HIGH SPEED RAIL IN SPAIN: SAVING ENERGY AND INCREASING SUSTAINABLE MOBILITY ALONG 25 YEARS OF SUCESSFUL EXPERIENCE

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INTERNATIONAL CONFERENCE ON
GREEN INITIATIVES & RAILWAY ELECTRIFICATION

I. **ADIF references, as Infrastructure Railways Manager in Spain**

II. Relevant results on Energy and Environment management

III. Energy Management technologies for High Speed

IV. Sharing Spanish experience with Indian HS projects:
Simulation of Energy savings over Thane-Nasik strecht *(feasibility study of New HSL Mumbai-Kolkata / phase 1: Mumbai-Nagpur)*

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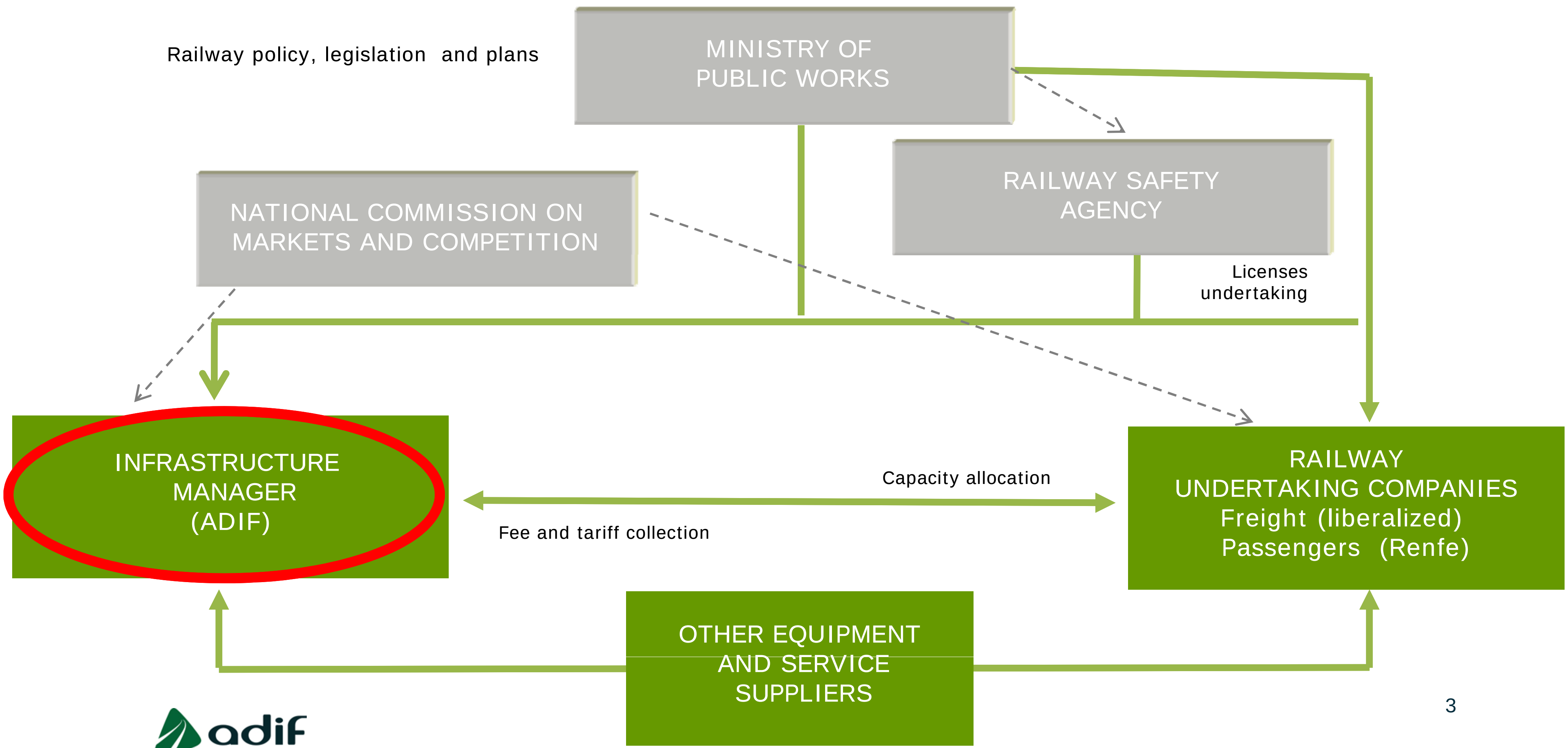
Background. Current Railways Scenario in Spain

- NEW LEGAL FRAMEWORK. RAILWAYS ACT (2003) AND ULTERIOR
  - In 2005, the National Railways company, RENFE, splits into Adif (the Infrastructure manager) and RENFE Operadora (railway undertaking in charge of transport operation, both passengers and freight).

    Both companies remain 100% state-owned.
  - Opening of rail freight (2007) and passengers (2013) traffics to competition



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Adif + Adif AV. Global Figures

- **Main investor in Spain, in last 25 years (around 57 bn $)**

In 2007-2016 High Speed: 36,000 M€ (40 bn $)
Conventional Rail: 6,000 M€ (7 bn $)

- **Staff:** 13,041 employees

Managed Rail Network: 15,296 km (9,504mi)

High Speed UIC gauge 1,435 mm : 2,590 km (1,609mi)

100% electrified AC

Conventional Lines (*Iberian gauge 1,668 mm*): 11,483 km (7,135 mi)
Out of which 616 km (383 mi) with HS parameters
80 % electrified DC

Mixed Gauge Network (UIC + Iberian gauge) 119 km (74 mi)
Out of which 22 km (13 mi) with HS parameters
100 % electrified DC

Metric gauge 1,000 mm: 1,207 km (750 mi)

- **HS Lines under construction or project:** 2,779 km (1,727 mi)

- **Managed Traffic:** 2.1 M trains /year 5,775 trains/day

198.3 M pass train-km/year 541,849 M pass trains-km/day **50,2% HSL**

- **Passengers:** 468 million passengers/year (36 million HS)

HS Lines. Landmarks

The Spanish network, a continuous evolution from 1992

1992 - **Madrid-Sevilla**: 471 km

2003 - **Madrid-Lleida**: 468 km (200 km/h ASFA).

Zaragoza-Huesca: 79 km

2005/06 **Lleida-Tarragona**: 95 km.

Córdoba-Antequera: 100 km.

Connection to Toledo : 21 km.

2007 - **Madrid-Lleida**: 468 km (300 km/h from May 2007)

Madrid-Valladolid: 181 km.

Antequera-Málaga: 55 km.

2008 - **Tarragona-Barcelona**: 88 km.

2010 - **Madrid-Cuenca**: 183 km.

Madrid-Albacete: 315 km.

Madrid-Valencia: 391 km

Mollet – Girona: 75 km

Intern. Connection with France: 20 km

2011 - **Ourense – A Coruña**: 150 km (Iberian gauge 1.668 mm)

2013 - **New Connection Barcelona-French Border** 131 km

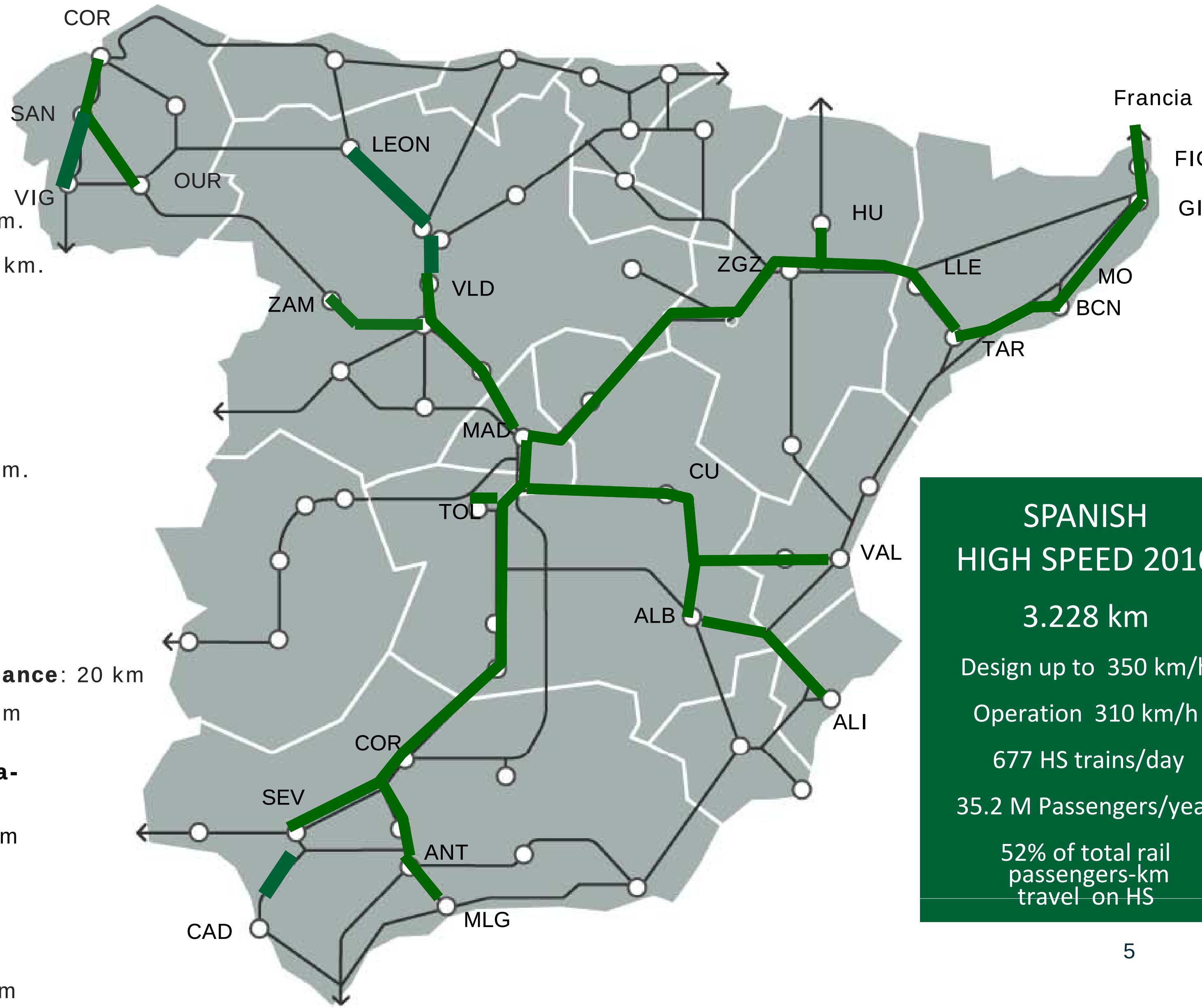
Albacete – Alicante: 165 km

2015 - **Santiago C. – Vigo**: 94 km (Iberian gauge 1.668 mm)

Sevilla – Cádiz : 71 km (Iberian gauge 1.668 mm)

