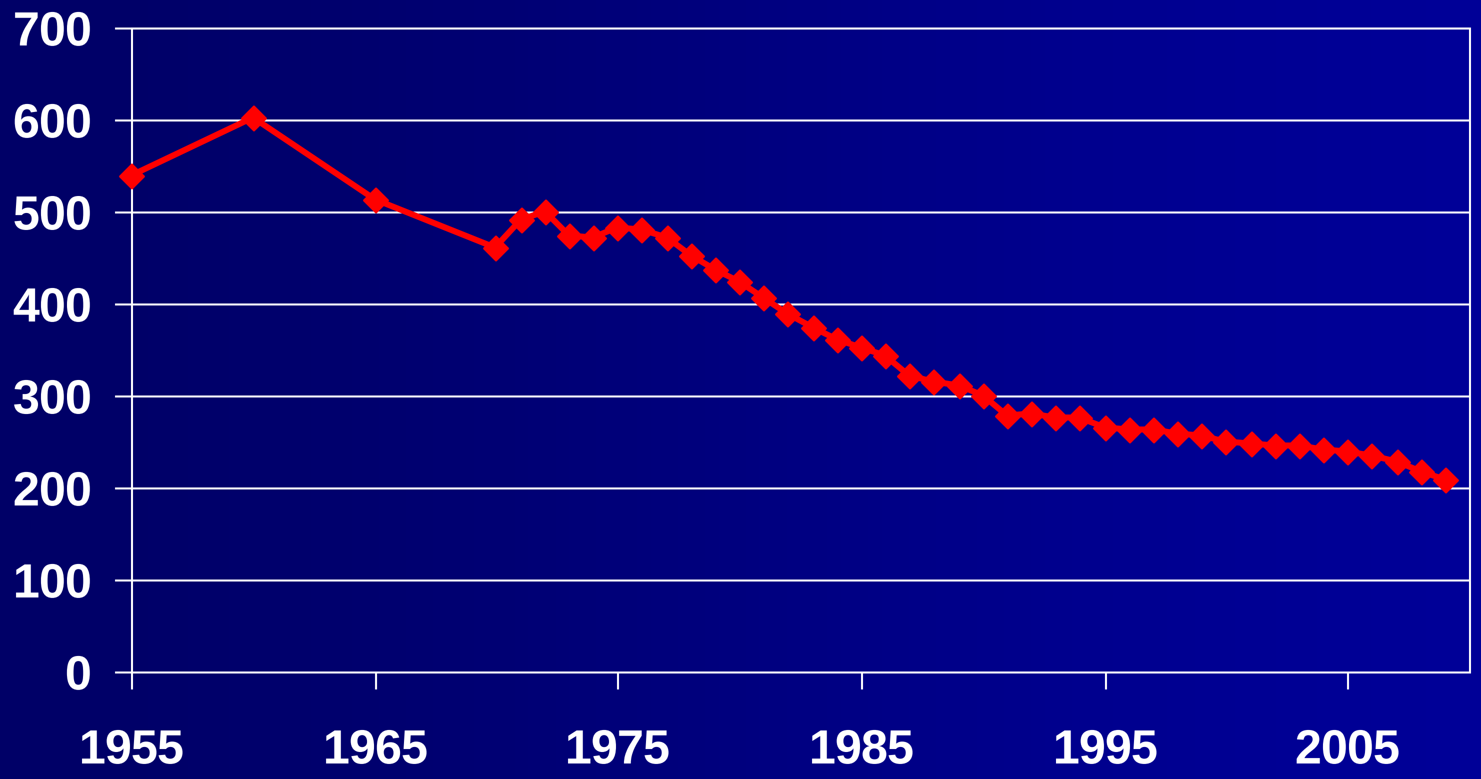
FRA 2009 Study: Energy Intensity of Rail Versus Truck in Competitive Markets (No Bulks)



Source: FRA, "Comparative Evaluation of Rail and Truck Fuel Efficiency on Competitive Corridors," November 19, 2009, pg 10

US Class I Average Fuel Intensity
(kJ/Tonne-Km)



Source: AAR, Railroad Facts, various editions.

Why the Improvement?

- Diesel technology
- 3 Phase AC traction and better DC traction controls
- Longer trains
- Unit trains
- Higher net/tare ratios
- Cost controls, including fuel

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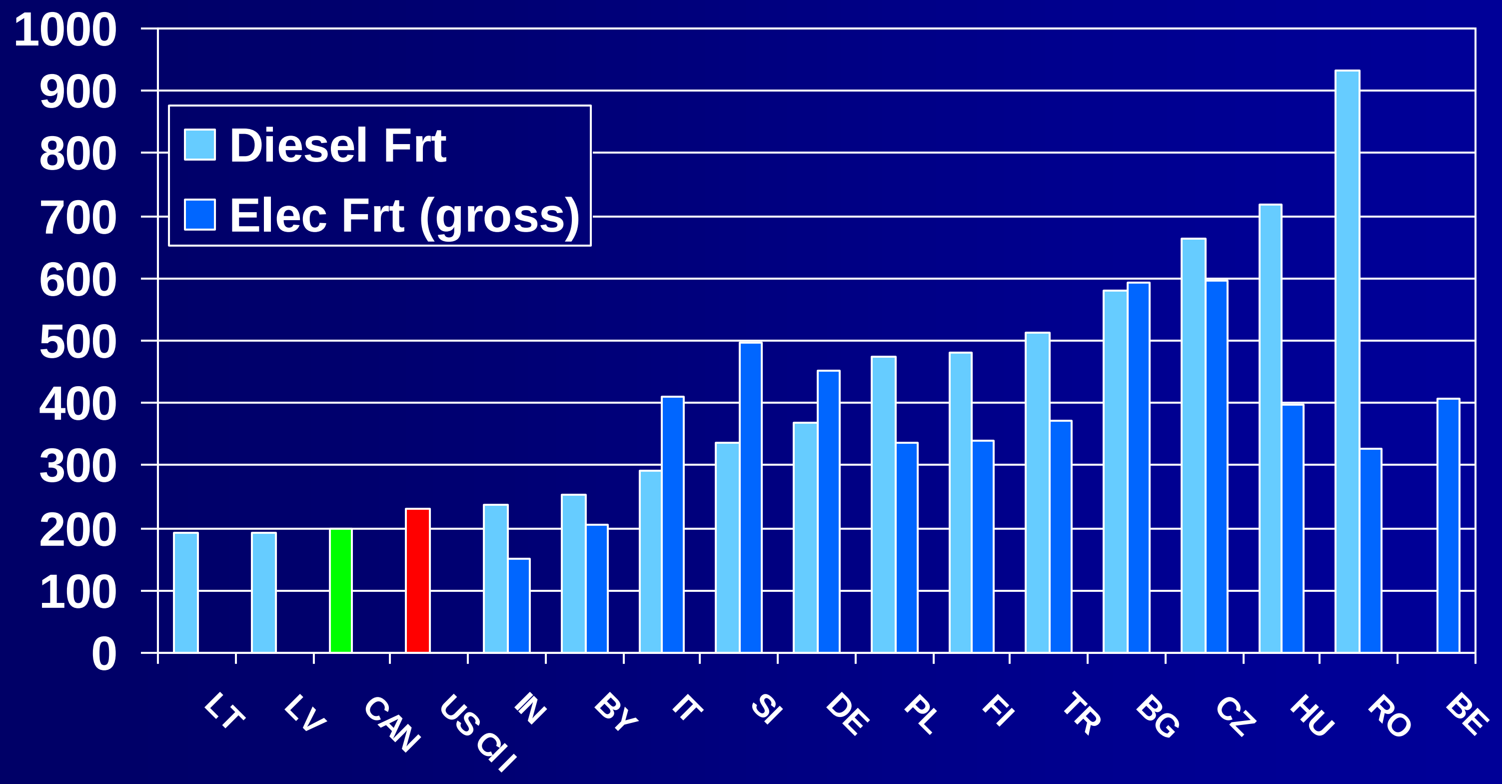
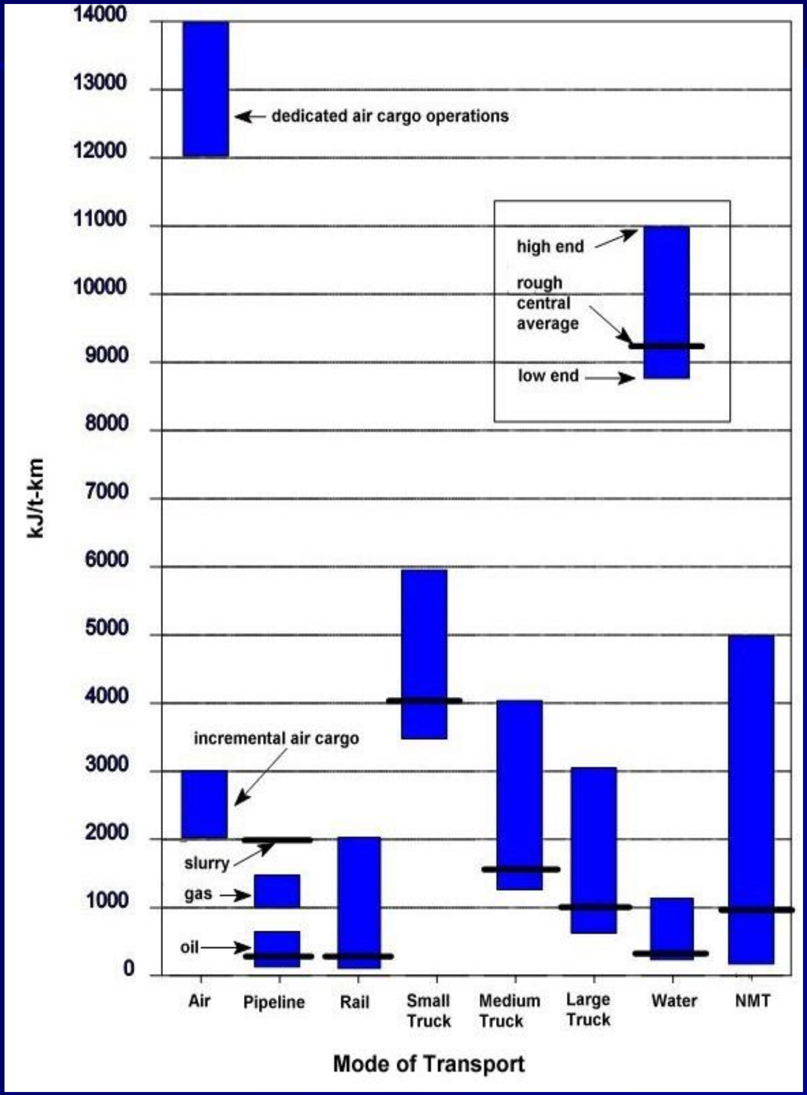
World Freight Rail Energy Intensity
(Frt Elec X 3 -- kJ/Tonne-Km)



