UIC HIGHSPEED Morocco 2023

HIGH-SPEED RAIL : THE RIGHT SPEED FOR OUR PLANET

Under the High Patronage of his Majesty King Mohammed VI

Session 3.3, Room Karam3
Operational performance / Energy efficiency

Moderator : Mr. DONG Xiaoqing
Researcher, Deputy director of the Aerodynamics and Vibration and Noise Research Laboratory , CARS, China

ONCF UIC

Session 3.3
Operational performance / Energy efficiency
Speaker Lists;

1

Mr.Yan Xia

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Mr.Charles Langlet

France

3

Mr.David Hughes

Ireland

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Ms.Inara Watson

United Kingdom

5

Mr. Hilal Tugyanoglu Erdogan

Turkey

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11TH WORLD CONGRESS OF HIGH-SPEED RAIL

Marrakech, 7-10 MARCH 2023

Introduction to UIC International Railway Standard *IRS60682 Design of a High Speed Railway- Energy*

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Session3-3.3 Operational performance / Energy efficiency

1. Overview

IRS series "Design of a high speed railway”

- IRS60680 Infrastructure
- IRS60681 Communicating and Signaling
- IRS60682 Energy
- IRS60683 Interface

❖ technical requirements common to all countries

❖ differentiated technical characteristics between different countries.

2022 UIC Excellence in Railway Publications Awards

❖ IRS60682 Energy has won **2022 UIC Excellence in Railway Publications Awards.**

❖ Award category: **Innovative with value-added**


Excellence in Railway Publications Awards

2022

Award category: Innovative with value-added

Name(s): Lei WANG

Company: China State Railway Group Co., Ltd.

Title: 60682 - Design of a high-speed railway - Energy

Forum/Platform: High Speed

Working group: HS

Publication date: June 2022

Simon FLETCHER
Director Europe and Chief Standardisation Officer

UIC RAILWAY PUBLICATIONS

100 YEARS ANNIVERSARY UIC INTERNATIONAL UNION OF RAILWAYS

2. Traction power supply and traction substation

- The traction power supply system consists mainly of the traction substation and the traction network.

2.1 Traction power supply system

- **Alternating current (AC) mode** shall be used for HSR for its high speed and high power load.
- Voltage and frequency are the main parameters of the traction power supply system, and all countries shall refer to the AC section of Table 1 and B.1 of **IEC 60850-2014, "Railway applications – Supply voltages of traction systems".**

2. Traction power supply and traction substation

2.2 Feeding mode of traction network

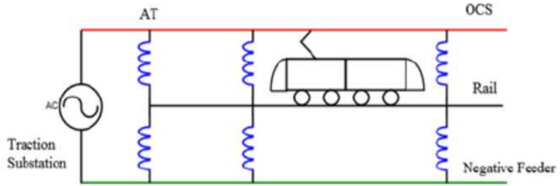


Fig. 1 - Diagram of AT feeding

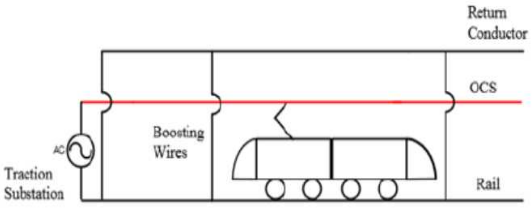


Fig. 2 - Diagram of direct feeding with return conductor

- Germany: direct feeding with return conductor;
- France: AT feeding;
- China: Both
- Japan: AT feeding;
- India: AT feeding.

2.3 Power supply for rolling stock

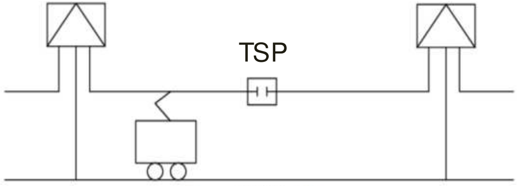


Fig.1 single-end feeding

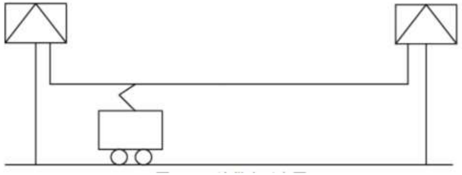


Fig.2 double-end feeding

- Germany uses double-end feeding
- France, China, Japan and India use single-end feeding.

2. Traction power supply and traction substation

2.4 Location of traction substations

- Facilitating leading in/out of overhead wires or power cables
- Suitable geological conditions, avoiding dangerous rock, flow sand, land slide, rock fall, etc.
- Avoiding air-polluted areas;
- Appropriate elevation, taking into consideration local rainfall and flood levels.

2.5 Main circuit

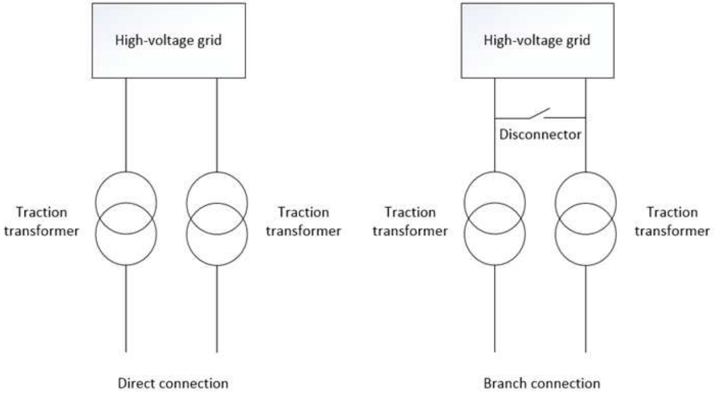


Fig. 3.3 Diagram of direct connection and branch connection

- Direct connection : less equipment and fewer costs
- Branch connection : flexibility

3. Overhead contact line system (OCS)

❖ An OCS is an electrical-mechanical system that provides traction power for rolling stock via current collectors.

3.1 Environmental characteristics

❖ **Spatial environment**

-- loading gauge, structure gauge, electrical clearance and pantograph-OCS interaction , etc.

❖ **Climatic environment**

-- temperature, humidity, ice, snow, wind, air pollution, lightning, etc.

❖ **Operational environment**

-- the traction unit, geometry of the pantograph, the number of and the distance between uplifted pantographs, headway, train speed, etc.

❖ **Earthquakes**

3. Overhead contact line system (OCS)

3.2 OCS pole, bracket and registration assembly

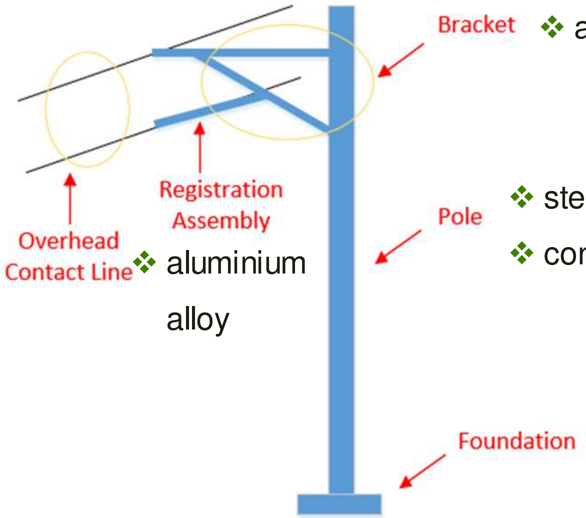


Fig. 4.1 Diagram of OCS structure

- Bracket: a cantilever
- Pole: steel; concrete
- Registration assembly: aluminium alloy