Valladolid – León: 166 km

Olmedo – Zamora: 103 km



SPANISH HIGH SPEED 2016

3.228 km

Design up to 350 km/h

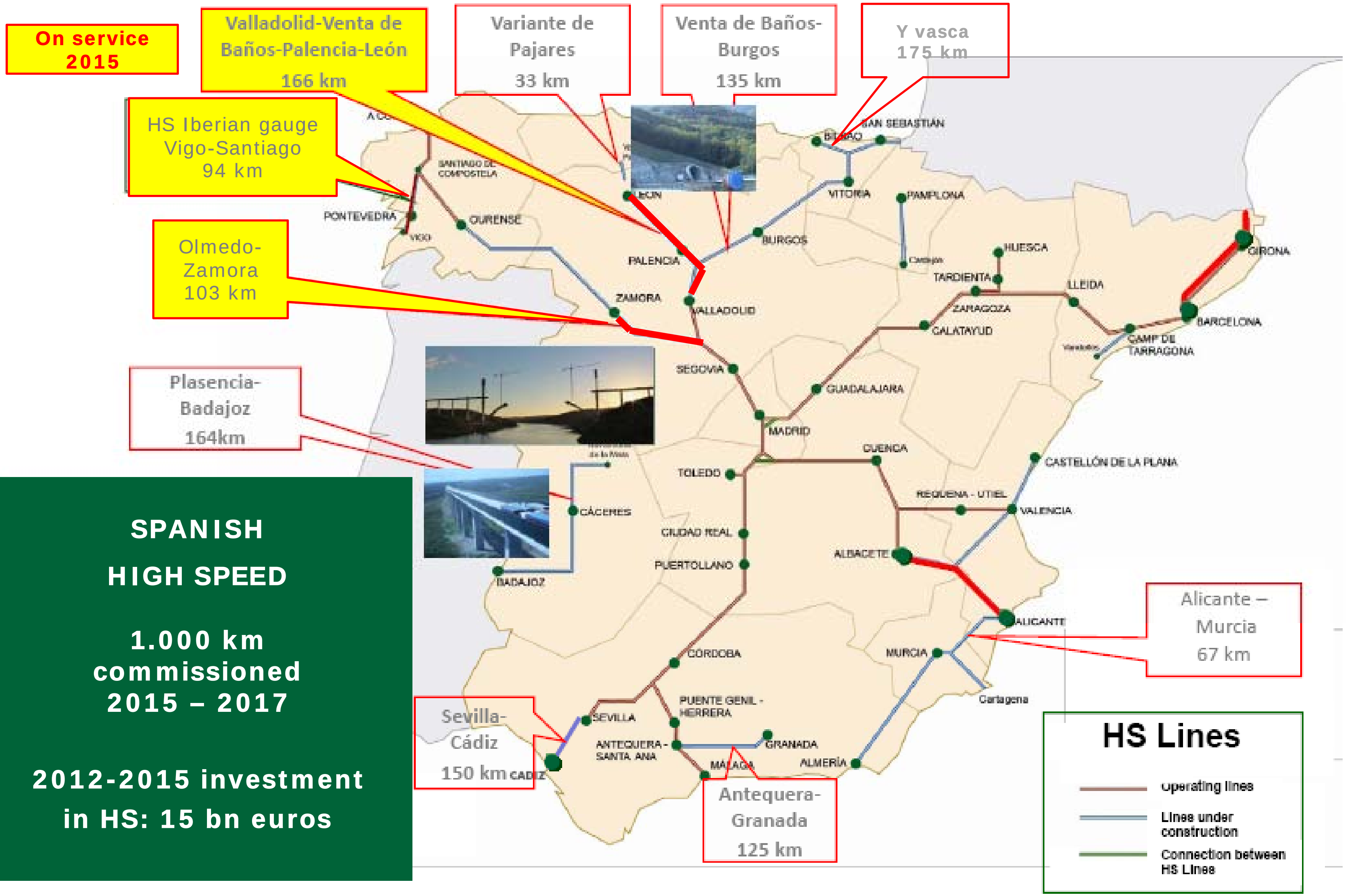
Operation 310 km/h

677 HS trains/day

35.2 M Passengers/year

52% of total rail passengers-km travel on HS

HS Lines. Overview 2015 - 2017 Current Works



SPANISH

HIGH SPEED

1.000 km commissioned 2015 – 2017

2012-2015 investment in HS: 15 bn euros

ON SERVICE SEPTEMBER 2017

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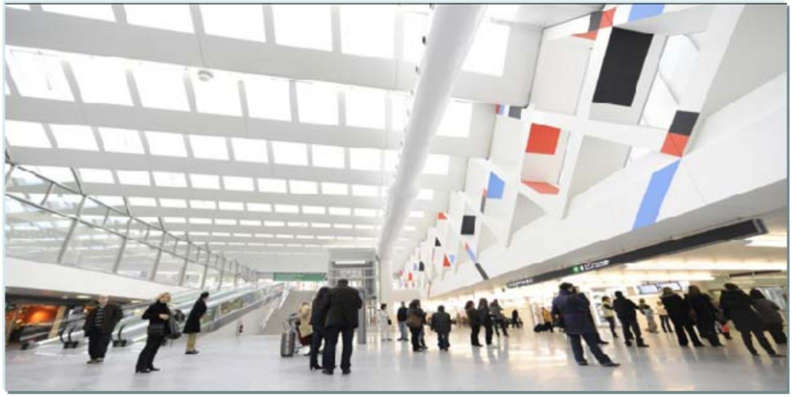
Stations



Madrid Puerta Atocha

Málaga María Zambrano (VIALIA)

Cuenca Fernando Zóbel (Brunel Award 2011)

47 High Speed Train Stations + 1.900 Conventional Lines Stations

- Adif has great expertise in Stations commercial management and income-generating activities.
- VIALIAs are a PPP system that provide funding for the design and construction of Stations and ensure revenues for concession holders and for Adif

Lines Upgrading / Improvement of performances over Conventional Lines

HSR + Conventional Lines

- Mixed traffic. Speed 220 km/h between Valencia and Tarragona
- Link to the main ports: Barcelona, Tarragona, Valencia, Alicante, Cartagena
- Line UIC gauge between Barcelona and Tarragona (HSL) and interim link Barcelona – French Border

Improvements actions on Conventional Lines

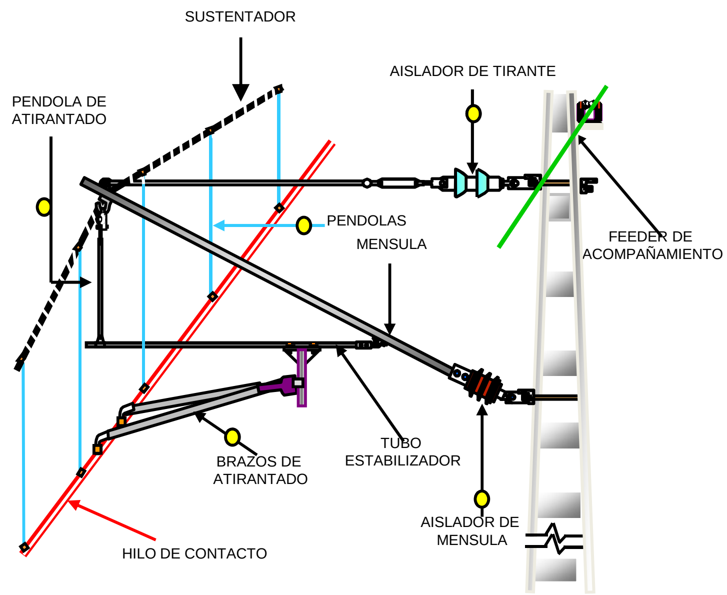
Improved lines Maximum speed 160 -> 200 -> 220 km/h

- Doubling of track (from single track case)
- Local new track sections to increase speed
- Track with UIC60 rail and monobloc concrete sleepers
- Installation of new jointless turnouts:

  Deviations: 100 km/h

  Siding tracks: 100 km/h
- New Catenary suitable for 220 Km/h
- New Signaling Equipments
- Elimination of Level Crossings
- Fencing
- Elimination of steel bridges without ballast