Energy Intensity Ranges in Freight Transport (Operating Energy Only!)



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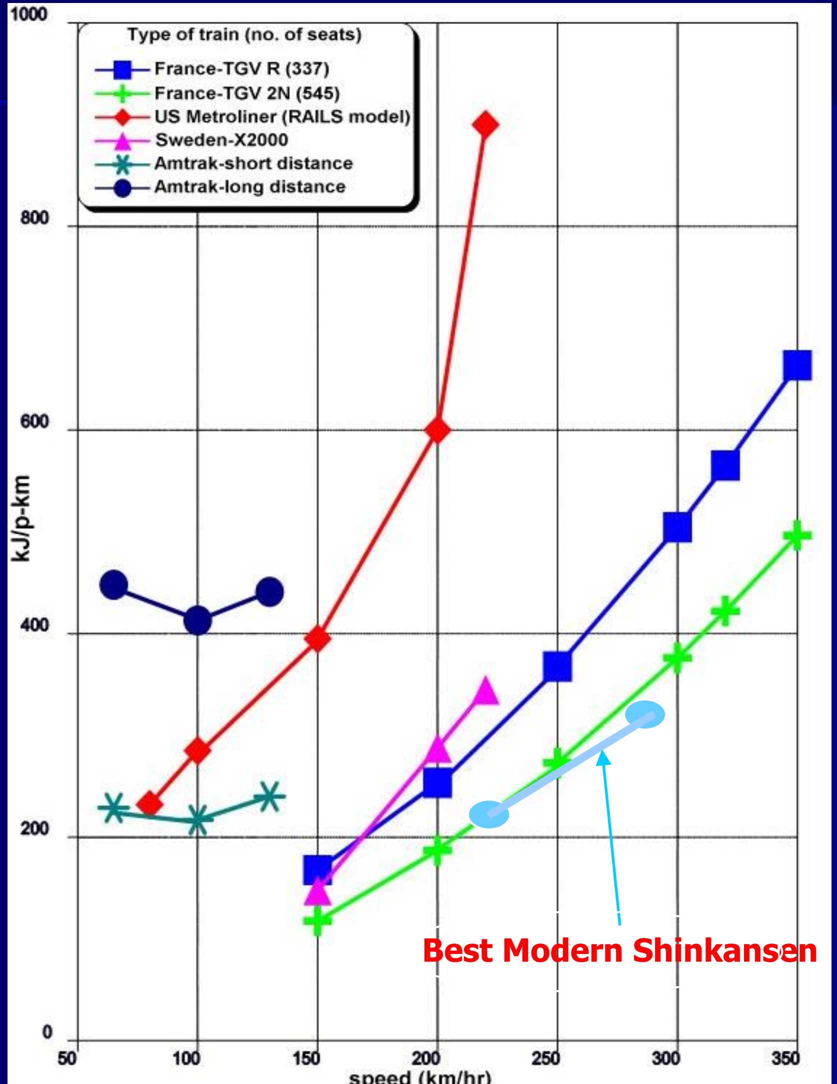
Energy Intensity in Rail Passenger Transport



NOTE: This is an estimate of gross energy consumed at the power plant, and not reported electrical energy consumed by the train.

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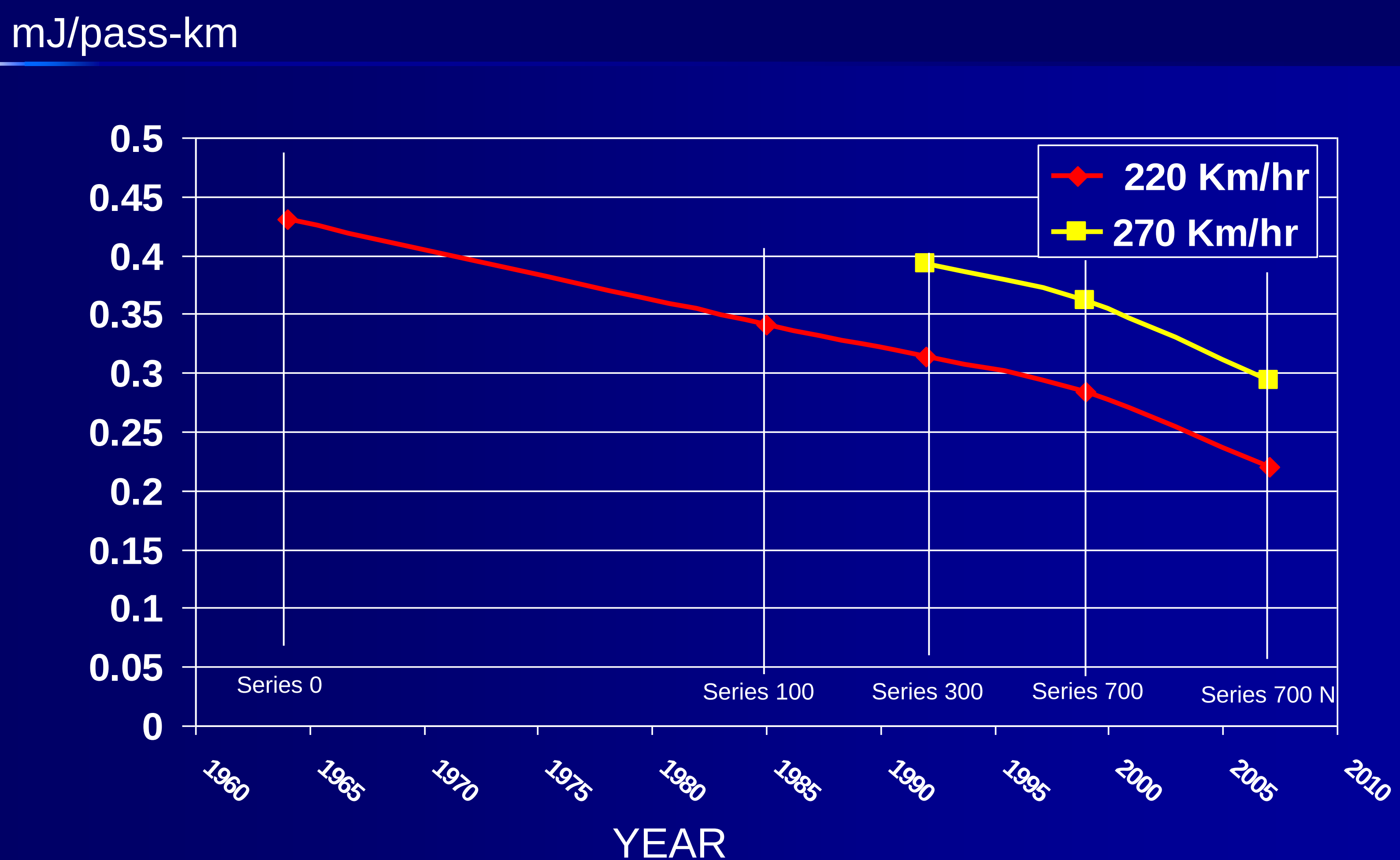
Shinkansen Energy Use: Change Over Time