3.3 Suspension

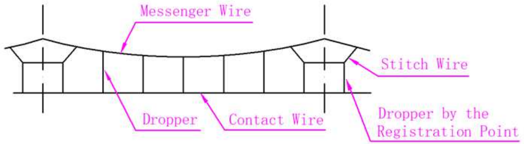


Fig. 4.2 Catenary suspension with stitch wire

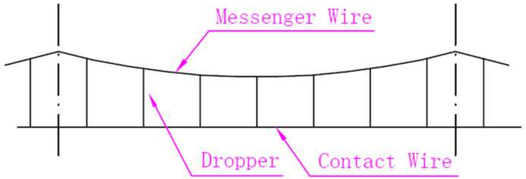


Fig. 4.3 Trolley-type suspension

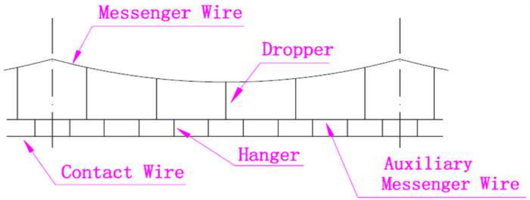


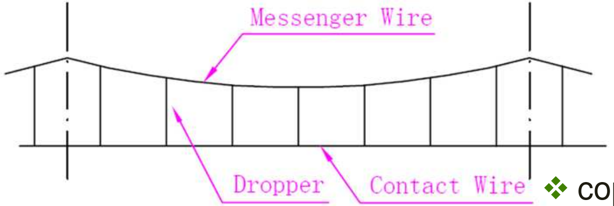
Fig. 4.4 Compound-type suspension

- Germany: catenary suspension with stitch wire;
- France: trolley-type suspension;
- China: mostly catenary suspension with stitch wire and trolley-type suspension in some cases for 250 km/h HSR;
- Japan: compound-type suspension for 320 km/h HSR, trolley-type suspension for 260 km/h HSR;
- India: compound-type suspension for 320 km/h HSR.

3. Overhead contact line system (OCS)

3.4 Contact wire and messenger wire

❖ copper, copper alloy or steel

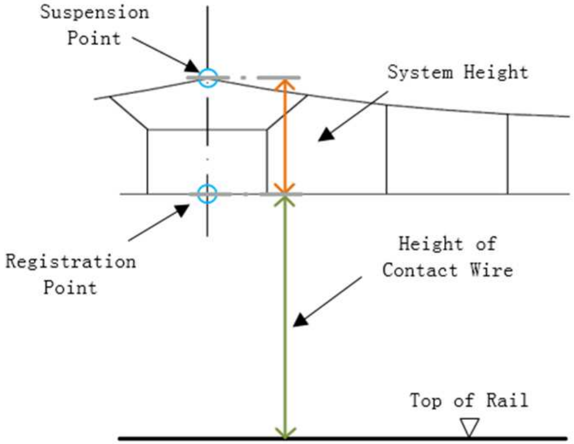


❖ copper or copper alloy

Fig. 4.3 Trolley-type suspension

❖ The **cross-sectional area and rated operating tension** of the wires should be determined on the basis of actual load cases through power supply calculation. The rated operating tension shall comply with safety requirements with regard to allowable working stress.

3.5 Main technical specifications



❖ The height of the contact wire

❖ System height

3. Overhead contact line system (OCS)

3.6 OCS longitudinal structure and equipment

- The design of the OCS's longitudinal structure mainly covers the span length, the tensioning section, the overlap, the midpoint anchor, the end anchor, the tensioning device, the overhead crossing, etc.; equipment mainly includes electrical sectioning and phase break, disconnector, etc.

3.7 Tensioning section and overlap

- The tensioning section is the basic unit of the OCS, covering several span lengths and includes anchors on both ends, an overlap connecting two neighbouring sections, and a midpoint anchor in some cases.

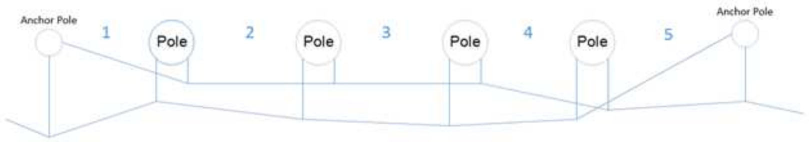


Fig. 4.6 Five-span overlap

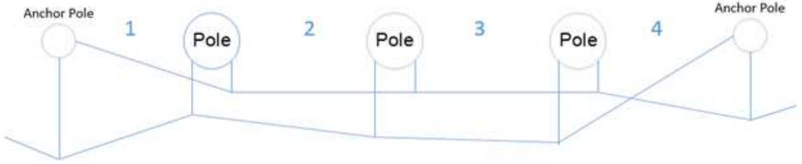


Fig. 4.7 Four-span overlap

4. Railway electric power system

➢ Means of electric power supply

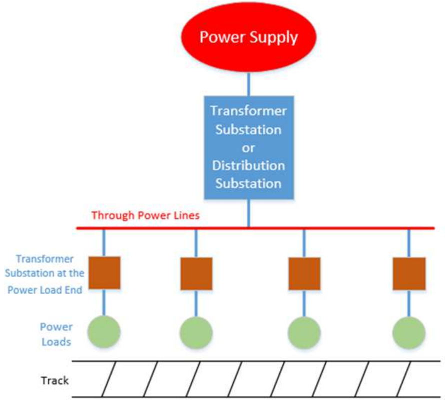


Fig. 5.1 Diagram of centralised electric power supply

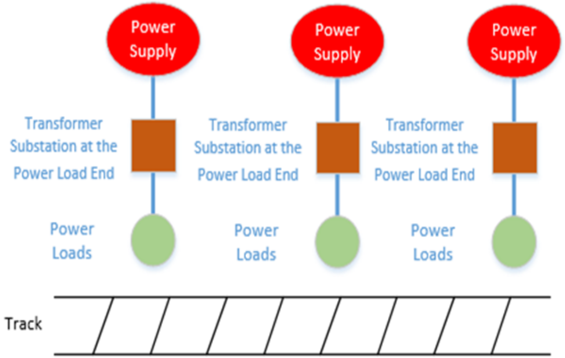


Fig. 5.2 Diagram of decentralised electric power Supply

❖ The railway electric power system is the main power supply to feed loads other than those fed by the traction power supply system.

❖ a technical and economic comparison, taking into account the power grid level, power load density, phase imbalance, reliability and management requirements, etc.

5. Supervisory control and data acquisition system (SCADA)

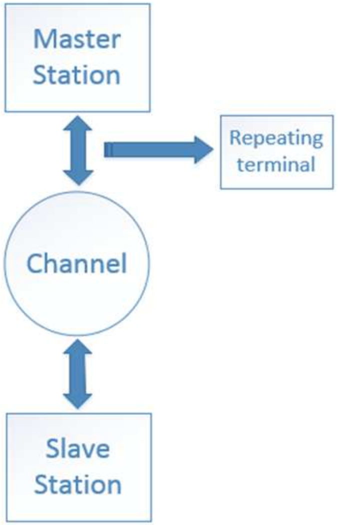
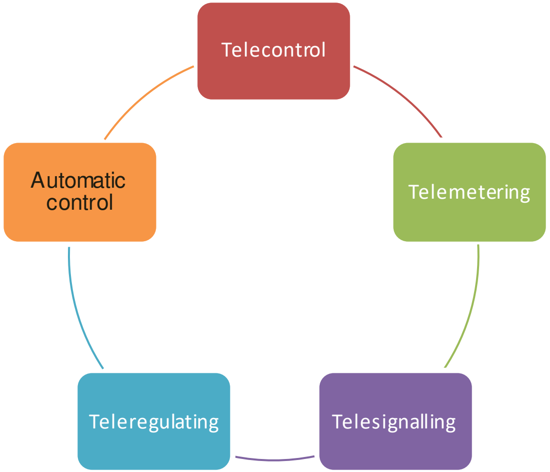


Fig. 6.1 Diagram of SCADA system

➢ Functions



❖ The SCADA system conducts real-time surveillance of the traction power supply system and the electric power system.

❖ The SCADA system mainly conducts telecontrol, telemetering, telesignalling, teleregulating, automatic control, etc.