Catenary CR 220



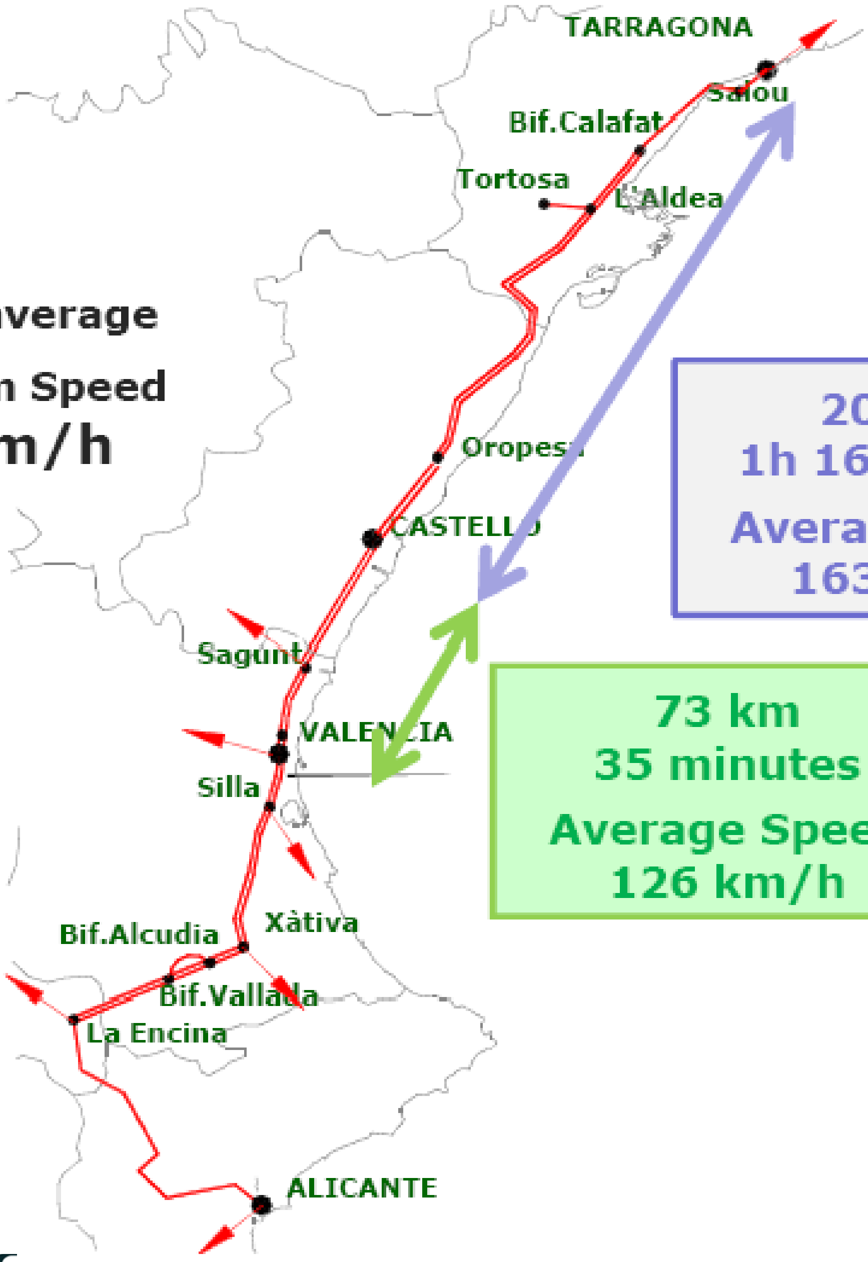
Unified Turnouts

Improving conventional lines: Mediterranean Corridor

Weighted average

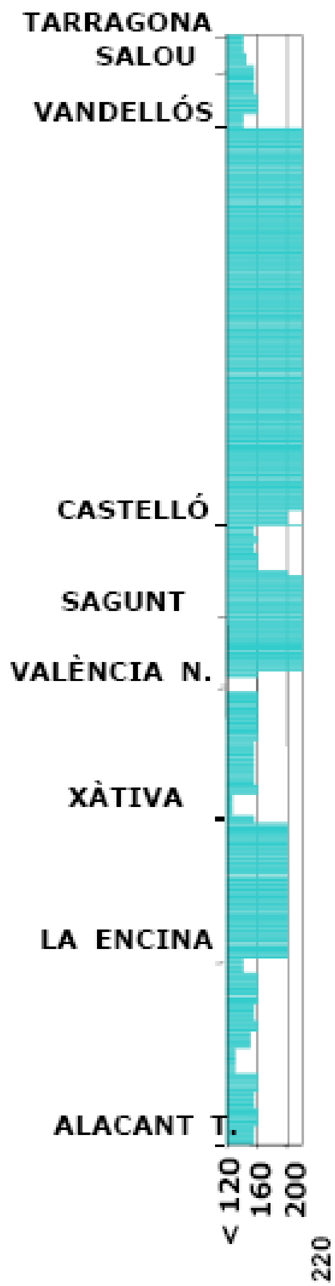
of Maximum Speed

197 Km/h



207 km
1h 16 minutes
Average Speed
163 km/h

73 km
35 minutes
Average Speed
126 km/h



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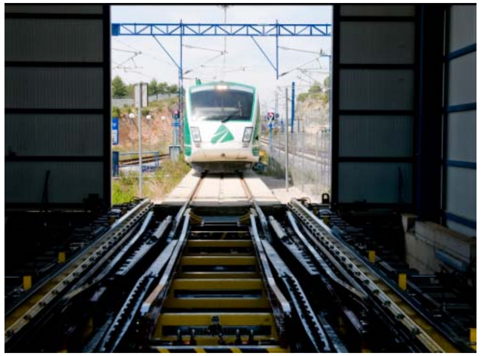
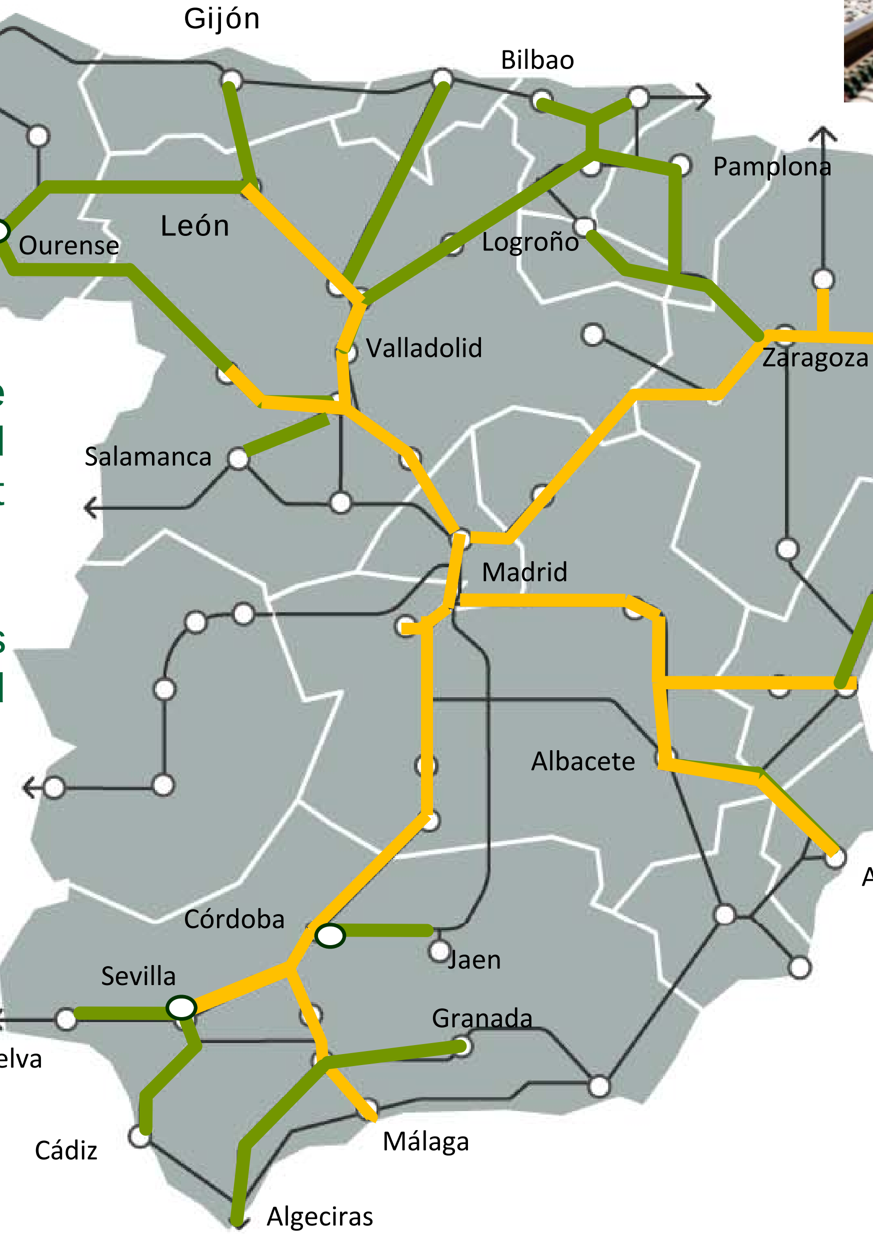


Interoperability. Gauge exchangers



- Automatic axle gauge exchangers for Standard and Spanish gauge performed at 20 km/h
- Technology of three rails track for Spanish and Standard gauge

High Speed Lines

Conventional Lines & HSL Ourense – A Coruña

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ADIF, a clear and robust framework to support environmental and energy savings goals

- **BUSINESS PLAN 2012-2016**
    - Protecting Environment

- **ENVIRONMENTAL POLICY** (ADIF's Chairman, June 2015)

- **PLAN FOR SOCIAL RESPONSIBILITY AND SUSTAINABILITY 2013-2016**

  * Good government * Economic Dimension
  * Social Dimension * Environmental Dimension

  ➢ Environmental intergration of infrastructures
  ➢ Contribution to the fight against climate change and efficient management of resources
  ➢ Compliance with environmental legislation
  ➢ Biodiversity protection

- **MASTER PLAN FOR SAVINGS AND ENERGY EFFICIENCY 2009-2014 & 2014-2020**

- **CERTIFIED MANAGEMENT SYSTEMS ISO 14001: OBJECTIVES AND GOALS FOR CONTINUOUS IMPROVEMENT**

Política de Medio Ambiente de Adif y Adif Alta Velocidad

Junio 2015

La planificación de las actividades de Adif y Adif Alta Velocidad consideran los conceptos de gestión sostenible, eficiencia y seguridad, que garantizan una adecuada gestión de los recursos y una protección ambiental.

Como expectativas de los grupos de interés, se identifica la gestión responsable de los recursos que se traduce en proyectos que aportan valor y bienestar a la sociedad.

Las directrices sobre la gestión y coordinación de actividades ambientales fija las responsabilidades y responsables de los procesos ambientales en Adif y Adif Alta Velocidad, aprovechando las sinergias entre diferentes áreas, con objeto de minimizar los posibles riesgos ambientales.

Dada la existencia desde el 31 de diciembre de 2013 de dos entidades, Adif y Adif-AV, se hace necesario actualizar y regular las funciones de ambas en el desarrollo de las actividades ambientales. Ello se plasma en la Adenda al Convenio de encomienda de gestión suscrito por el Administrador de Infraestructuras Ferroviarias (Adif) y Adif Alta Velocidad el 31 de enero de 2014 para la encomienda a Adif Alta Velocidad de la gestión integral ambiental y la gestión integral de la supervisión, del soporte técnico y de los servicios a obra, en cuyo objeto se encuentra la prestación por Adif Alta Velocidad a Adif del servicio de gestión integral medioambiental.

En base a todo lo expuesto, Adif y Adif Alta Velocidad asumen para su gestión ambiental, los siguientes compromisos en su POLÍTICA DE MEDIO AMBIENTE:

1. Impulsar compromisos para la mejora del desempeño ambiental sobre la base de la implantación, auditoría y certificación periódica de sus criterios ambientales, basados en la norma ISO 14001.
2. Asegurar que siempre se actúa de conformidad con las obligaciones de cumplimiento legal así como otros requisitos de aplicación, y en colaboración con los Organismos oficiales encargados de su supervisión.
3. Lograr la integración ambiental del ferrocarril manteniendo el máximo respeto hacia los espacios naturales y el patrimonio arqueológico, preservando todos sus valores y recuperando aquellos entornos que se hayan podido ver afectados.
4. Requerir de las empresas filiales, contratistas y proveedores idéntico compromiso ambiental, mediante la suscripción de los documentos contractuales correspondientes.
5. Definir procedimientos internos que garanticen la protección del medio ambiente y la prevención de la contaminación durante todas las fases del ciclo de vida, con atribución precisa de las responsabilidades así como de las herramientas internas para su control y seguimiento.
6. Desarrollar planes de disminución del consumo energético y las emisiones de CO_2, tanto en la construcción, como en el mantenimiento y la explotación de infraestructuras e instalaciones ferroviarias.
7. Racionalizar el consumo de agua así como la generación de residuos y de aguas residuales, minimizar la afección a los suelos así como recuperar aquellos que hayan sido contaminados y adoptar todas las medidas técnica y económicamente viables con el fin de reducir el impacto por ruido y vibraciones en las fases de diseño, construcción y explotación de infraestructuras e instalaciones ferroviarias.
8. Determinar el riesgo ambiental asociado con amenazas y oportunidades, así como considerar el factor ambiental en las estrategias empresariales.
9. Implantar programas específicos de formación y sensibilización ambiental para el personal operativo, técnico y directivo de todas las unidades organizativas de Adif y Adif Alta Velocidad.
10. Promover el compromiso con el medio ambiente desde la Alta Dirección. Proveer los recursos humanos, económicos y materiales necesarios para garantizar el cumplimiento de estos compromisos y comunicar pública y periódicamente los resultados de su aplicación en aras de la transparencia.

Los principios de la Política de Medio Ambiente configuran el marco en el que se establecen los objetivos y metas de Adif y Adif Alta Velocidad con el fin de contribuir a la mejora ambiental y al logro de la sostenibilidad del sistema ferroviario.

adif ALTA VELOCIDAD adif

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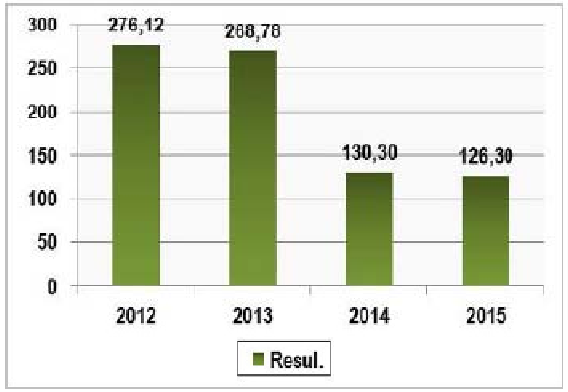
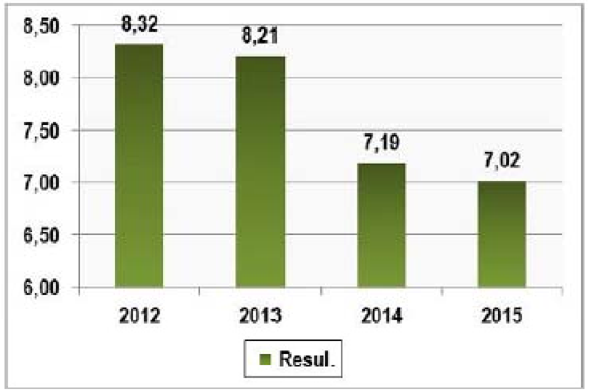
RESULTS ON OUR OWN ACTIVITIES AS INFRASTRUCTUR MANAGER

Electric energy consumption (Million kWh/year)



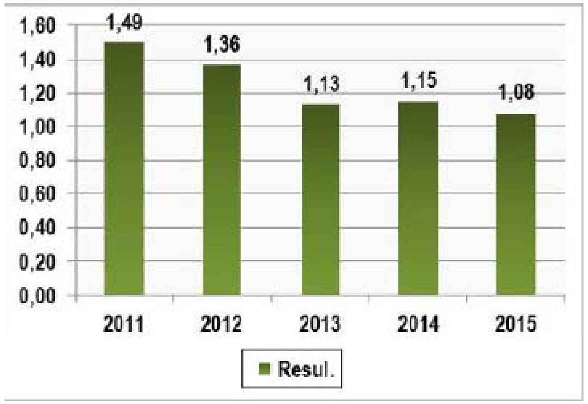
8b2. Consumo de Energía Eléctrica en las actividades propias (Mill. KWh/año)

Fuel consumption (Million l/year)



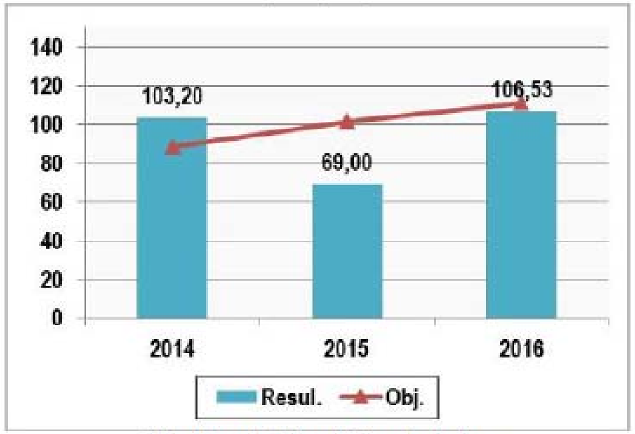
8b3. Consumo de Gasóleo en las actividades propias (Mill. l/año)