Data from Toyonori Noda, Japan Central Railway, presentation to Nagoya Conference entitled "The Tokaido Shinkansen and Superconducting Maglev – Contributing to a Low-Carbon Society," Charts entitled "The Energy Efficiency of Shinkansen Rolling Stock," and "The Environmental Superiority of the Tokaido Shinkansen." Assumes 60% load factor.

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Why the Improvements?

- Vehicle design (drag and weight) have offset speed increases
- HSR involves only limited acceleration rates and duration
- Traction improvements (3 Phase AC)
- Longer trains
- Could level off, but may not stop
- Similar improvements with air and auto.

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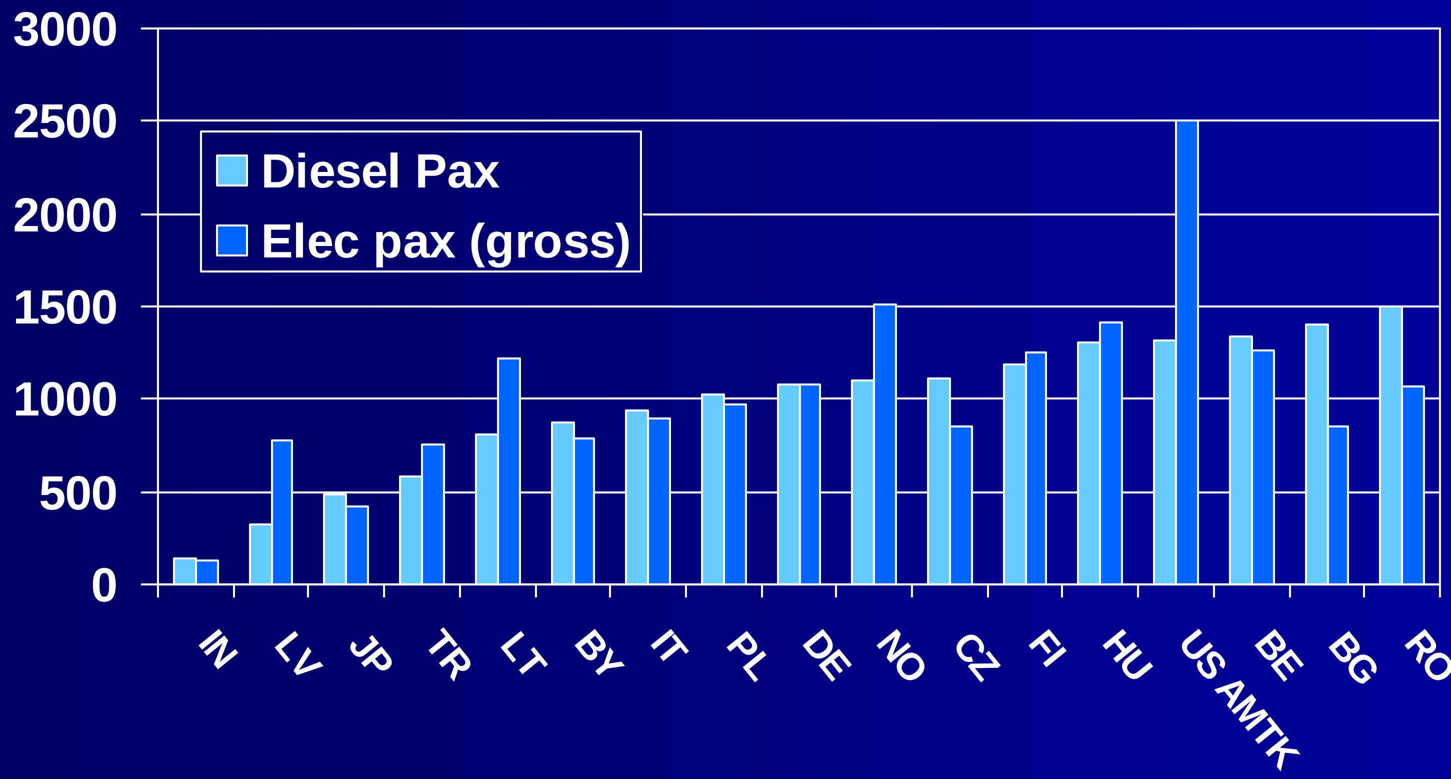
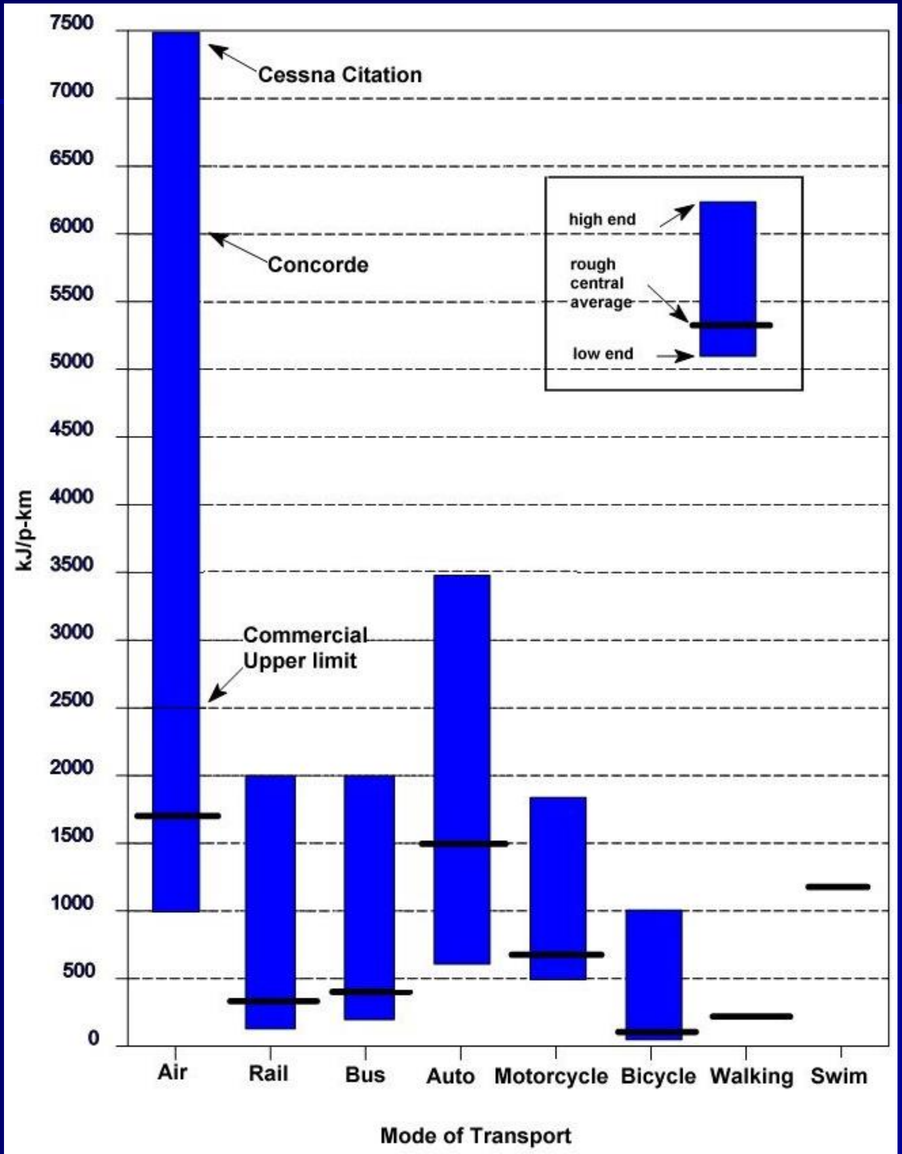
World Passenger Rail Energy Intensity