THANK YOU

❖ Email: 15120074099@163.com

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Marrakech, 7-10 MARCH 2023

How to reduce energy consumption of high-speed trains
Alstom experience

LANGLET Charles
Product Director High-Speed Trains, ALSTOM
Session3- 3.3 - Operational performance / energy efficiency

ONCF UIC

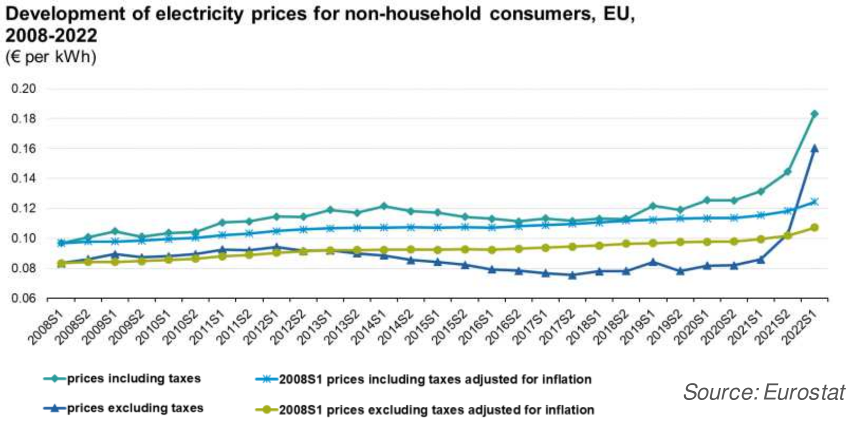
Agenda

1. Why is energy consumption important at high-speed ?
2. What are the main factors of energy consumption at high-speed ?
3. Energy breakdown of an High-Speed Train
4. What can be improved to further reduce energy consumption ?
5. Case Study

Why is energy consumption important at high-speed ?

Energy cost

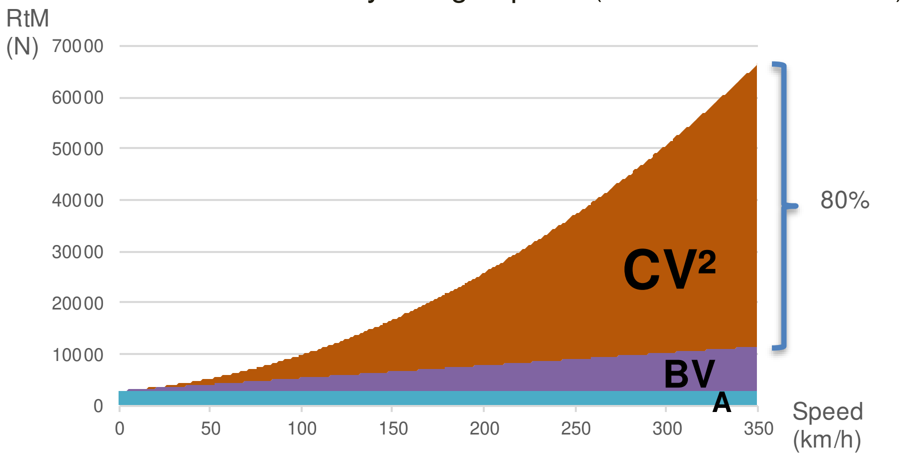
- Electricity **cost increasing** (nearly double in 15 years)
- Energy can **represent 30% or more** of the train Life Cycle Cost over 30 years



Source: Eurostat

High-Speed requires energy

- Needed power on the catenary line:
  $P_{Line} = P_{Wheel} + P_{Aux} + P_{Comfort} + P_{Losses}$
- Resistance to motion:
  RtM (in N) = A + B x S + C x S²
  ➔ C coefficient is key at high-speed (80% of RtM at 300km/h)



What are the main factors of energy consumption at high-speed ?

Train design is only 1 type of key energy consumption factors

Infrastructure
- Line gradients, curve radius
- Tunnels (cross section, length…)
- Catenary voltage/frequency
- Etc.

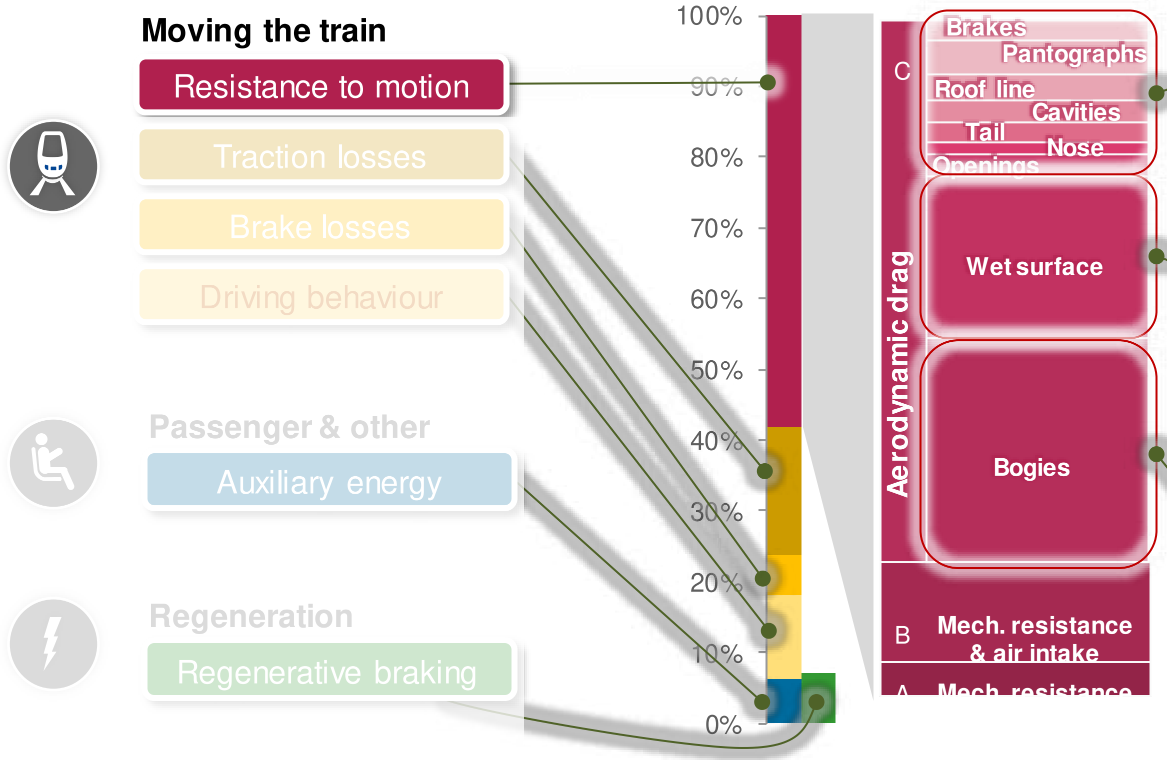
Environment
- Ambiant temperature
- Sun radiation
- Wind
- Etc.

Operation
- Max speed
- Time table
- Load condidtions
- Yearly mileage
- Driving style
- Auxiliaries (nb of doors, toilets…)
- Etc.

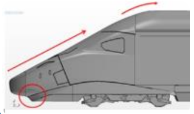
and…

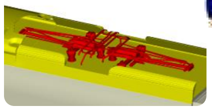
Train design
- Aerodynamism
- Train weight
- Traction efficiency
- Auxiliaries efficiency
- Etc.

Energy breakdown of an High-Speed Train

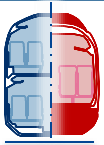


Enhanced aerodynamics (nose shape, fairings, minimize cavities, optimized car jonction…)
➔ ~10% energy savings

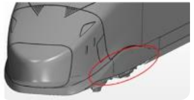


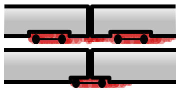


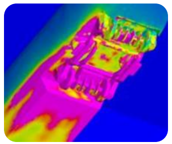
Double deck same surface
→ **volume optimization** (more people in same volume)



- Bogie area represent ~30% of Energy conso.
- **Articulation** has 25 to 30% less bogies and minimizes inter-car cavities.
- **Enhanced integration** (secondary suspension…).
- **Bogie fairing** to reduce cavity impact.