Water consumption (Million m³)



8b1. Consumo de agua en las actividades propias de Adif (Mill. de m3)

Total Savings on GWh equivalent



8b5. Ahorro total en GWh equivalentes

Total Savings on CO_2 tons

8b6. Ahorro total en toneladas de CO2

Energy efficiency. Total Saving (Million €)

9b7. Eficiencia energética. Ahorro total (Mill. de €)

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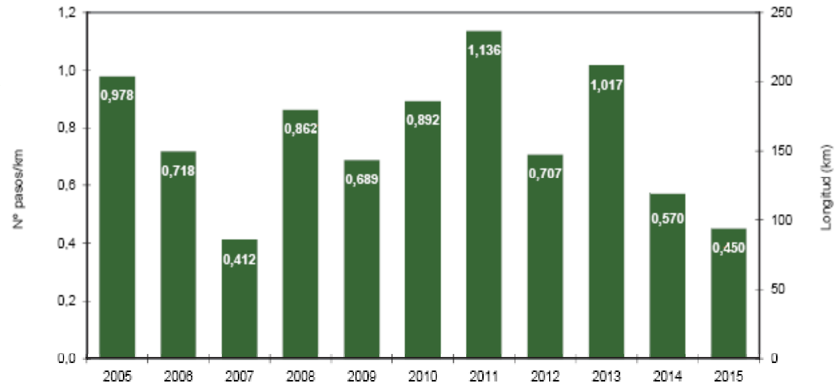
WORK SITES: KEY PERFORMANCE INDICATORS AND ENVIRONMENTAL OBJECTIVES

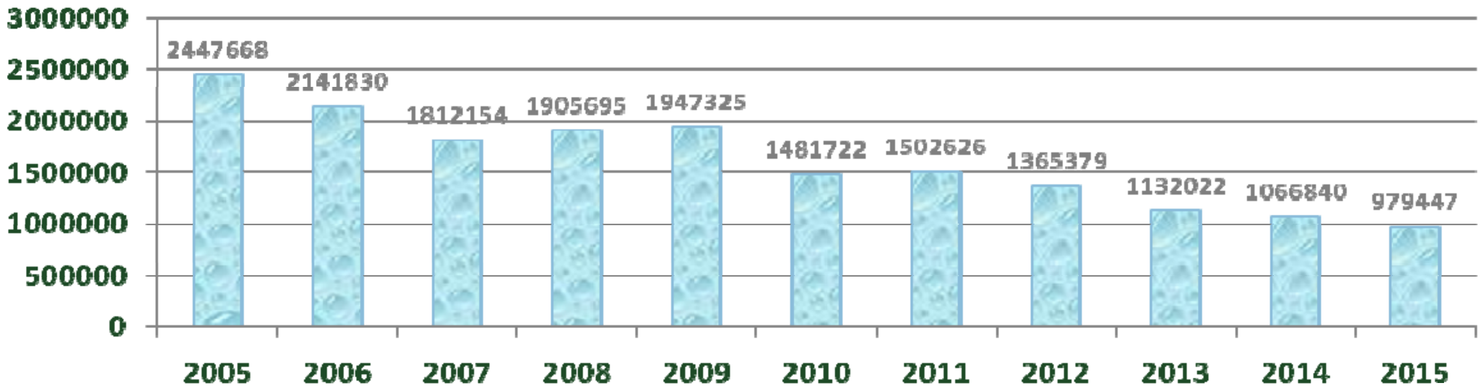
OBJECTIVE

1 MINIMIZE THE SURFACE OCCUPED
2 PRESERVE AREAS OF NATURAL INTEREST
3 PRESERVE CULTURAL HERITAGE
4 PRESERVE SOILS
5 PRESERVE FLUVIAL SYSTEM AND VEGETATION
6 PREVENT POLLUTION
7 PRESERVE FAUNE
8 RESTORATION OF NATURAL ENVIRONMENT WIHT ECOLOGICAL AND LANDSCAPING APPROACH



Permeability of the infrastructure to the passage of ungulate fauna (nº crossings / km)

2 EXAMPLES



Water consumption (m³)

Source: Environmental Yearly Rapport 2015 Adif &Adif AV

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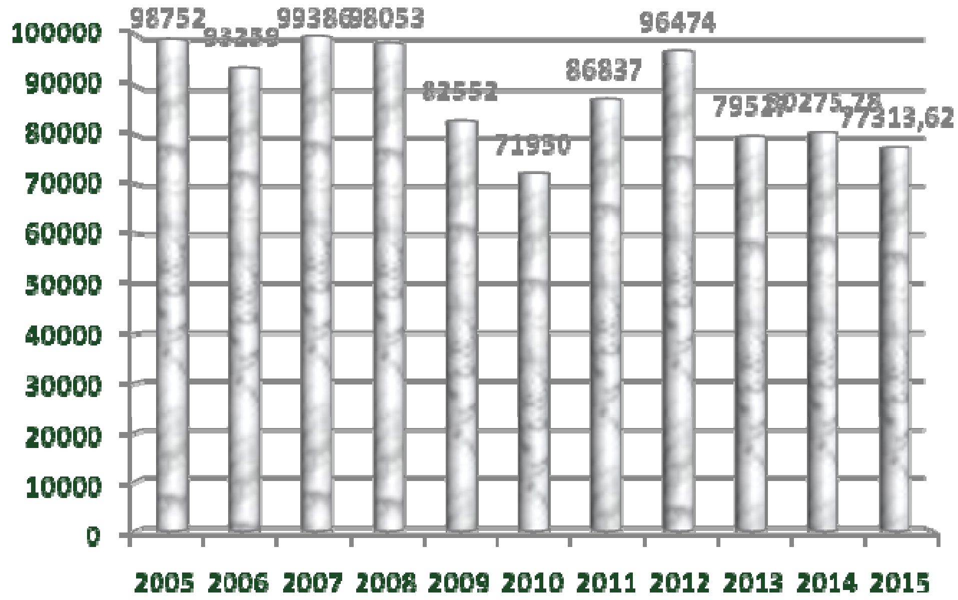
GLOBAL ENVIRONMENTAL RESULTS

GREENHOUSE GAZ EMISSIONS BY OWN ACTIVITIES

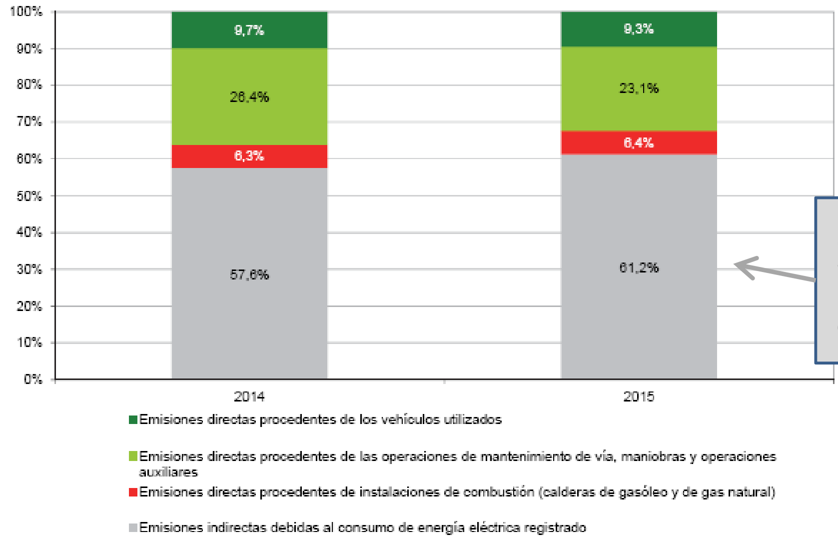


Unit: ton of CO_2-equivalent

Source:
Environmental Yearly Rapport 2015 Adif &Adif AV

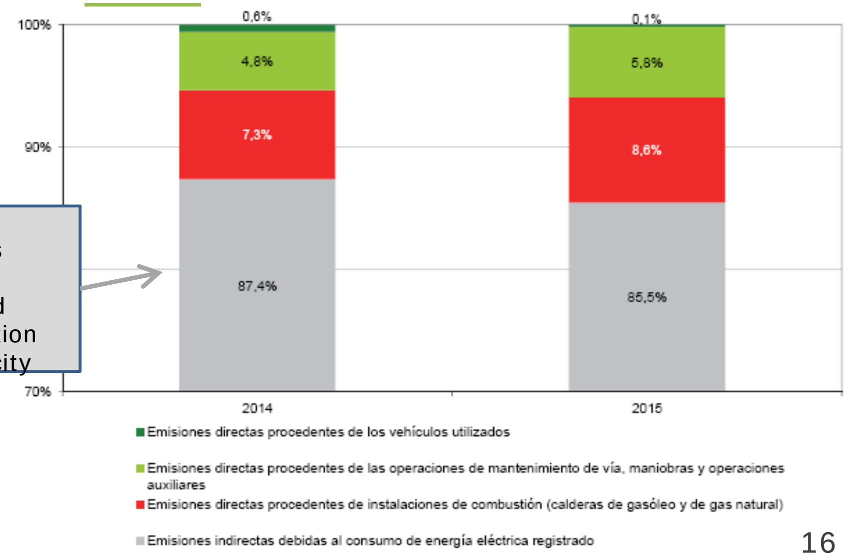
Contribition from different sources to Greenhouse Gaz Effect (on %)

Adif



Indirect emissions from registered consumption of electricity

Adif AV



MASTER PLANS FOR SAVINGS AND ENERGY EFFICIENCY
2009-2014 2014-2020

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ROLE & WEIGHT OF ELECTRICITY

ADIF

TOTAL 100 %

- TRACTION 93,15 % (93,15 %)
  - ELECTRICITY 67,40 % (67,40 %)
  - FUEL DIESEL 25,75 %
- UDT 6,85 %
  - ADIF HS 2,82 %
  - ADIF 4,03 %

ELECTRICITY (67,40 %)	
ADIF H.S.	0,00 %
ADIF	0,28 %
RENFE-OP.	66,24 %
OTHER RAIL CO.	0,88 %

66,24 %

FUEL DIESEL (25,75 %)	
ADIF H.S.	0,16 %
ADIF	1,25 %
RENFE-OP.	21,62 %
OTHER RAIL CO.	2,71 %

ADIF HS (2,82 %)	
ELECTRICITY	2,50 %
COMB.AUTOM.	0,02 %
COMB.HEATING	0,02 %
GAS	0,27 %

ADIF (4,03 %)	
ELECTRICITY	3,18 %
COMB.AUTOM.	0,50 %
COMB.HEATING	0,24 %
GAS	0,11 %

2,50 % 3,18 %

UDT: Uses Different to Traction

RU's Railway Undertakings: RENFE-OP & Other Railway Co

89% of total RENFE´s rail transport is made by electricity

Acting over three Axes

- **MANAGEMENT MEASURES** — **34 actions**
- **TECHNICAL MEASURES**
- **RENEWABLE ENERGY GENERATION SYSTEMS** — **49 actions**

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Until July 2014, we have got savings of 17% for UDT energy consumption on ADIF & ADIF HS