(Elec Pass X 3 -- kJ/Pass-Km)



Source: UIC, International Railway Statistics, 2007

Energy Intensity Ranges in Passenger Transport (Operating Only)



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The Overall Balance: Freight Versus Passenger Services

- About 90% of all rail activity is in top 6 groups (N.A., CHA, IND, RUS, Japan, EU25)
- About 8.8 trillion world net tonne-km by rail
- About 2.2 trillion world passenger-km
- Rough avg. freight is 300 kJ/Tonne-Km and 800 kJ/Pass-Km
- (8.8/2.2)x(300/800)=1.5, so freight consumes about 60% of all rail energy
- If we use best practice for both, this could rise to 75% of all rail energy used by freight

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So What About Rail in Energy Conservation?

- IS rail energy efficient?
- Modal shifts in freight and passenger
- Electrification?
- The potential for HSR

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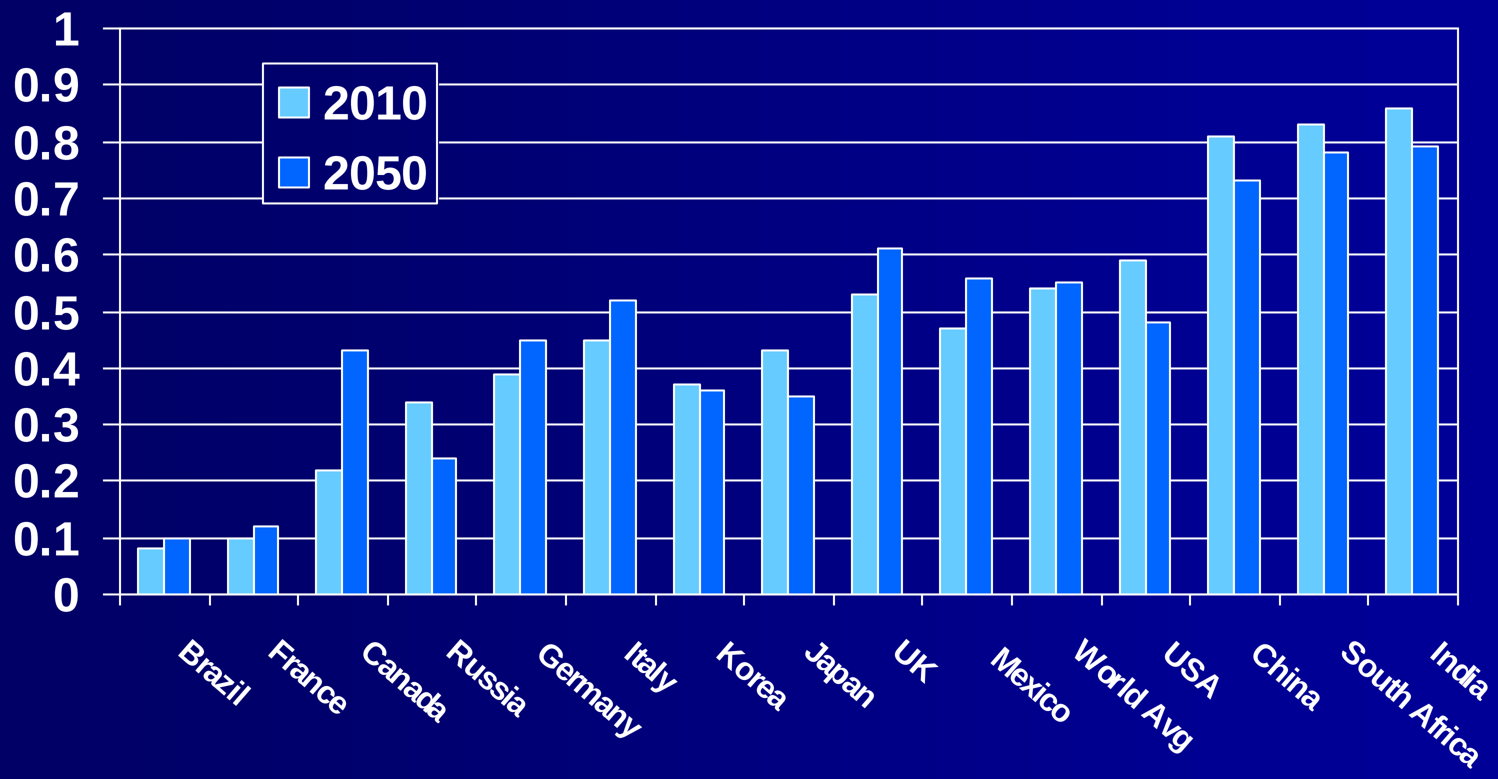
Rail Electrification May Not Be the Answer

Upstream CO_2 Emissions From Electricity Generation

(Kg CO2/kW-Hr)



THE HSR Story

- World today
- E.U. Plans
- China's Plans
- And the U.S. possibilities by 2050?