Energy breakdown: example TGV on a 320 km/h trip
Resistance to motion: example TGV A 300 km/h

Energy breakdown of an High-Speed Train

Moving the train

Resistance to motion

Traction losses

Brake losses

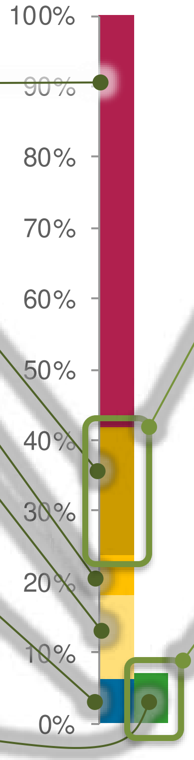
Driving behaviour

Passenger & other

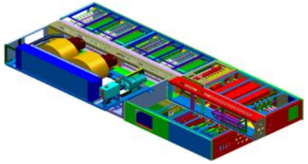
Auxiliary energy

Regeneration

Regenerative braking

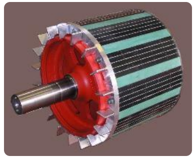


Simplification of kinematic chain
Example: reduction 5 to 3 gears motor-to-axle on AGV



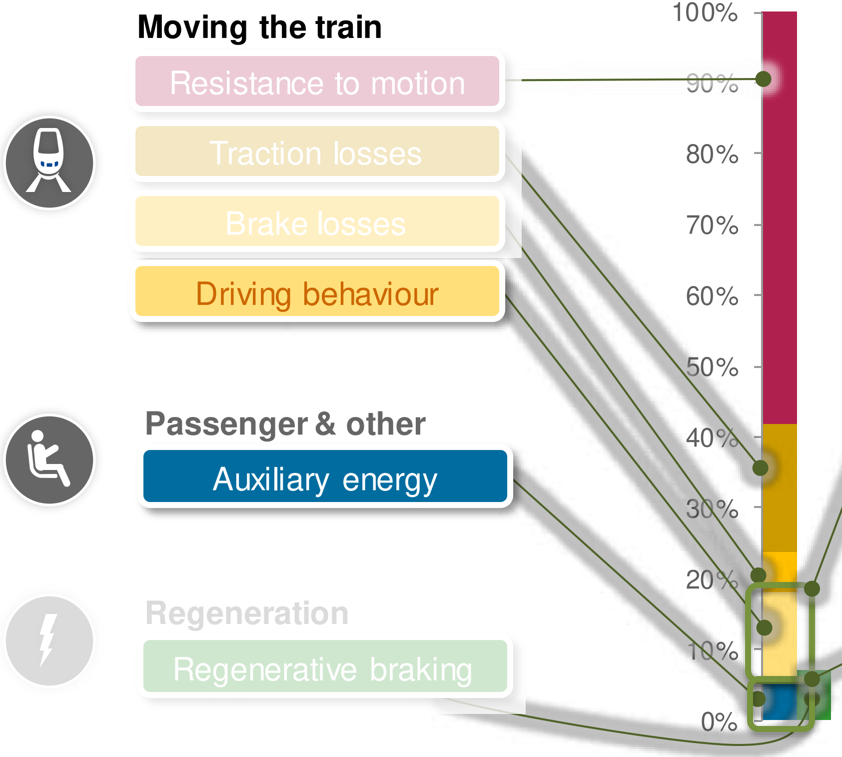
New generation of inverters
IGBT water-cooled, higher frequency…

Permanent Magnet Motor
High efficiency for some mission profiles (less losses due to harmonics…)



- **Lower train weight** reducing brake energy need
- **Intelligent braking blending** at train level
- Increase use of **regenerative braking** & increased regenerative power ➔ 5 to 10% energy reduction

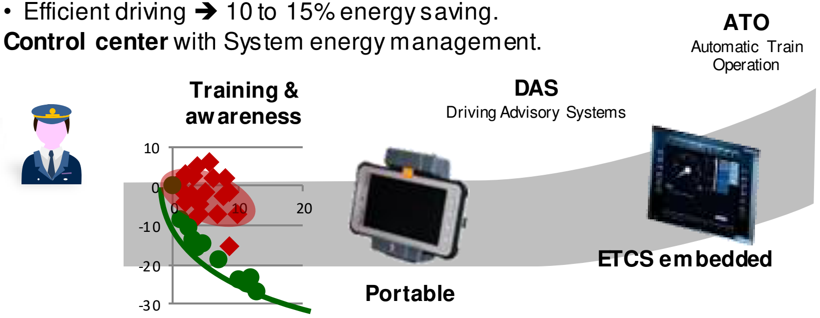
Energy breakdown of an High-Speed Train



Solutions to **maximize Driving Efficiency:**

- Tests show energy differences up to 30% between drivers.
- Efficient driving ➔ 10 to 15% energy saving.

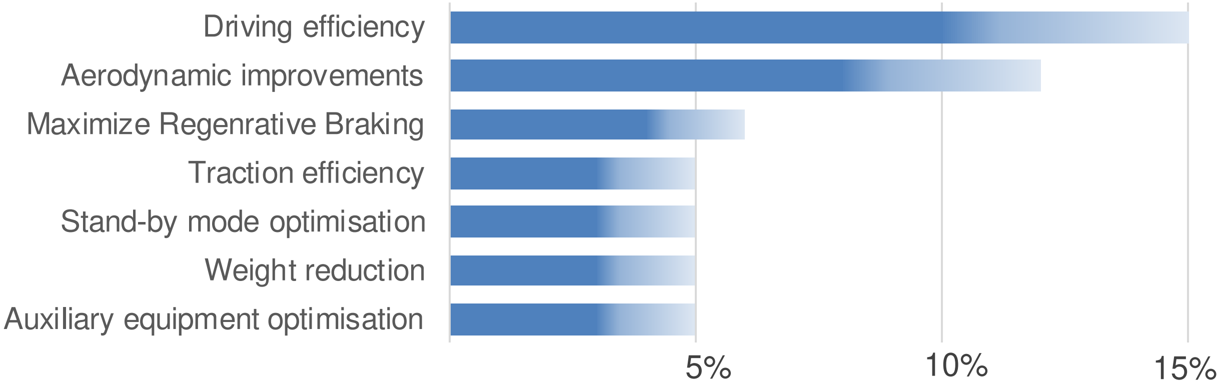
Control center with System energy management.



- **Intelligent parking modes** (automatic door closing, improved stand-by mode of the HVAC)
- Improvement of **cooling systems** (higher frequency, variable regulation…)
- **Smart CO_2 control** – manage fresh air, optimise heating & cooling power based on temperature.

Further developments

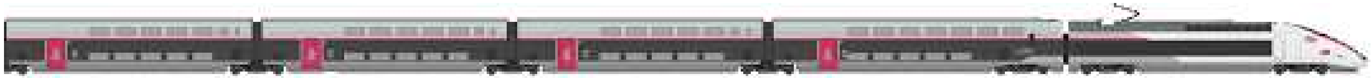
- **Energy reduction additional potential savings:**



- **Example of Case by case analysis:**
  - Bogie Fairings: savings vs potential impact on maintenance costs
  - PMM vs ASY motors: depending on mission profiles
  - HVAC: energy consumption vs natural cooling solutions

Case study: Avelia Horizon vs. Euroduplex

Euroduplex (RGV 2N2)



Traction

- Improved traction efficiency reducing energy consumption
- Increased use of electrical brake
- Modified tractive effort curve for lower overall power

-10 to 15%

Traction energy vs. Euroduplex -25 to 30%

Resistance to motion

- Aerodynamic improvements (nose shape, fairings…)

-6 to 10%

RtM energy vs. Euroduplex **-15 to 20%**

Auxiliaries

- Reduction of traction auxiliaries
- Reduced lightning energy consumption thanks to LED

-3 to 5%

Auxiliaries energy vs. Euroduplex **-15 to 18%**

HVAC

- HVAC resizing and improved parking mode

-1 to 3%

HVAC energy vs. Euroduplex **-25 to 35%**

Avelia Horizon

Total energy consumption **-25 to 30%**

THANK YOU

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HIGH PERFORMANCE PASSIVHAUS STANDARD THE HIGH SPEED ROUTE TO LOW CARBON

David, HUGHES
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Session3-3.3 Operational performance / Energy efficiency