MASTER PLAN FOR SAVINGS AND ENERGY EFFICIENCY 2014-2020

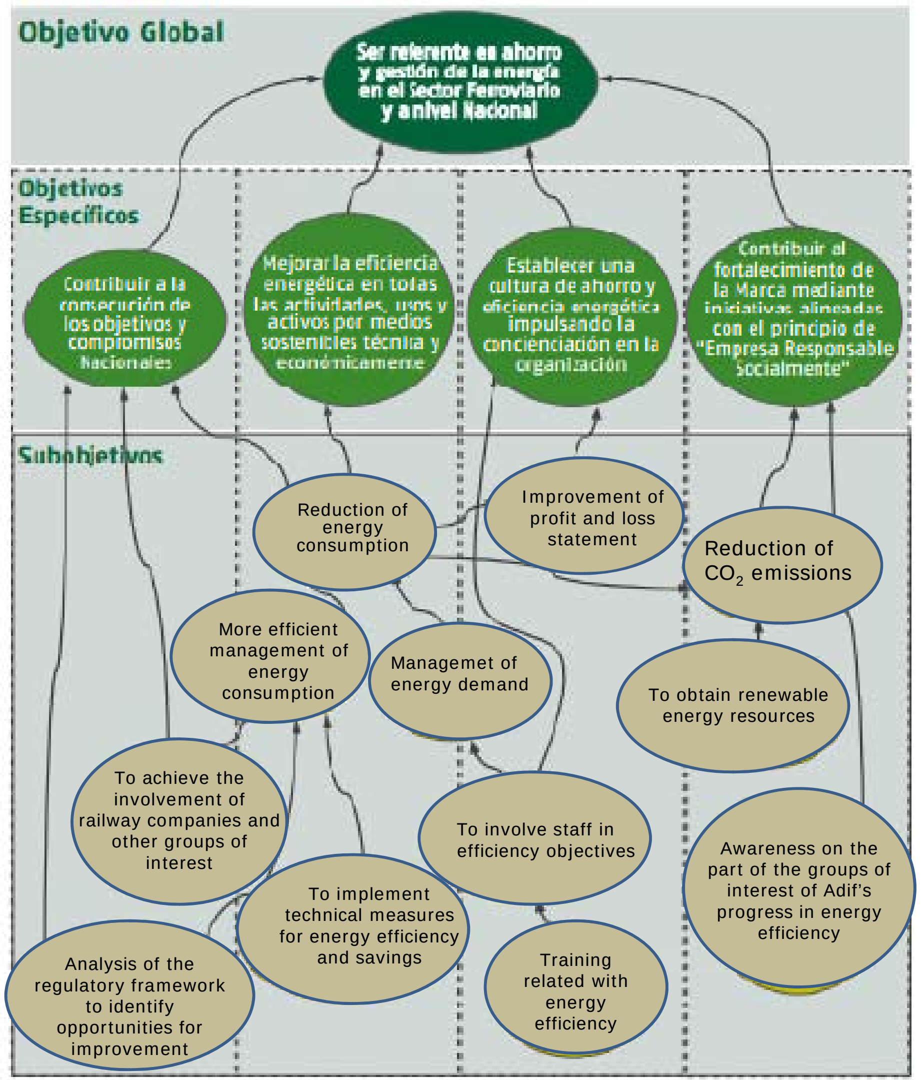
OBJECTIVES MAP

GLOBALOBJECTIVE:
To be a reference in Energy management and savings in the Rail Sector and at national level

SPECIFIC OBJECTIVES

- ✓ To contribute to the achievement of national objectives and commitments
- ✓ To improve energy efficiency in all activities, uses and assets through technical and environmentally sustainable means.
- ✓ To establish a savings and energy efficiency culture, promotings the awareness of the organisation.
- ✓ To contribute to the enhancement of the Brand through initiatives aligned with the principle: “Socially Responsible Company”.

54. Plan Director de Ahorro y Efic. Energ. 2014-2020. Mapa de Objetivos



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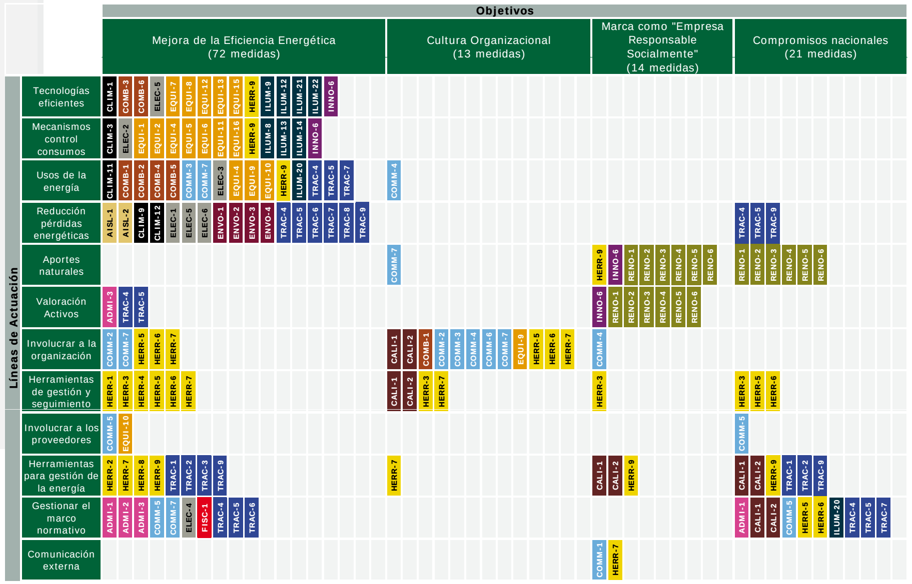
RELATIONSHIP BETWEEN OBJECTIVES (4), ACTION LINES (12), USES AND MANAGEMENT AREAS (15)

Objectives, lines of action, uses and management scope relation

Objectives	Lines	Uses and management areas
Improve energy efficiency in all **ADIF** activities, uses and assets by technically and economically sustainable means	Reduce energy losses	▪Administrative
Establish a culture of energy saving and efficiency in ADIF by promoting awareness in the organization	Use more efficient technology	▪Isolation
Contribute to the Brand strenghtening through initiatives aligned with the principle of "Socially Responsible Entity" set in the Strategic Plan.	Implement control mechanisms on consumption	▪Quality
Contribute to the achievement of National goals and commitments through the implementation of activities to improve energy efficiency	modify the uses of energy	▪ Heating and Air Conditioning
	Take advantage of natural inputs	▪Fuel
	Give value to the Adif's managers	▪Communication
	Manage the regulatory framework	▪Electricity
	Promote a culture of energy saving and efficiency	▪Enclosure
	Design tools for more efficient energy management	▪Equipment
	Involve suppliers in improving energy efficiency	▪Fiscal
	Create tools for management and monitoring of measures	▪Tools
	Develop an adequate external communication	▪Lighting
		▪Innovation
		▪Traction
		▪Renewable



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MASTER PLANS: RESULTS AND MEDIUM TERM OBJECTIVES

Master Plan appraisal includes an evaluation of **cost and savings** (energy, CO_2 emisions) related to each one of the initiatives

Along the **2009-2016** period, we have got an **accumulated saving of 427,14 Gwh$_{equiv}$** (with an economical value of **30.13 Mill €**) and **88,353 t CO_2**, for an estimated cost of **10,03 Million €**

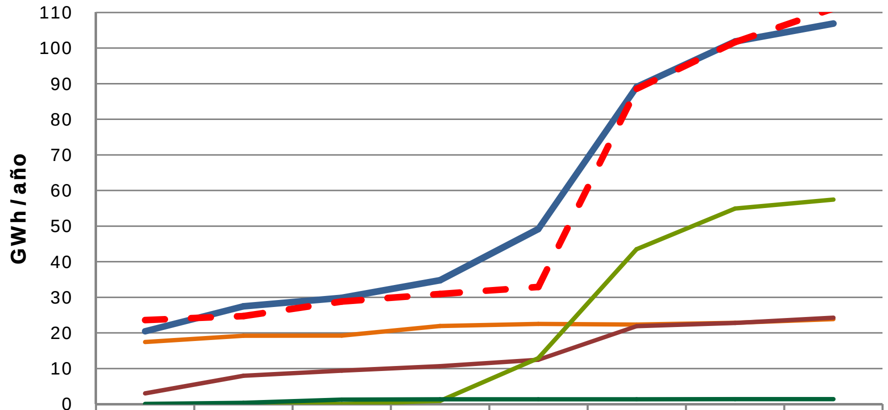
Current 2014-2020 Master Plan fixes an objective for **2020** of **163,69 Gwh$_{equiv}$** (83% higher than 2014 result) for ADIF and ADIF AV together

2016 | Accum.2009-2016

Cost	Results on Savings		
10,03 Mill €	**106,90 GWh$_{equiv.}$ / year**	**6,98 Mill € / year**	**19.183 t CO_2 / year**
10,03 Mill €	**427,14 GWh$_{equiv.}$**	**30,13 Mill €**	**88.353 t CO_2**

	2014	**2020**
Adif	25,34 Gwh$_{eq}$/año	56,88 Gwh$_{eq}$/año
Adif AV	63,78 Gwh$_{eq}$/año	106,81 Gwh$_{eq}$/año

ADIF A.V + ADIF 2016



	2009	2010	2011	2012	2013	2014	2015	2016
Gestión	17,42	19,17	19,23	21,90	22,52	22,34	22,82	23,86
Medidas Téc.	3,00	7,92	9,39	10,65	12,43	21,90	22,77	24,25
Tracción	0,00	0,00	0,00	0,88	12,87	43,53	54,93	57,43
Energía Renov.	0,01	0,34	1,24	1,33	1,35	1,35	1,36	1,36
TOTALES	20,43	27,44	29,86	34,76	49,17	89,12	101,88	106,90
Objetivos	23,60	24,70	28,80	30,90	32,90	88,58	101,70	111,15

SOME EXAMPLES OF FLYERS / ACTIONS RELATED WITH TRACTION

DESARROLLAR MECANISMOS PARA LA MEDICIÓN Y FACTURACIÓN DE LOS CONSUMOS DE ENERGÍA ELÉCTRICA DE TRACCIÓN — TRAC-1 — GESTIÓN

METERING AND BILLING TOOLS FOR TRACTION ENERGY CONSUMPTION

DESARROLLAR HERRAMIENTAS PARA FACILITAR LA CONDUCCIÓN EFICIENTE — TRAC-2 — GESTIÓN

TOOLS FOR EFFICIENT DRIVING

PROYECTOS "FERROSMARTGRID" y "MERLIN" — INNO-6

APPLICATION OF INTELLIGENT ELECTRIC NETWORK CONCEPT TO RAIL ELECTRICAL NETWORKS

DISEÑO Y CONSTRUCCIÓN DE SUBESTACIONES EVOLUTIVAS — TRAC-7

DESIGN AND CONSTRUCTION OF EVOLUTIVE SUBSTATIONS

RECUPERACIÓN DE ENERGÍA DE FRENADO REGENERATIVO EN LA RED CONVENCIONAL — TRAC-4

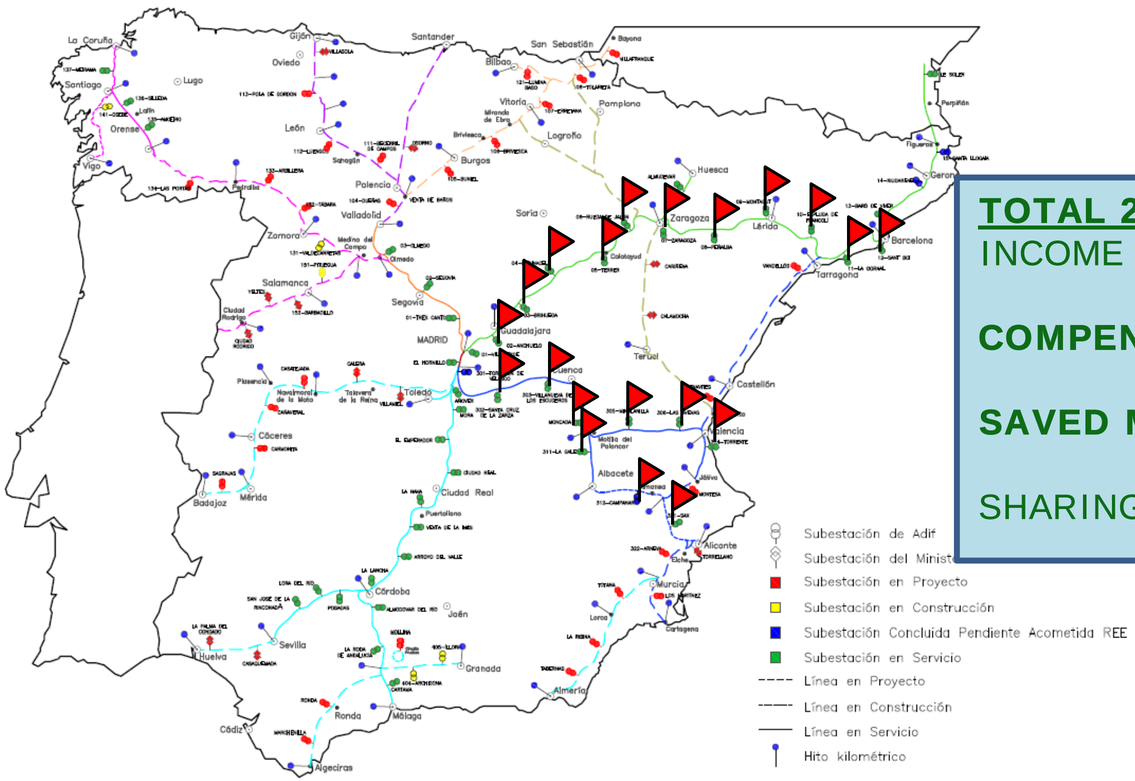
RECUPERATION OF REGENERATIVE BRAKING ENERGY ON CONVENTIONAL DC NETWORK

A main program

Recuperation of Braking Energy on HIGH SPEED LINES and Neting to High Voltage public grid (TRAC-5).