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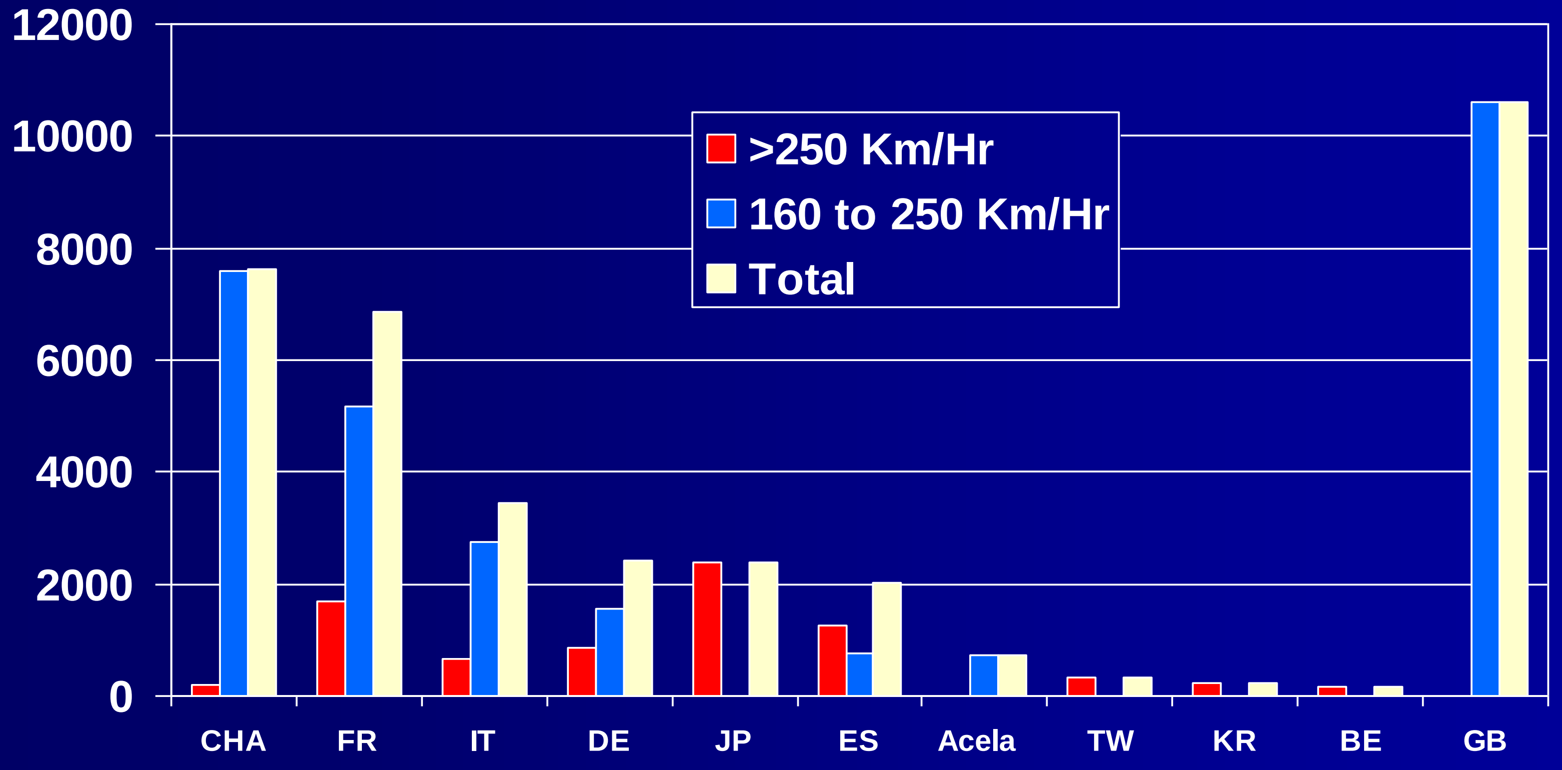
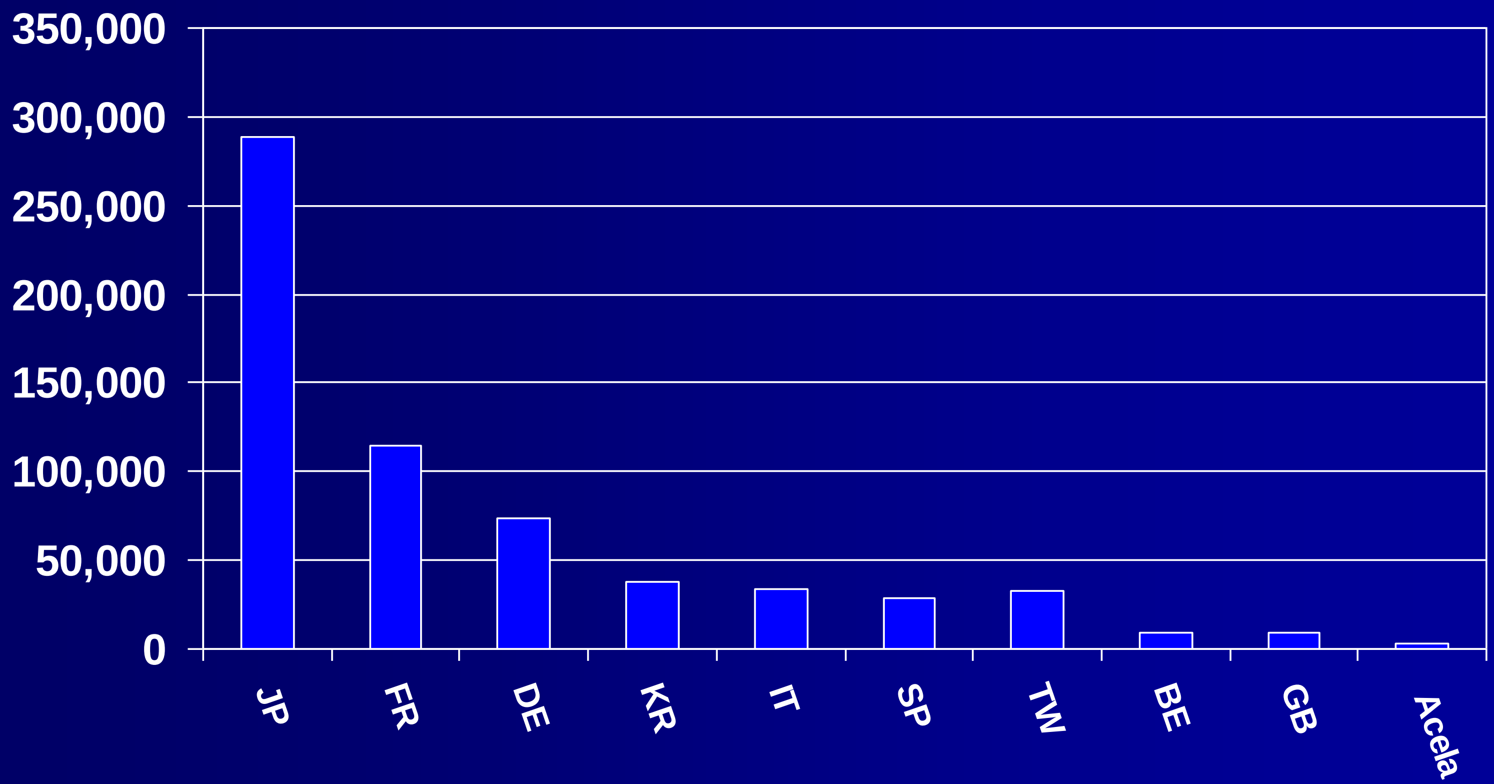
Kilometers of "High Speed" Line 2009



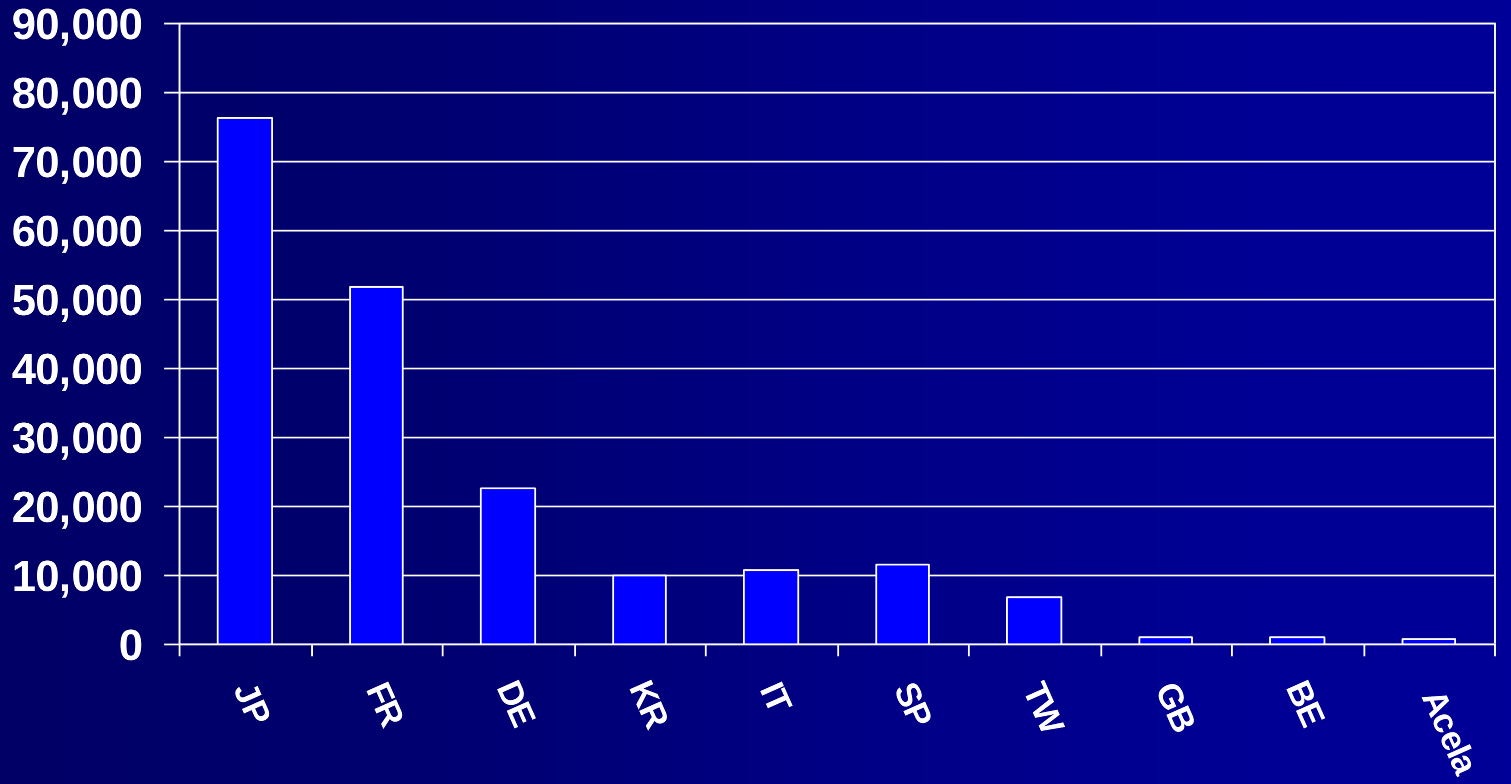
“High Speed” Passengers 2009

(000)