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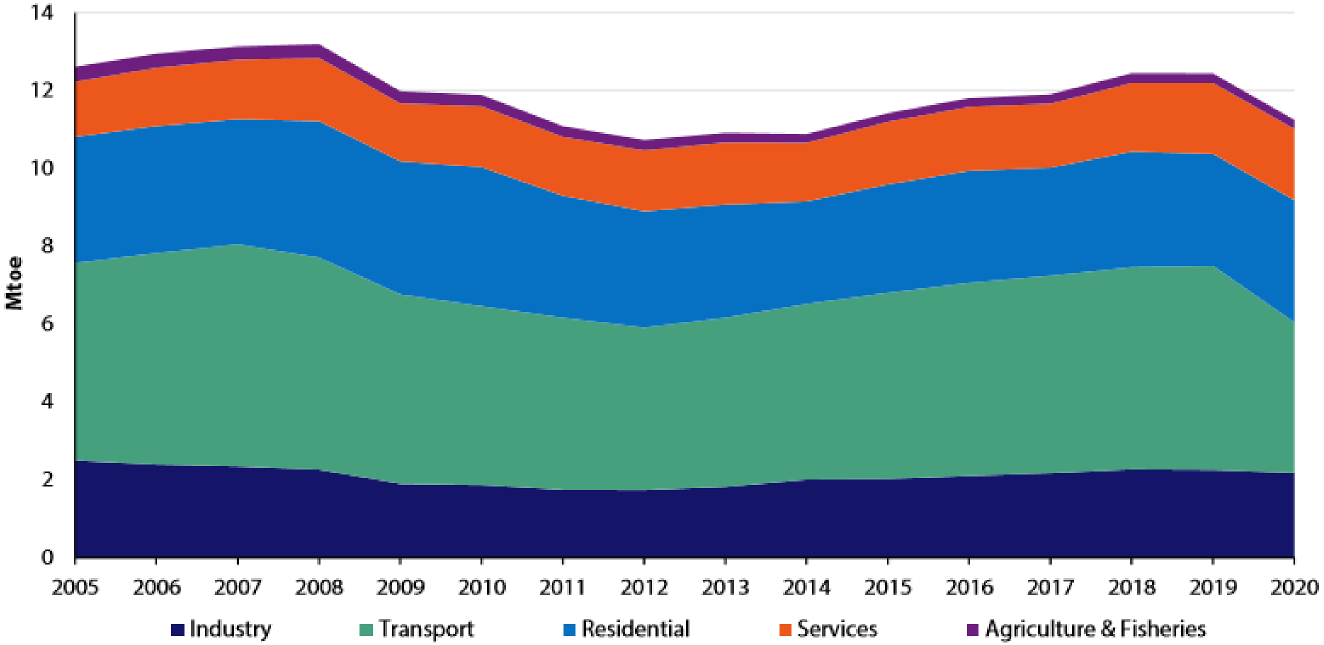
ACROSS THE WORLD ENERGY USE IS BROKEN DOWN AS FOLLOWS

Buildings
40%

Transport
40%

Industry
20%



Source: SEAI

HIGH PERORMANCE NEEDS TO BE MEASURED AGAINST A TARGET OR STANDARD
350.Org Keep 80% Fossil Fuels in the Ground

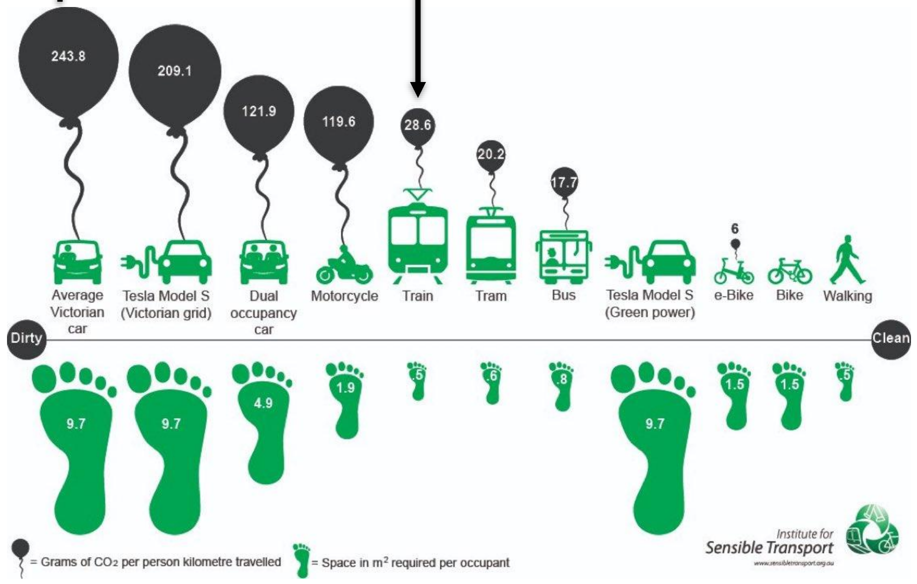
HIGH PERFORMANCE IN BUILDINGS USING PASSIVHAUS ACHIEVES A 90% REDUCTION IN ENERGY AND EMISSIONS

And we can do it moving people from car plane to high speed train

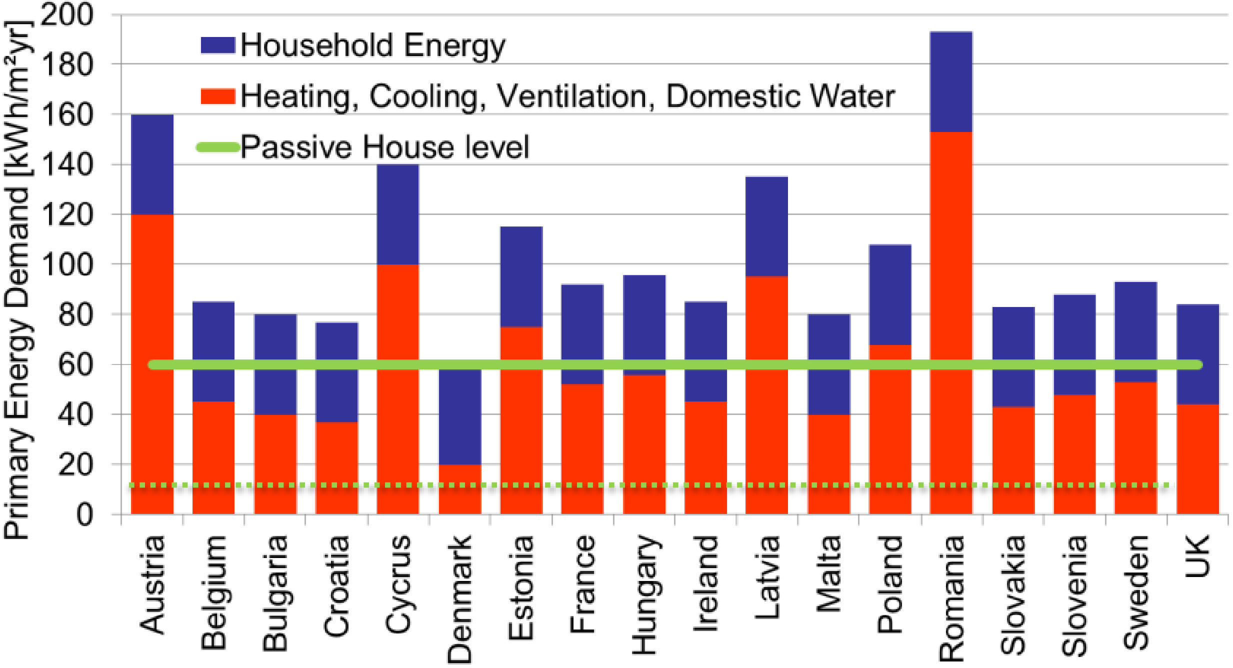
>88%

we have done it before with lighting

>90%



WE CAN DO IT WITH BUILDINGS USING THE HIGH PERFORMANCE PASSIVHAUS STANDARD FOR NEW AND OLD



PASSIVHAUS STANDARD ULTRA LOW POWER REQUIREMENT

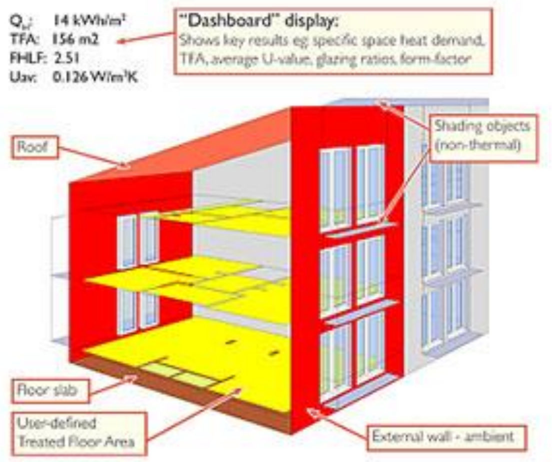
- 10 W/sq m maximum instantaneous demand for space heating or cooling…
- So how big a ‘boiler or chiller’ do you need for a 100 sq m house?
- Answer 10W x 100sq m or 1000W or 1 kW
- That is a one bar ‘electric fire’ or the power of a toaster
- Put another way 1 candle emits 30W of heat power so a 21 sq m living room could be heated by 7 candles