HSL Madrid-Levante: 9 substations with an stimated energy saving of 11 GWh/year
2016: 19,123 trains/year 7.2M tr-km/year Income Energy: 159.2 GWh/year Recovered: 5.55%

HSL Madrid-Barcelona-Frontera Francesa: 11 substations with an stimated energy saving of 33 GWh/year
2016: 66,828 trains/year 18.2M tr-km/year Income Energy: 381.3 GWh/year Recovered: 8.87%



TOTAL 2013-2016
INCOME ENERGY 1,334 GWh
COST 87.1 Million €
COMPENSATED ENERGY
105 GWh 7.86%
SAVED MONEY 7.2 Million €
7.89%
SHARING: 50%ADIF 50%RENFE

POTENTIAL YEARLY SAVINGS ON THE WHOLE HS NETWORK
2,590km 677 trains/day 1,056 GWh **SAVINGS 73.56 GWh 6.9% 4.5 Million €**

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THE ESSENTIAL ROLE OF RAILWAY UNDERTAKINGS
ADIF ⟺ RENFE COLLABORATION IN SPAIN

MAIN ACTIONS, PROGRAMS AND PROJECTS ON ENERGY EFFICIENCY ➡ BY RENFE

- **Increasing load factor in the latest period linked to new HS services**
- **New rolling stock with energy efficiency criteria**
- Eco-driving included in training programs
- **Energy recovery actions: billing in AC substations since 2013** and extending reversibility to DC substations
- Project for efficiency with integrated approach: **Metering** + **Efficient ATO** + **Switch off** of parked trains
- Pilot trains powered by Liquefied natural gas and Hydrogen cells (Innovation projects)

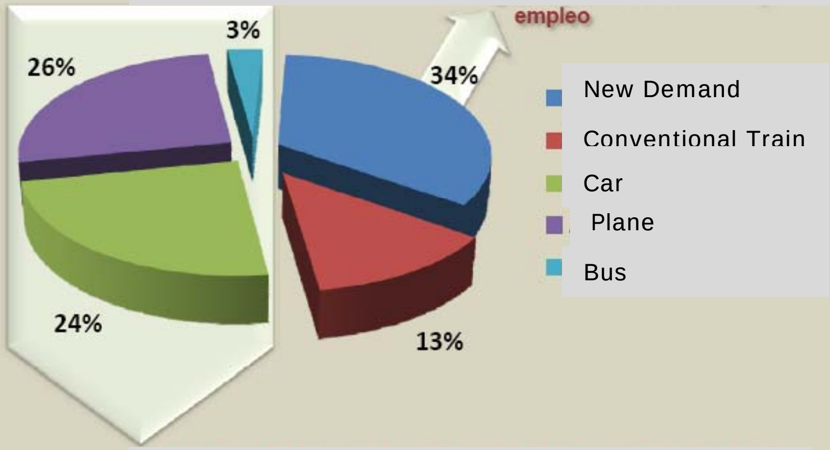
RENFE Serie 730 trains
Electric AC DC – Diesel
Double gauge 1668-1435 mm

➢ Increasing load factor

HS generates Growth and employment year

HS Madrid - Sevilla: Success from 1992, the first explotation

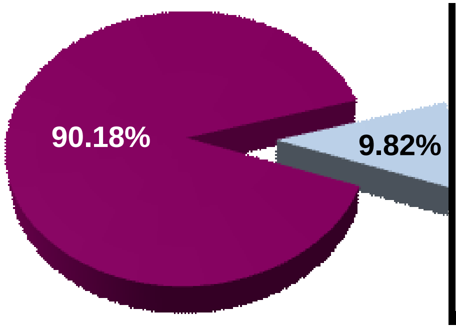
34% new demand induced by Hig Speed



HS transfer passengers from other transport modes less respectful with environment

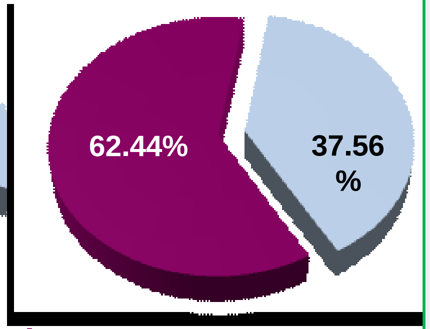
Madrid - Sevilla

■ TRAIN ■ PLANE



Madrid-Barcelona

■ TRAIN ■ PLANE



2014: 72.17% occupation 86.29%

Market share Madrid-Sevilla HS 90,2% in 2015

➢ **FROM 1992 (25 YEARS)** HS SERVICES IN SPAIN HAVE TRANSPORTED 358 MILLION PASSENGERS (90 M OF THEM ON VARIABLE GAUGE TRAINS) SAVING:

12,9 MILLION TONNES OF CO_2

2,6 MILLION TON EQUIVAL. FUEL

4,29 Billion EUR (total investments 51,76 B EUR)

➢ HS TRAINS IN SPAIN HAVE **29% LESS ENERGY** CONSUMPTION BY PASSENGER THAN CONVENTIONAL TRAINS

➢ HS TRAINS IN SPAIN AVOID **3kg CO_2 EMISSIONS** FOR EACH PASSENGER COMING **FROM CONVENTIONAL TRAINS** AND **31kg CO_2 FROM CAR AND PLANE** AS A MEAN VALUE

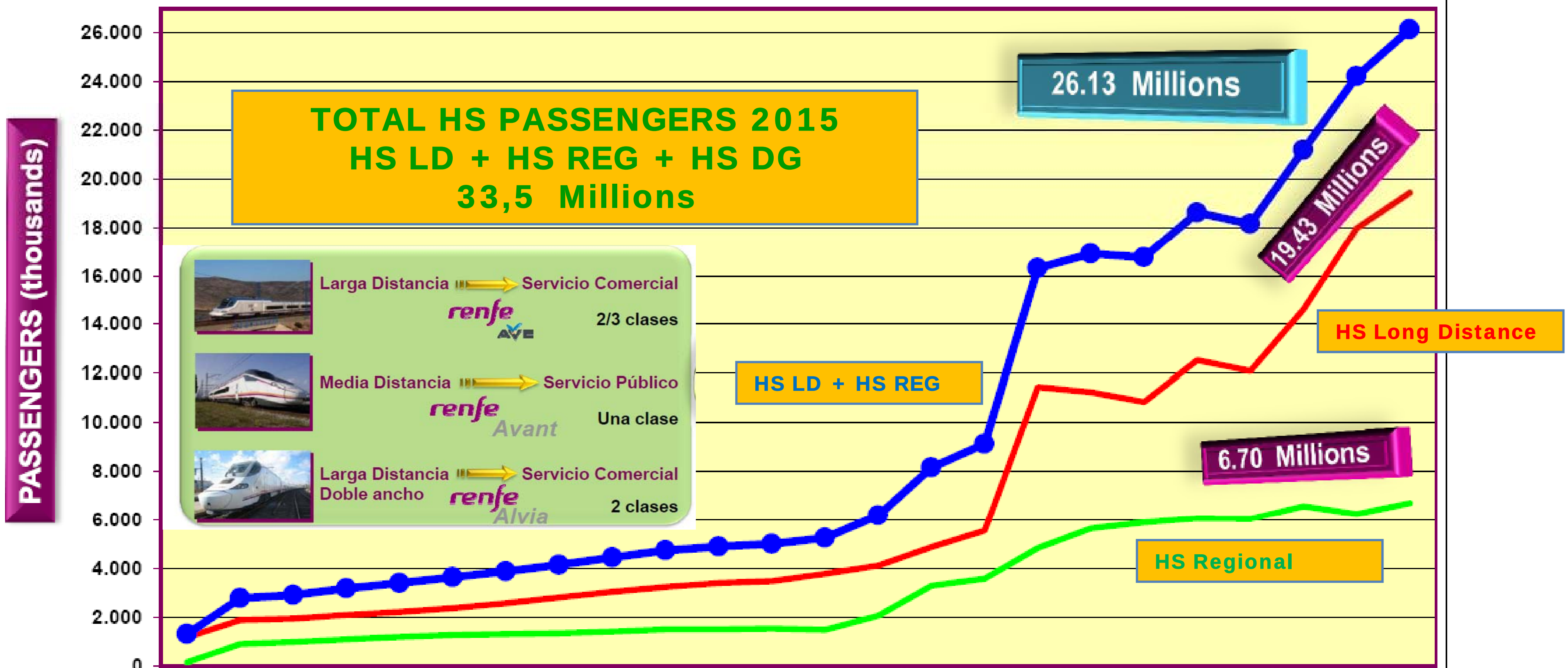
➢ RENFE'S **CARBON FOOTPATH** 24.2gr CO_2 / Unit Transport (56% less than 1990 figure)

Source: FFE / Transportation Research Record Review 2010

Evolution of High Speed traffic

Double Gauge trains add 7.4 Millions passengers in 2015

Growth higher than 23% in 2015



	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
HS L. Distance	1.176	1.875	1.936	2.087	2.207	2.369	2.568	2.805	3.036	3.236	3.394	3.479	3.783	4.120	4.878	5.559	11.461	11.250	10.851	12.536	12.101	14.616	17.968	19.428
HS Regional	135	903	977	1.088	1.189	1.270	1.306	1.342	1.412	1.504	1.504	1.534	1.480	2.063	3.289	3.576	4.841	5.652	5.902	6.070	6.044	6.564	6.248	6.699
TOTAL	1.311	2.778	2.913	3.175	3.396	3.639	3.874	4.147	4.448	4.740	4.898	5.013	5.263	6.183	8.167	9.135	16.302	16.902	16.753	18.606	18.145	21.180	24.216	26.127
Increase		111,9%	4,9%	9,0%	7,0%	7,2%	6,5%	7,0%	7,3%	6,6%	3,3%	2,3%	5,0%	17,5%	32,1%	11,9%	78,5%	3,7%	-0,9%	11,1%	-2,5%	13,8%	33,5%	23,4%

SOURCE: RENFE

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The Madrid-Zaragoza- Barcelona corridor, with more than 7.2M passengers, saved 135,1 M € of external costs in 2011

Fuente: RENFE

76.6 M€ on climate change

6.6 M€ on air pollution

46.4 M€ on accidents

5.5 M€ on other effects (urban effects on landscape and nature, land occupation and fragmentation and other effects)

And 152 M€ on travel times reduction by year

Rail reduces external costs

Distribution of time reduction because of Shift from other modes (Total traffic)
Total hours saved: 8.412 M hours/year