Note: Includes all passengers above 160 Km/Hr

"High Speed" Passenger-Km 2009
(000,000)



Note: Includes all passengers above 160 Km/Hr

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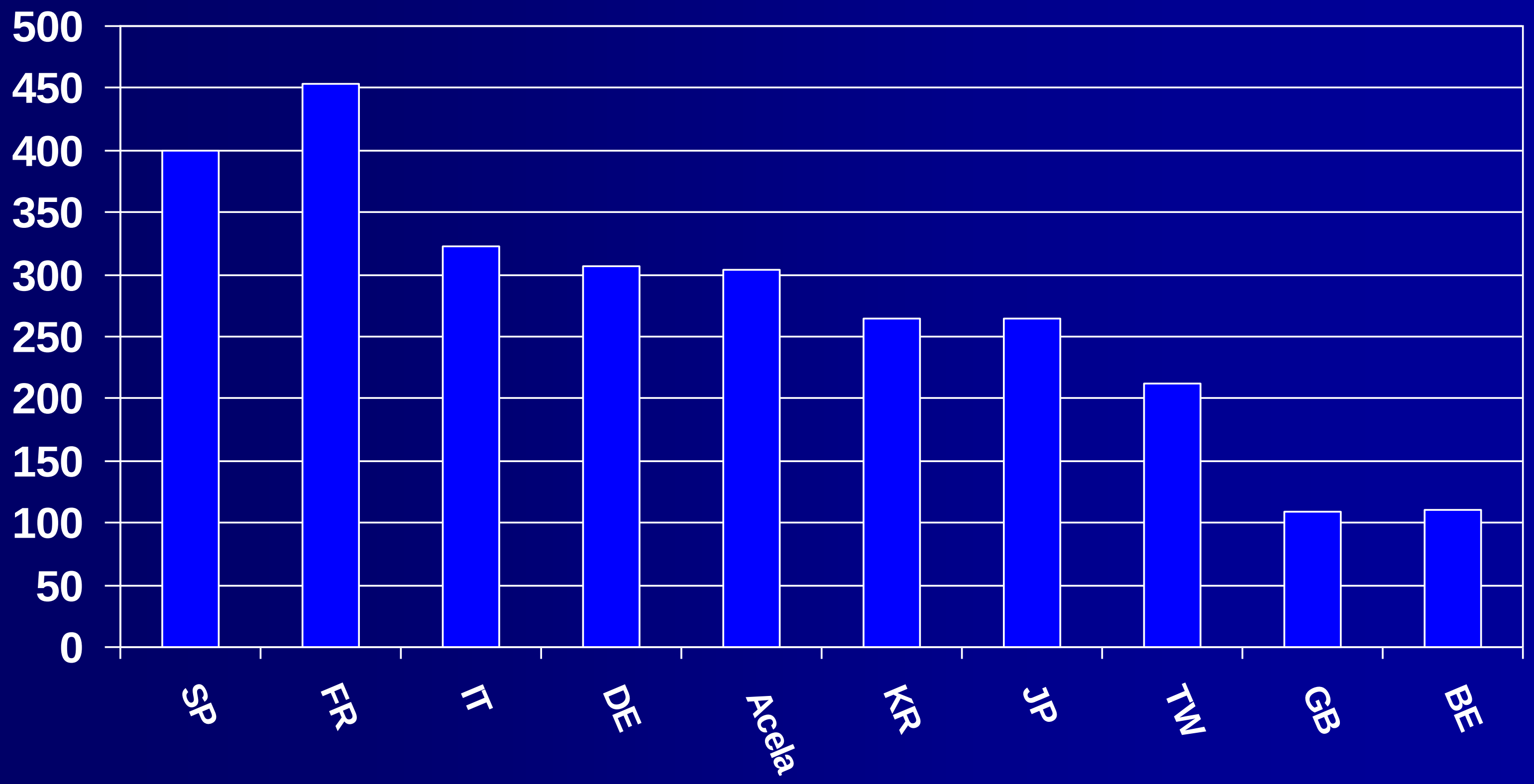
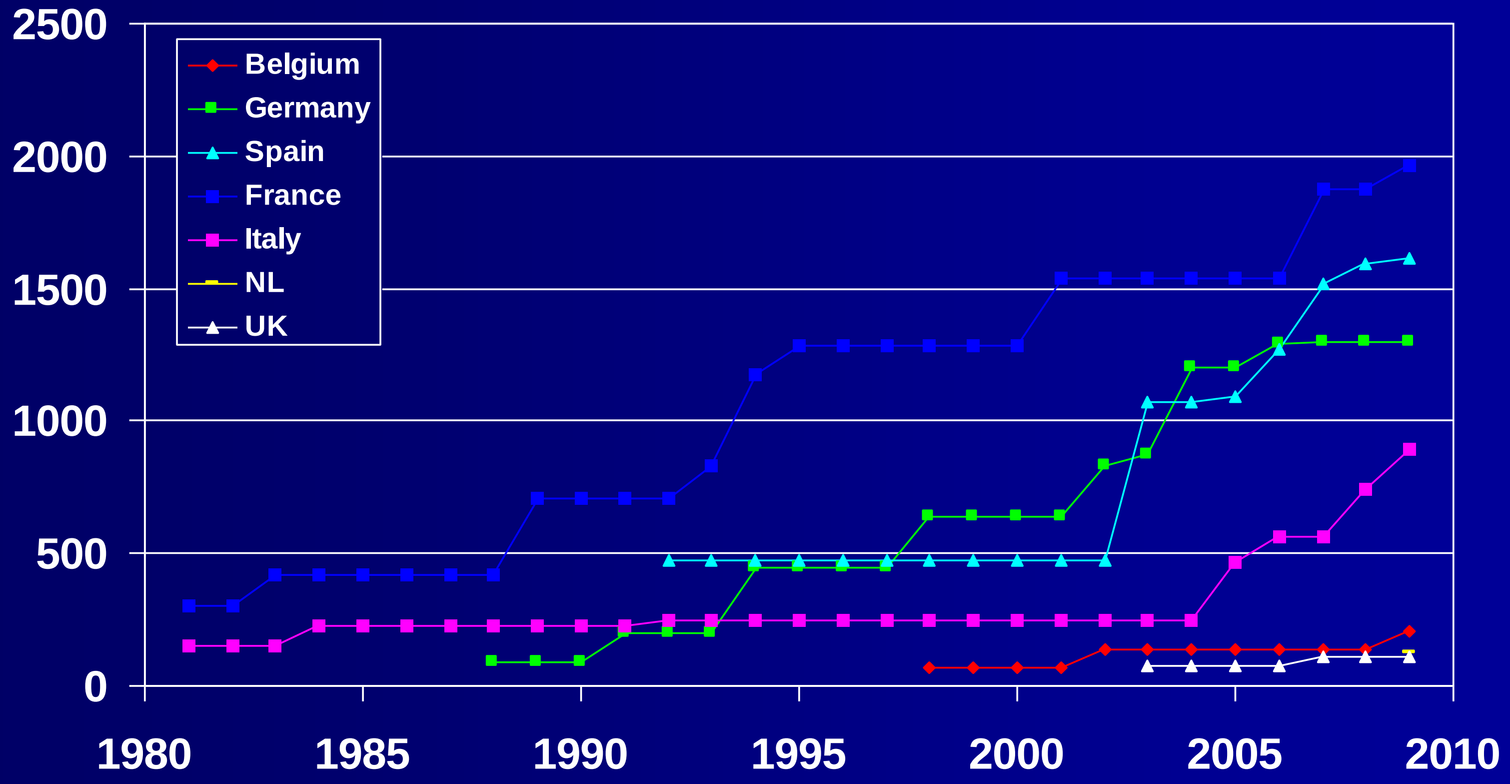
Average "High Speed" Trip Length (Km) 2009