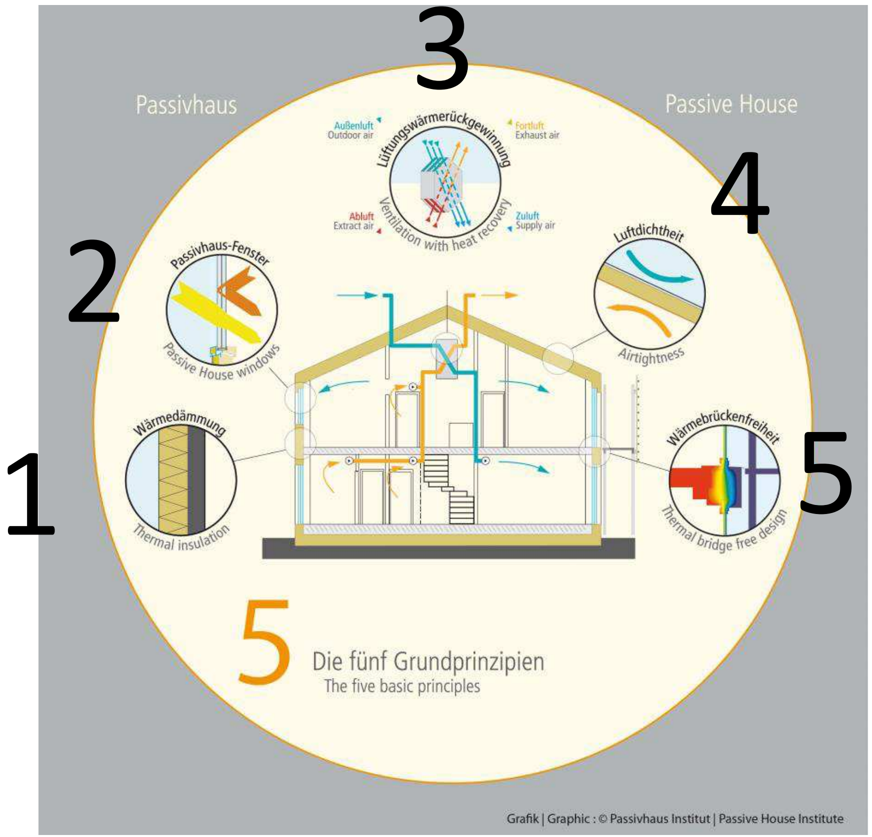
= 100 sq m

= 3 sq m

PASSIVHAUS 5 RULES ONE SPREADSHEET

Spreadsheet is automatically calculated off SketchUP model.





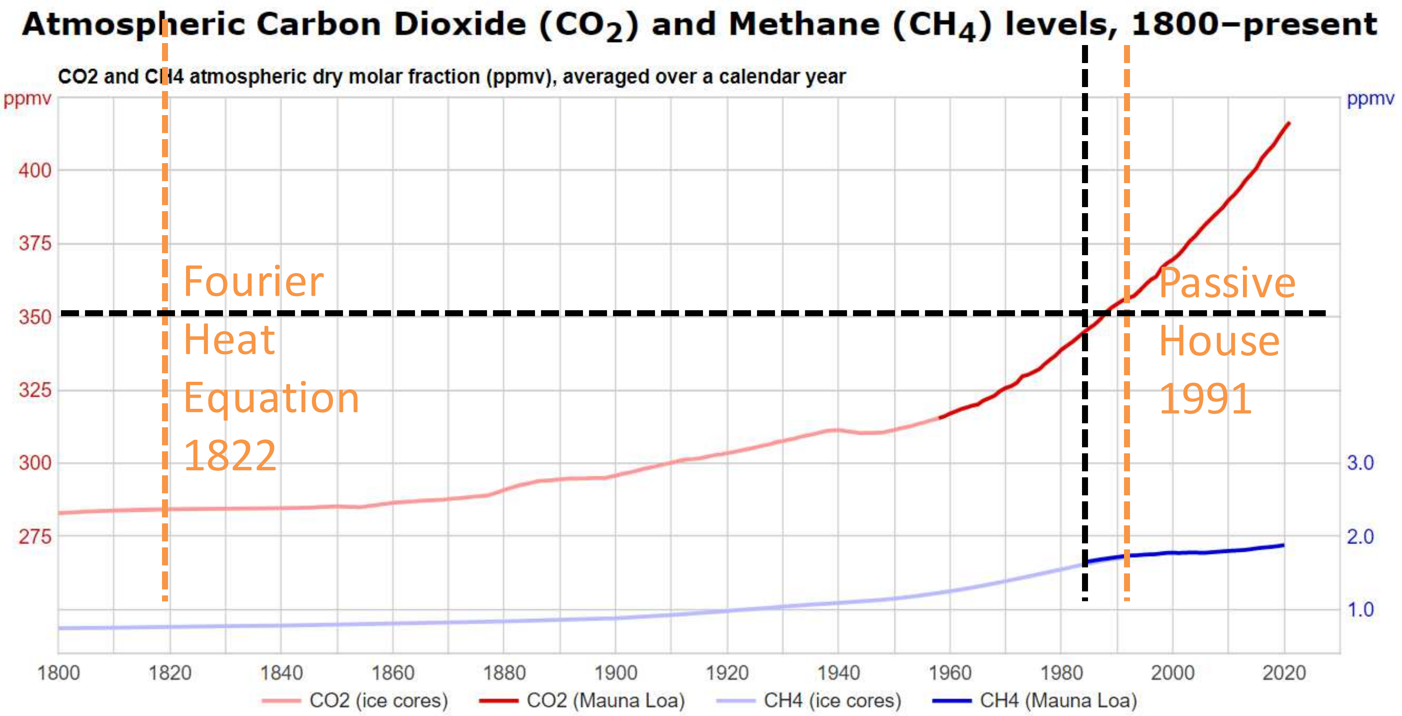
TWO HIGH PERORMANCE EXAMPLES

Kent Station Cork 2008 Net Zero and Portlaoise Passivhaus 2011

- Text (Arial 12 pt)


Kent Station Cork - World's First Carbon Zero/Energy Zero Railroad Station 2006-2009

IPCC COP 1 1981 PASSIVHAUS 1991



PASSIVHAUS NEW BUILD AND RETROFIT OUT-PEFORMS ALL OTHERS

Text (Arial 14 pt)

- Text (Arial 12 p

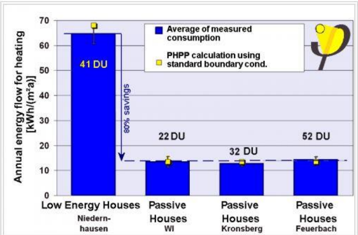
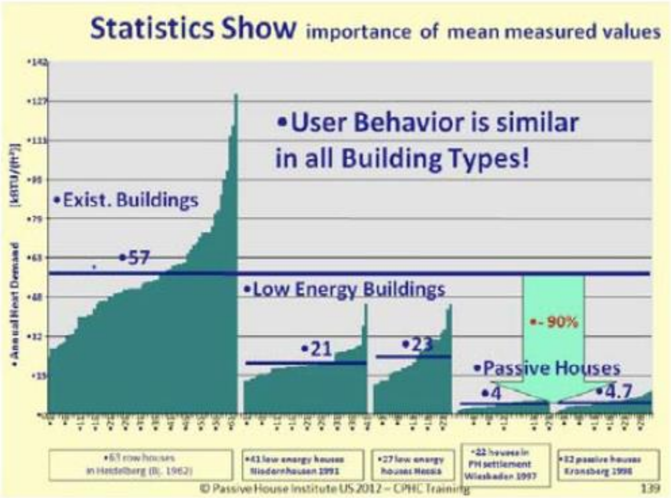


Fig. 6: This diagram summarises the comparison of the consumption measurements of the reference settlement (left, 65 kWh/(m²a)) and the three Passive House developments (about 13 kWh/(m²a) in each case). The consumption in the Passive Houses based on these measured values is about 80% less than in the low energy homes of an already good standard. All average values are in quite good agreement with the values previously calculated using the Passive House Planning Package (PHPP).