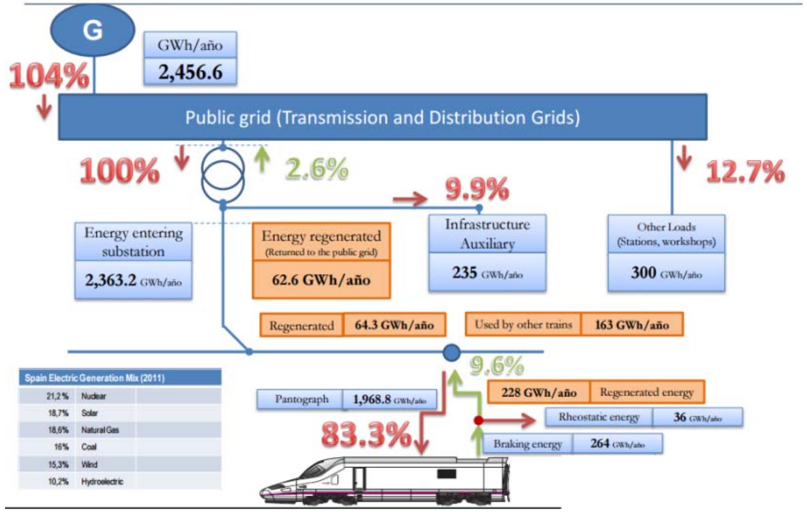
Regenerative Braking

- ✓ Available for **95% of RENFE vehicles**
- ✓ **ADIF – RENFE** have signed a contract to bill the electricity recovered during braking process in some High-Speed lines **with AC** (around **6-9% of the total traction** usage).
- ✓ New project aims to extend the reversible procedure to **DC in commuting metropolitan services where figures might rise up to 30%.**

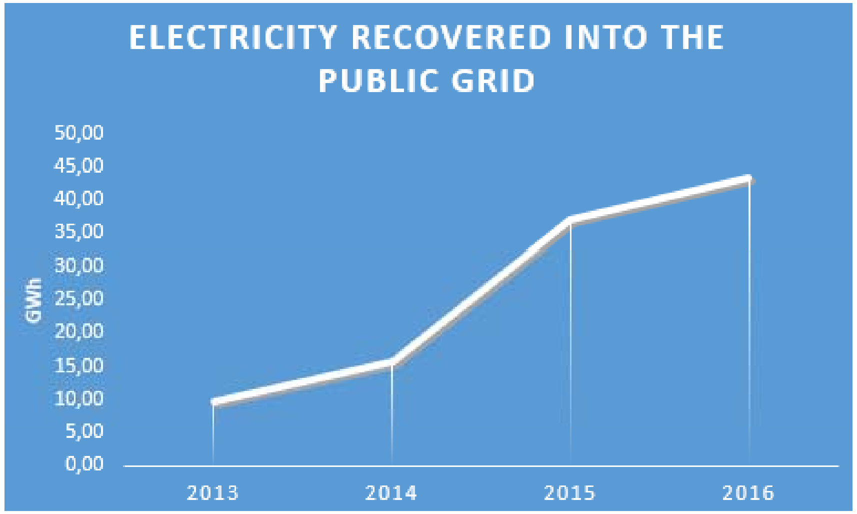
Inside EU-MERLIN project the DC reversible substation in La Comba (Málaga) was tested in 2015 and continues

2015- August 2017

TOTAL	SAVINGS	
7.13 GWh	1.95 GWh	27,3%
0.457 Million €	0.134 M€	29,3%



HS Services



➢ New rolling stock with energy efficiency criteria + Metering + Efficient ATO + Switch off of parked trains

Renfe is implementing an energy efficiency integrated Project to reduce overall consumption of traction uses

The Project includes the following actions:

- **Efficient Metering System** to replace in partnership with ADIF the current billing scheme based on Gross TKm by **billing based on real consumptions**
- **Efficient ATO** aiming fostering energy reductions of Eco-driving (average range **11-19%**, **máximum 31%)** of total energy consumption in some services and corridors
- **Switch off** auxiliary consumptions of parked trains (Eco-mode)

ADAPTED R.STOCK
100 HS Trainsets
100 Freight Locomotives

New MSAV25K-46 Sensors - GPS - Central Unit - 3GTransmission
Automatic Economy driving system (Efficient ATO): BEDS
Automatic Switch off for hotel load

NEW ROLLING STOCK

22,5 M€ / train
521 seats (103+2 1st / 416 2nd)
200 m / 12 cars (3+8+1)
-43% operation cost per pax
13.83 kWh energy consumption
30,8 kW / ton Traction power
350 km/h

- **BUT, FROM A GENERAL AND FULLY INCLUSIVE POINT OF VIEW,**
  IS HIGH SPEED A PROFITABLE DECISION?
  a very recent reflection by RENFE's General Director

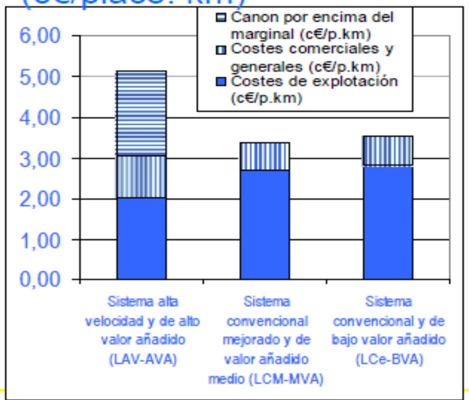
But, What about costs?

AV operating costs are lower

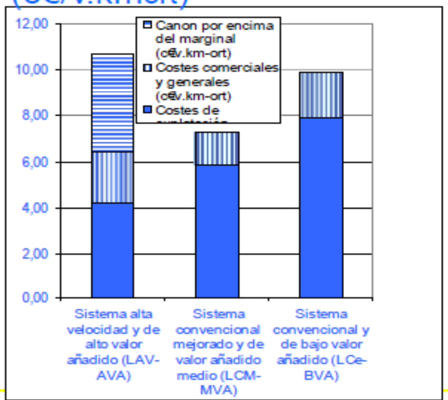
Speed not only doesn't increase operating costs, but reduces them

Attention, the costs necessary to move the train (operating c.) must be separated from the costs not related to movement.

Cost per unit bid (c€/place. km)



Cost per traffic unit (c€/v.kmort)



Alberto García Alvarez / Ciudad real/Sevilla, october 5, 2017

High Speed system financial results. Concept

Financial result (of the infra system+operation):

+ Revenue (from transport)–
- Variable operating costs (energy, material maintenance, train staff, on-board and track-side service, distribution costs,...)
- **Fixed capital costs of the operation (repayment and financial depreciation of rolling stock and the sales system)**
- Variable costs of exploiting the infra. (spreading, contact wire wear, etc.)
- **Fixed operating costs of the infrastructure (line surveillance, instantaneous safety monitoring, fixed part of the track, etc.)**
- **Fixed capital costs of the infrastructure (amortization and financial costs of the line).**

There is no clear relationship between the maintenance costs of a high-speed and a conventional line.

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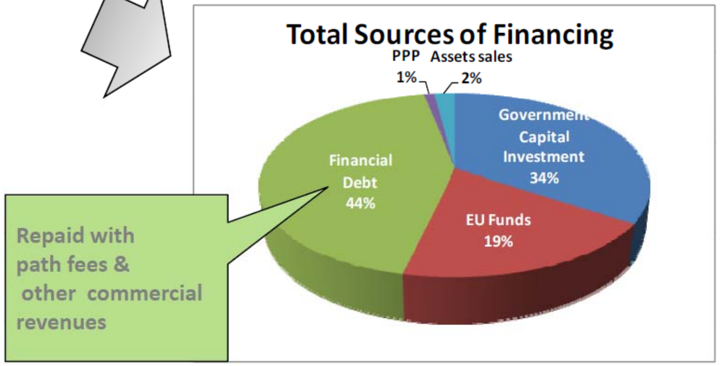

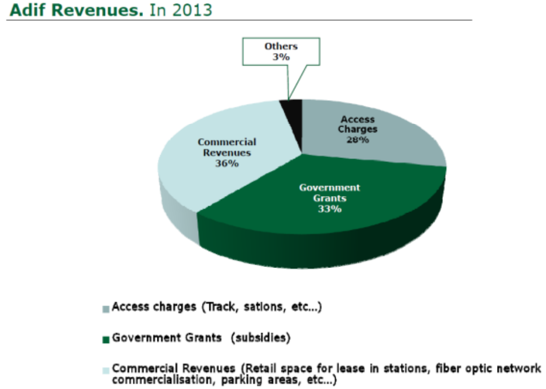

ADIF's yearly Revenues

ADIF's total sources of financing for Construction of HS Lines

High-speed lines have a positive Ebitda

Incomes, Costs and Results of Spanish Rail Network

(by Spanish National Commision on Market and Concurrence, 2014)

Tabla 4. Ingresos, costes y resultado de la RFIG (2014)

Thousand Euros	High Speed Lines	Intercity Lines	Commu-ters	Other Lines	TOTAL
Incomes from Infra Charges	432.133	21.214	48.419	4.780	506.546
Other Incomes	8.641	14.318	14.588	7.494	45.041
Total Incomes	**440.774**	**35.533**	**63.007**	**12.273**	**551.587**
Explotation expenses	- 273.300	- 260.256	- 287.555	- 142.638	- 963.748
EBITDA	167.474	- 224.723	- 224.548	- 130.365	- 412.162
Amortization	- 157.989	- 12.935	- 17.608	- 12.405	- 200.936
Financing costs	- 197.619	- 660	0	0	- 198.279
Results	- 188.133	- 238.318	- 242.155	- 142.770	- 811.377

Fuente: CNMC. Informe sobre Cánones 2015

I. ADIF references, as Infrastructure Railways Manager in Spain

II. Relevant results on Energy and Environment management

III. Energy Management technologies for High Speed

IV. Sharing Spanish experience with Indian HS projects: Simulation of Energy savings over Thane-Nasik strech *(feasibility study of New HSL Mumbai-Kolkata / phase 1: Mumbai-Nagpur)*

ENERGY MANAGEMENT TECHNOLOGIES FOR HIGH SPEED

Traction Power System (TPS) used in Spanish High Speed network

Energy consumption of High Speed trains. Case of Spain

Eco Driving

Smart Grid

New AC substation concept

Conclusions

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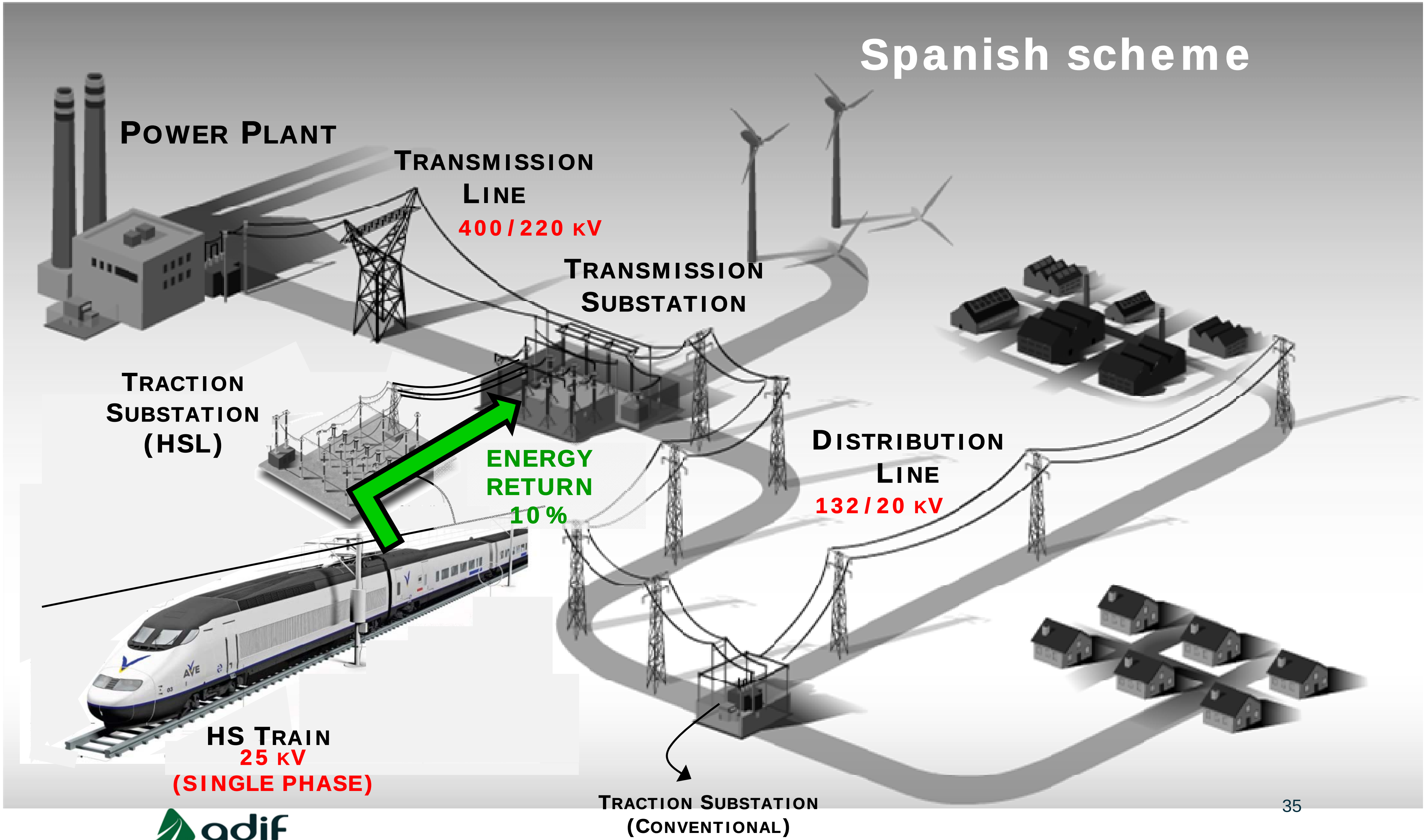
Traction Power System (TPS) used in Spanish High Speed network