Note: Includes all passengers above 160 Km/Hr

E.U. HSR Line Km



Source:http://ec.europa.eu/transport/publications/statistics/statistics_en.htm (3.5 Infrastructure)

E.U Rail Network Development

E.U Rail Network Development						
Category of Line	**Max Speed (KM/Hr)**	**Length in 2008 (Km)**	**Length in 2010 (Km)**	**Length in 2015 (Km)**	**Length in 2020 (Km)**	**Planned Total after 2020**
I	>250	5,583	6,359	11,343	15,028	21,023
II	~200	3,971	4,205	5,204	7,115	9,728
III	Specific	139	169	298	1,055	1,104
Total		9,693	10,733	16,845	23,198	31,855

Source: MVV Consulting and Tractabel Engineering, “European High Speed Rail-An Easy Way to Connect,” presentation 24 April 2009

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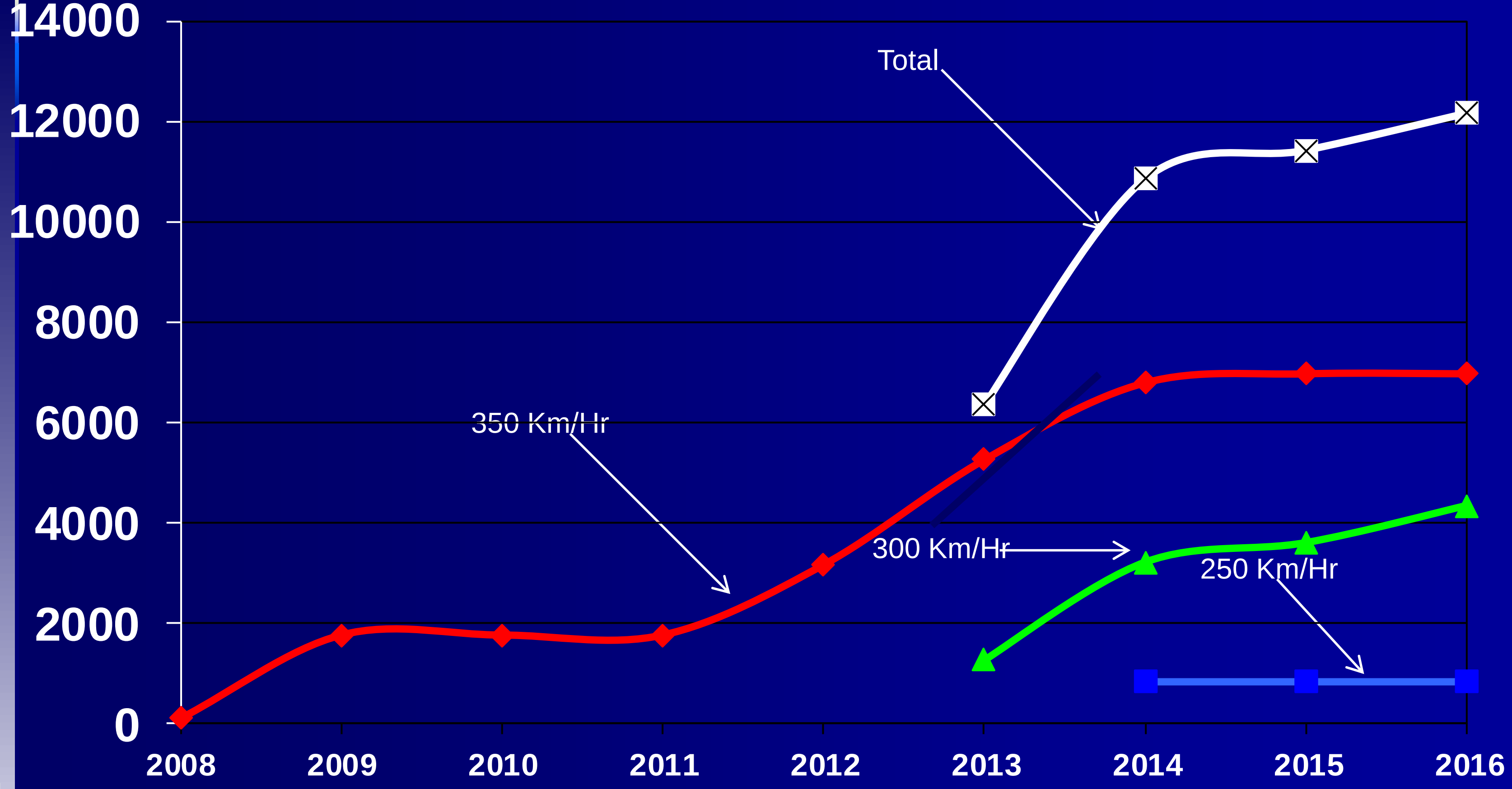
Planned Km of HSR In China