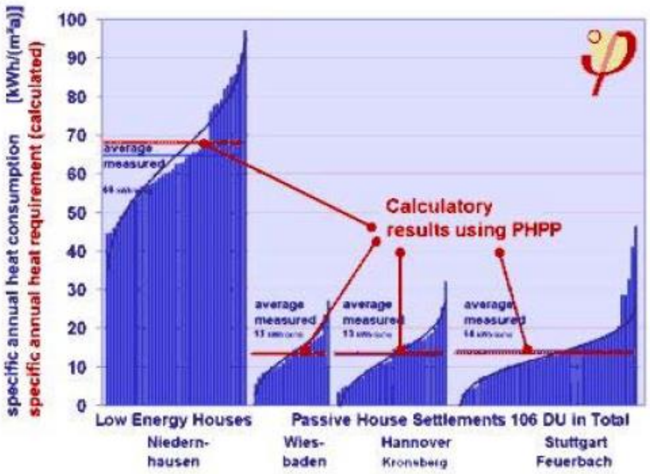
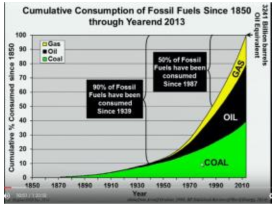


Figure 2 The chart on the left illustrates the energy saving potential of going from typical building performance to Passive Buildings, the image on the right shows post occupational evaluation studies in Europe on Low Energy and Passive Buildings. The range of values measures will vary with human behaviour but in and about a statistical mean that is predicted by the Passive House Software Package. This means that statistically the energy savings predicted will be achieved across the building stock as a whole and that a 90% reduction or 36% of the EU's energy imports can be saved.

EMBODIED CARBON IN NEW BUILDINGS WITH CAREFUL DETAILS CAN BE LOWERED

TABLE 2: A1–A3 ECFs for typical structural materials

Material	Type	Specification/details	A1–A3 ECF ($kgCO_2e/kg$)	Data source
Concrete	*In situ*: piling, substructure, superstructure	Unreinforced, C30/37, UK average ready-mixed concrete EPD[1] (35% cement replacement)	0.103	MPA, 2018[2]
		Unreinforced, C32/40, 25% GGBS cement replacement[3]	0.120	ICE V3[4]
		Unreinforced, C32/40, 50% GGBS cement replacement	0.089	ICE V3
		Unreinforced, C32/40, 75% GGBS cement replacement	0.063	ICE V3
		Unreinforced, C40/50, 25% GGBS cement replacement	0.138	ICE V3
		Unreinforced, C40/50, 50% GGBS cement replacement	0.102	ICE V3
		Unreinforced, C40/50, 75% GGBS cement replacement	0.072	ICE V3



Carbon sequestration in timber

The timber values in Table 2 exclude carbon sequestration – the removal of carbon dioxide from the atmosphere via photosynthesis, and the temporary storage of this carbon within the timber.

Inclusion of carbon sequestration in the reported embodied carbon value depends on the scope of calculation:

- Stages A1–A5: Report sequestration separately alongside the A1–A5 value reported.
- Stages A–C: Include sequestration within the total A–C value reported.

In the absence of product-specific data, carbon sequestered can be taken as **-1.64kgCO$_2$e/kg** (this factor is based on standard timber properties – refer to *CEC* to calculate this figure more accurately).

The sequestration factor is multiplied by the timber material quantity in the same way that the A1–A3 ECF is.

Concrete Slab
1.0 m wide
0.3 m deep
1.0 m length
0.3 m3 x 2400kg/m3
720 kg/m x 0.1 kgCO2e/kg

72 kg CO2e

Mass reduction

55.5%

CO2e reduction

-248%

((-107.2 -72)/72) x 100

Concrete
1.0 m wide
0.1 m deep
1.0 m length
0.1 m3 x 2400kg/m3
240 kg/m x 0.1 kgCO2e/kg
24 kg CO2e/m

Timber
1.0 m wide
0.2 m deep
1.0 m length
0.2 m3 x 400kg/m3
80 kg/m x -1.64kgCO2e/kg
-131.2 kg CO2e
-107.2 kg CO2e

THANK YOU

11TH WORLD CONGRESS OF HIGH-SPEED RAIL

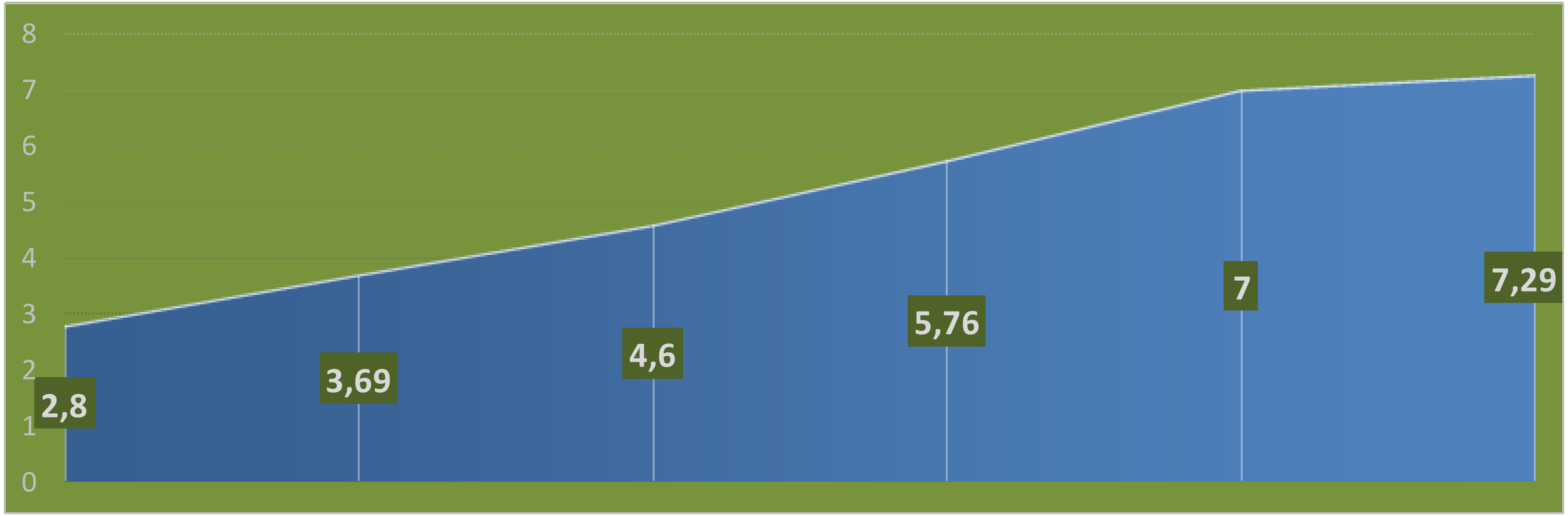
Marrakech, 7-10 MARCH 2023

Factors Affecting the Energy Consumption of High-Speed Railways

Dr Inara Watson
LSBU, UK
Session number and Name

ONCF UIC

INCREASE IN CO2 EMISSIONS WORLDWIDE 1970-2020 BY THE TRANSPORT SECTOR (GtCO2)



Source: https://www.statista.com/statistics/1291615/carbon-dioxide-emissions-transport-sector-worldwide/

TECHNICAL CHARACTERISTICS OF HSRS IN SELECTED COUNTRIES

Country	Operator	Train Sets (number)	Average Traction Power (kW)	Max Op Speed (km/h)	Axle Load (ton)	Total number of seats	Average Capacity of Train (seats)
France	SNCF	408	8770	320	17.0	193734	475
Germany	DB AG	280	7000	320	14.2-18.0	139881	500
Italy	FS	182	7800	300	15.1-17.0	89441	440
Spain	Renfe	229	6100	300	16.0-18.0	69291	241
Japan	JR	405	12000	300	11.4-16.0	381019	950
Turkey	TCDD	19	7200	300	17.0	8276	424
S. Korea	Korail	144	10200	300	17.0-N/A	81975	560