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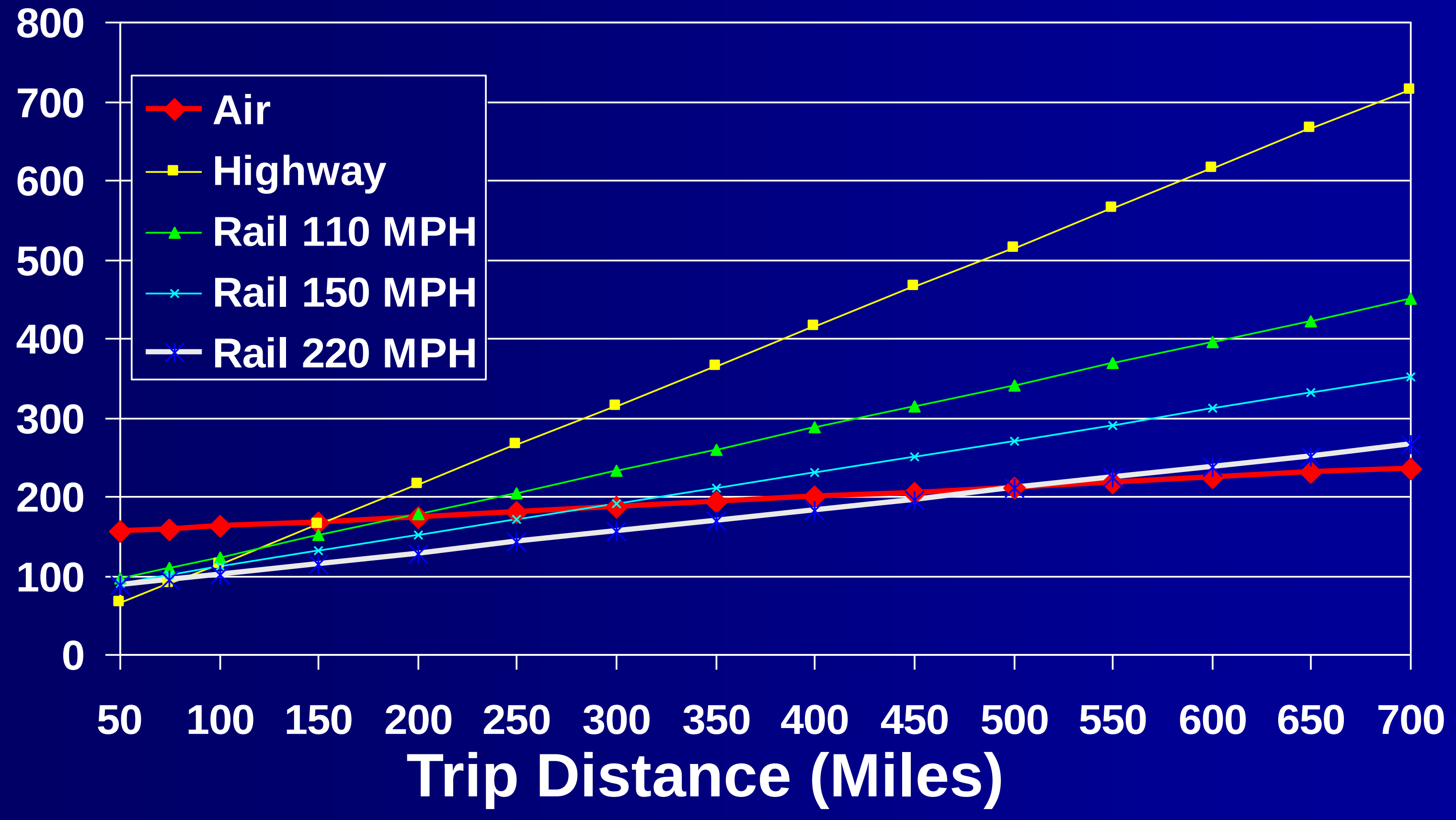
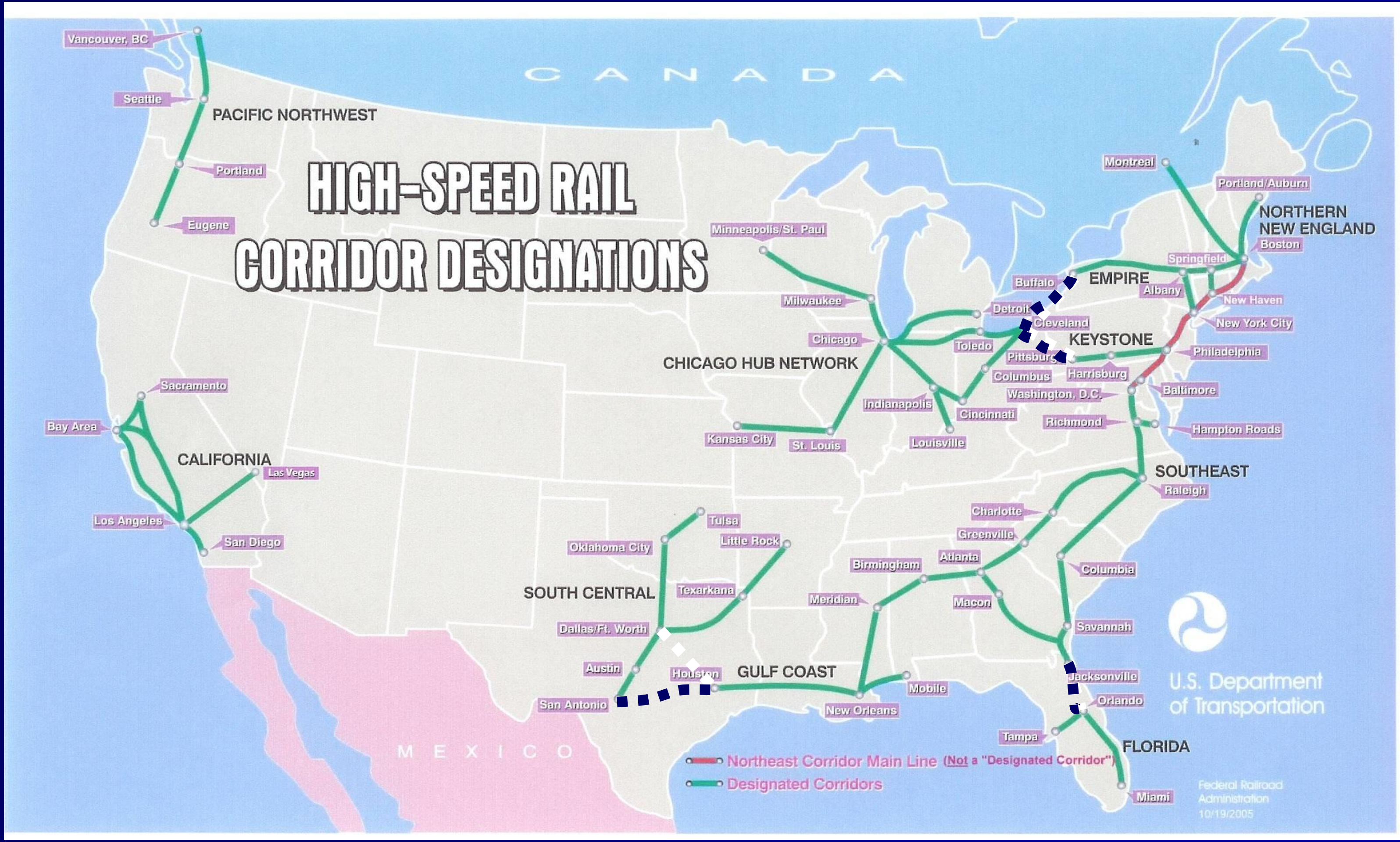
The Role of Speed:

Total Trip Time in Minutes



The Ten FRA Designated Corridors and the NEC



▪▪▪▪▪▪ Indicates link added to FRA base

Emission Factors for HSR Analysis

Emission factors in 2050 (grams CO2/passenger-mile)

	Low	Midrange	High
Rail*	15.14	51.53	71.94
Auto**	96.62	115.41	134.19
Air***	175.52	186.80	198.07

* Rail low is based on 0.030 kWhr/seat-km and 188 grams CO2/kWhr
  Rail high is based on 0.049 kWhr/seat-km and 547 grams CO2/kWhr
  Rail mid range is based on 0.04 kWhr/seat-km and 480 grams CO2/kWhr (IEA proje

** Auto low is based on 90 grams CO2 /vehicle-km
   Auto high is based on 125 grams CO2/vehicle-km
   Auto Midrange is simple average of high and low

*** Air low is based on 109 grams CO2/passenger-km
    Air high is based on 125 grams CO2/passenger-km

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Summary Program

Corridor	HSR Line Miles	2050 Corridor Population (million)	2050 Corridor Trips (millions)	Total CO2 savings (metric tonnes)		Low Infrastructure Cost (2009$ Millions)	High Infrastructure Cost (2009$ Millions)
				Low	High		
California	1,088	54.1	101.0	1,292,113	3,878,697	35,904	63,104
Pacific Northwest	467	14.5	12.3	76,070	245,354	7,005	9,340
Florida	478	31.6	28.9	135,212	509,228	7,170	26,768
Chicago Hub	2,137	39.1	66.0	544,612	1,502,751	49,151	74,795
South Central	1,202	33.0	63.9	759,691	2,416,287	14,424	52,888
Southeast	1,659	33.2	84.4	795,858	2,604,359	29,862	49,770
Gulf Coast	1,024	22.0	21.6	219,380	688,417	18,432	30,720
NEC	457	54.5	35.0	289,370	874,338	11,425	26,049
Keystone	486	16.6	9.9	34,030	166,381	11,178	17,010
Empire	630	28.1	22.6	188,070	722,979	12,600	17,010
Northern New England	665	15.3	9.9	54,681	185,283	13,300	17,955
TOTAL	10,293	277.0	455.5	4,389,087	13,794,074	210,451	385,409

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So What Can We Safely Say About Railways and Energy

- Rail freight almost always saves energy, but some types of service save more than others:
  - Coal and bulks most efficient
  - Savings diminish with lighter weight cargo
- With high load factors, conventional rail passenger service saves some energy/CO2, both in mass transit and intercity:
  - Greatest saving is versus air, auto is moderate (depending on load factor for auto) and bus is least
- HSR can make some contribution to saving energy/CO2:
  - Energy intensity goes up with speed, but design can help
  - Potential market also goes up with speed, and immense volumes help
  - Implementing HSR on a massive scale in the U.S. would be a real challenge to policy, funding, management and politics

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What Could be Done on the Passenger Side?

- Clearer understanding and valuation of all externalities (not just CO_2)
- Stable Federal planning, funding and policy to match State investments
- Congestion pricing for all modes
- Willingness to pay for public benefits and tax public externalities
- Better integration of intercity and urban planning and transport systems

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What Could be Done on the Freight Side?

- DO NOT "RE-REGULATE" and keep freight railroads private. The market has handled and will handle most of the freight challenges if we let it.
- Clearer understanding and valuation of all externalities (not just CO2) to support public investment in private facilities
- Stable Federal planning, funding and policy to match private investments where appropriate
- Congestion pricing and balanced funding for all modes
- Willingness to pay for public benefits and tax public externalities

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