HSRS IN SELECTED COUNTRIES IN 2019

Country	Ratio Pass-km/seat	Ratio mass/seat ton/seat	Average Age (years)	Distributed Power	Concentrated Power	Articulated	Tilting	Double Decker
France	0.181	0.777	21	---------	408	408	------	270
Germany	0.224	0.997	19	177	103	-------	75	--------
Italy	0.204	1.011	17	123	59	25	73	--------
Spain	0.268	1.041	14	115	114	114	90	--------
Japan	0.300	0.515	13	405	---------	-------	268	20
Turkey	0.145	0.816	6	19	---------	-------	-----	-------
S. Korea	0.266	0.912	10	---------	144	144	-----	-------

COMPARISON OF DIFFERENT TYPES OF HIGH-SPEED TRAINS IN TERMS OF POWER SYSTEMS, AXLE LOADING, AND CAR BODY MATERIALS

Country	Main Constructor	Train	Power system	Axel Loads (ton)	Car Body
France	Alstom	AGV	Centralized	17	Aluminium with Carbon
Japan	Hitachi	Shinkansen- Series 0	Distributed	16	Carbon Steel
Japan	Hitachi	Shinkansen-Series 700	Distributed	11.4	Aluminum alloy
Spain	Talgo	Talgo 350	Centralized	17	Aluminium
Italy	Hitachi Rail Italy	ETR1000	Distributed	17	Aluminum alloy
Germany	Siemens	ICE1	Centralized	19.5	Aluminium-silicon alloy
Germany	Siemens	ICE2	Centralized	19.5	Aluminium-silicon alloy
Germany	Siemens	ICE3	Distributed	15	Aluminium
South Korea	Hyundai Rotem	KTX-Sancheon	Centralized	N/A	Aluminium
Turkey	Siemens	HT80000	Distributed	17	Aluminium

DATA AND RESEARCH METHODS

Most of the data is drawn directly from International Union of Railways (UIC) statistic websites and used in research from 2010-2017.

The selected HSR systems are in the following countries: Japan (JP), South Korea (KR), Germany (DE), France (FR), Italy (IT), Spain (ES), and Turkey (TR).

DATA AND RESEARCH METHODS

DEA is a method that measures the efficiency of similar Decision-Making Units. The DEA is a non-parametric method based on the assumption that the production function of fully efficient DMUs is not known.

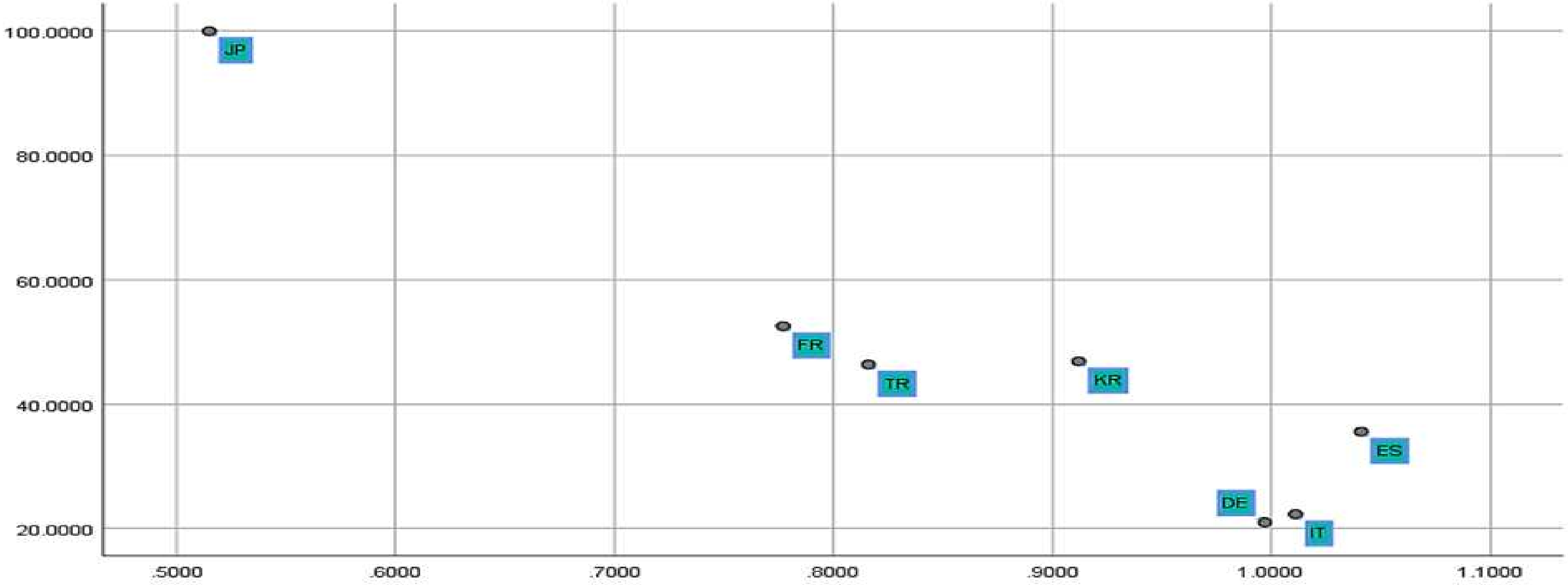
To statistically analyse the results of the DEA approach and the selected variables, the IBM-SPSS Statistics software has been applied.

THE MAIN FINDINGS IN BENCHMARKING THE SELECTED HSR IN TERMS OF ENERGY EFFICIENCY

Period	KR	ES	DE	TR	FR	IT	JP
2010	47.23	37.77	21.34	18.68	56.35	22.03	100
2011	48.20	33.25	19.49	24.76	51.20	24.03	100
2012	51.89	30.99	19.78	34.17	48.21	24.99	100
2013	50.58	35.43	21.16	49.96	48.15	23.28	100
2014	50.12	35.07	20.87	58.21	48.75	22.59	100
2015	47.23	35.97	20.32	62.88	52.17	21.33	100
2016	42.14	37.70	21.88	56.57	55.96	20.21	100
2017	37.69	38.18	23.03	65.82	59.57	19.82	100
Average	**46.89**	**35.55**	**20.98**	**46.38**	**52.55**	**22.29**	**100**

Efficiency score of DEA CRS input-oriented model for selected HSRs in period 2010-2017 by year (%)

THE MAIN FINDINGS IN BENCHMARKING THE SELECTED HSR IN TERMS OF ENERGY EFFICIENCY



Scatterplot of energy efficiency scores and weight/seat ratio weight per seat ratio

THE MAIN FINDINGS IN BENCHMARKING THE SELECTED HSR IN TERMS OF ENERGY EFFICIENCY

		Energy	Weight	Utilization
Energy	Pearson Correlation	1	-.951**	.585
	Sig. (2-tailed)		.001	.167
	N	7	7	7
Weight	Pearson Correlation	-.951**	1	-.657
	Sig. (2-tailed)	.001		.109
	N	7	7	7
Utilization	Pearson Correlation	.585	-.657	1
	Sig. (2-tailed)	.167	.109	
	N	7	7	7

**. Correlation is significant at the 0.01 level (2-tailed).

Correlation between energy efficiency scores and weight/seat ratio and seat utilization

THE MAIN FINDINGS IN BENCHMARKING THE SELECTED HSR IN TERMS OF ENERGY EFFICIENCY

- The increasing number of passenger-km per seat increases the energy efficiency score.
- A decrease in vehicle mass, improved design of HSRS and increased occupancy of trains will support the reduction of energy consumption by HSRS and, as a result, will improve the energy efficiency of the railways.
- Reducing the axle load will minimise infrastructure maintenance, increase speed, and reduce energy consumption.
- The higher utilisation of seats will require fewer trainsets, will lead to increases in productivity of an operation, increases the capacity of the line, and reduction in energy consumption.
- Using more advanced rolling stock can increase speed and reduce energy consumption.

THANK YOU