Traction Power System (TPS) used in Spanish High Speed network

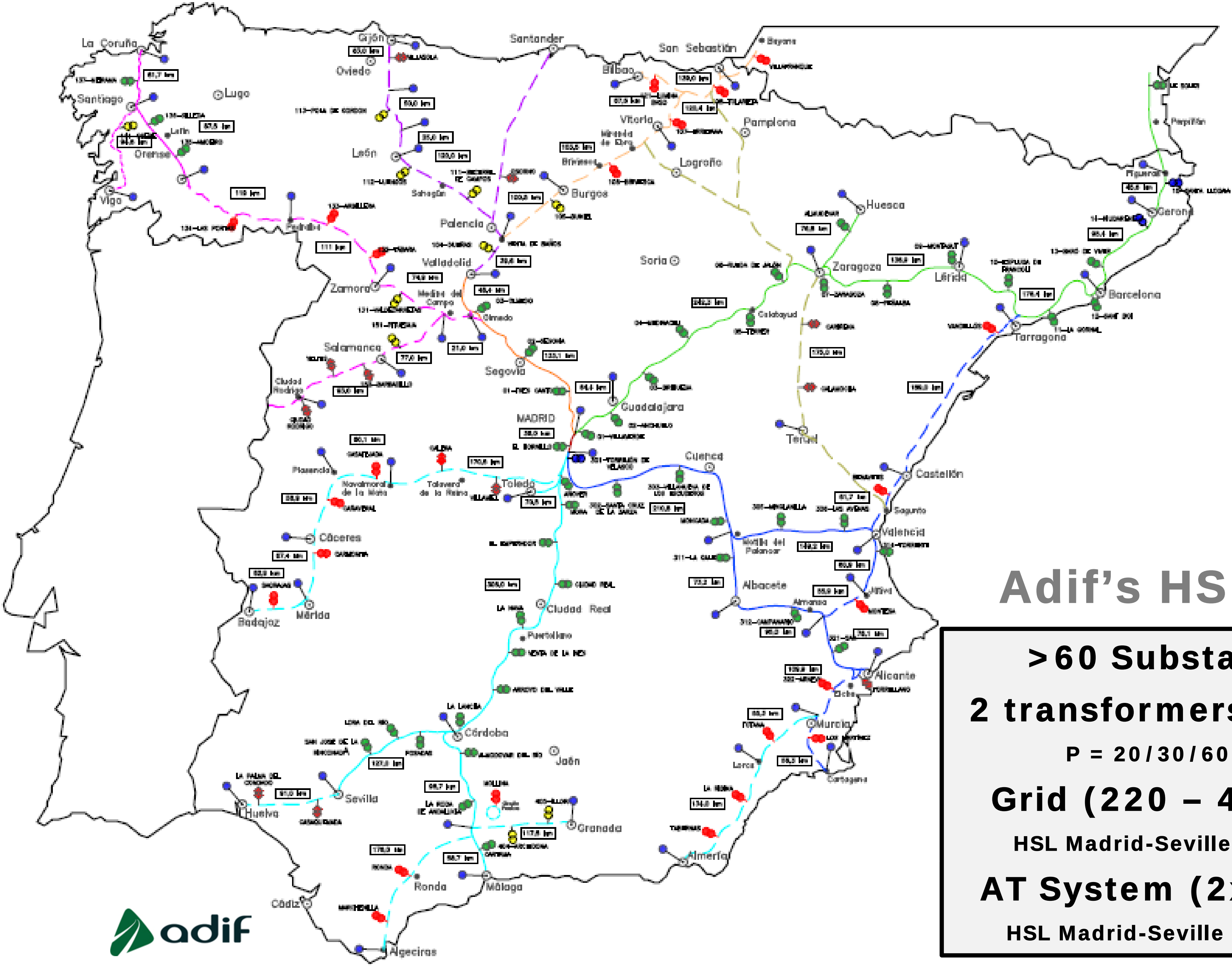
Four general characteristics:

1. **High power demanded** ⇨ Grid with high short-circuit power (In Spain: Grid = Transport Line).
2. **AC system** (single-phase): *25 kV, 50 Hz*.
3. **Very efficient system** (infrastructure & rolling stock): e.g. *Electric power regenerated*.
4. **Source of disturbances**.

Traction Power System (TPS) used in Spanish High Speed network



Traction Power System (TPS) used in Spanish High Speed network



Adif's HS TPS

>60 Substations

2 transformers (2 x P)

P = 20/30/60 MVA

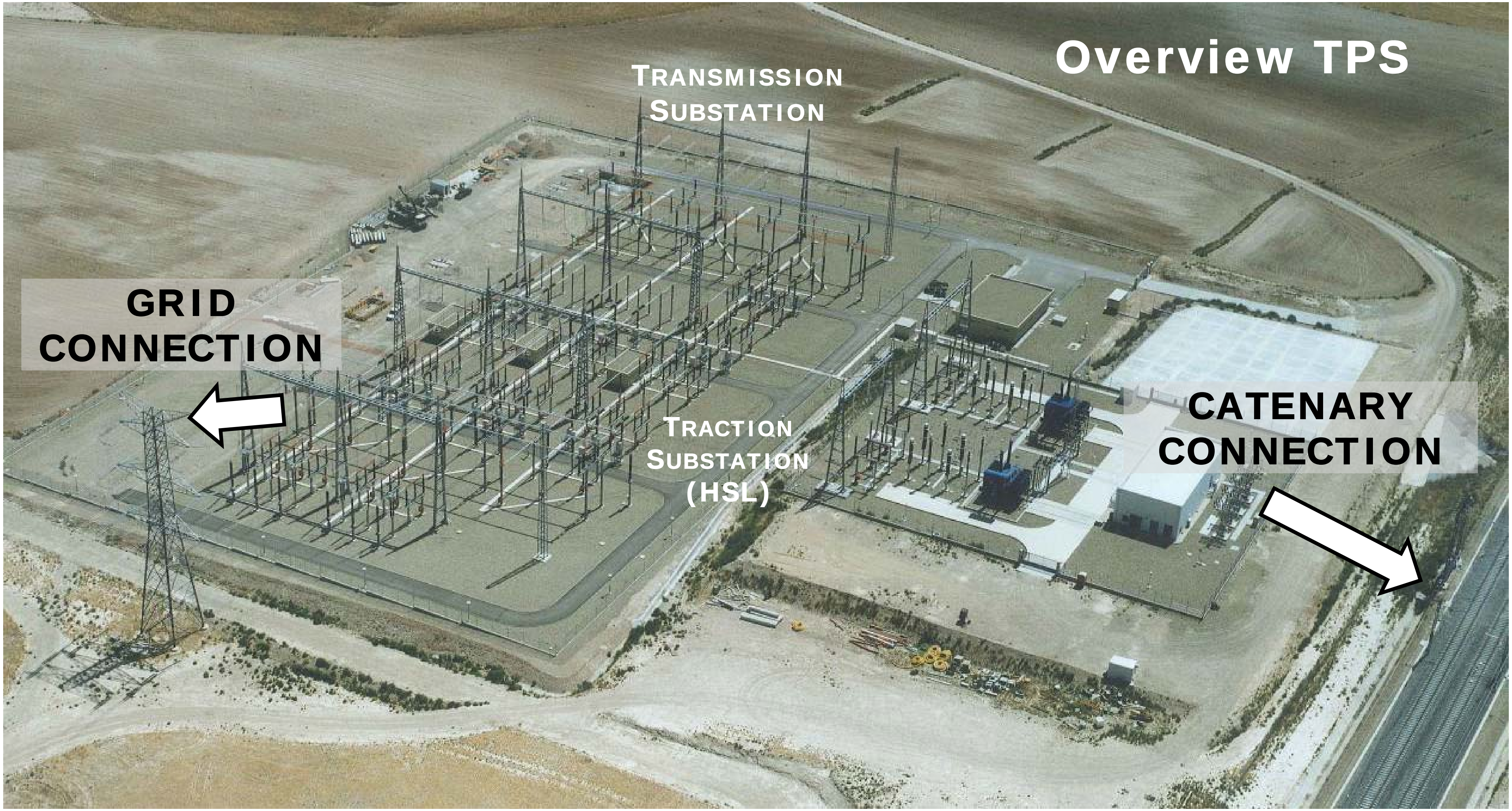
Grid (220 – 400 kV)

HSL Madrid-Seville (132 kV)

AT System (2x25 kV)

HSL Madrid-Seville (1x25 kV)

Traction Power System (TPS) used in Spanish High Speed network



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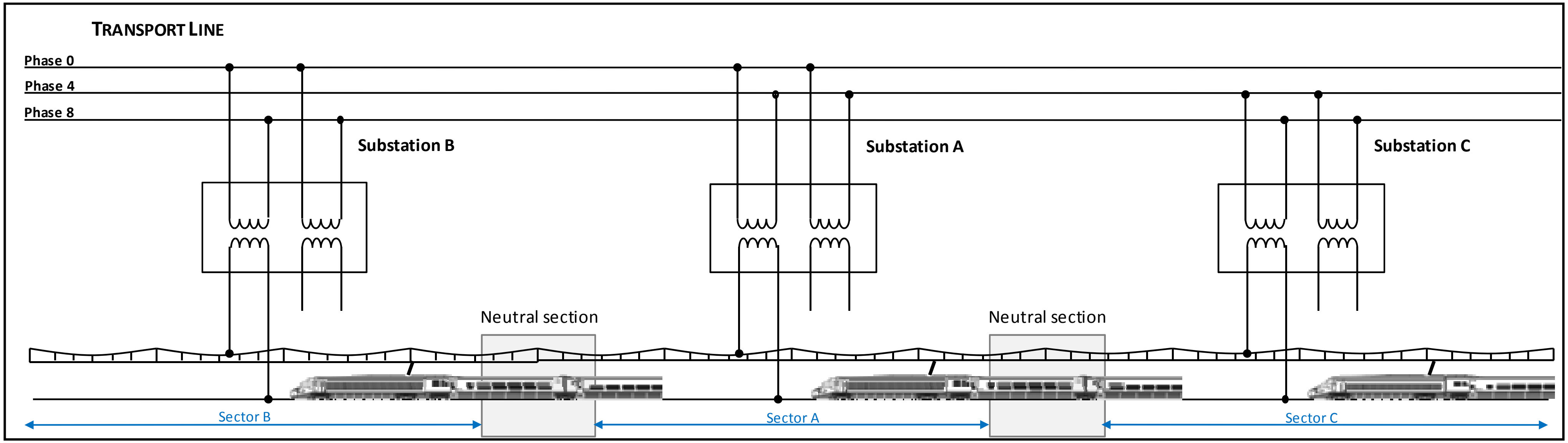
Traction Power System (TPS) used in Spanish High Speed network

GRID CONNECTION: pure single-phase connection



HSL

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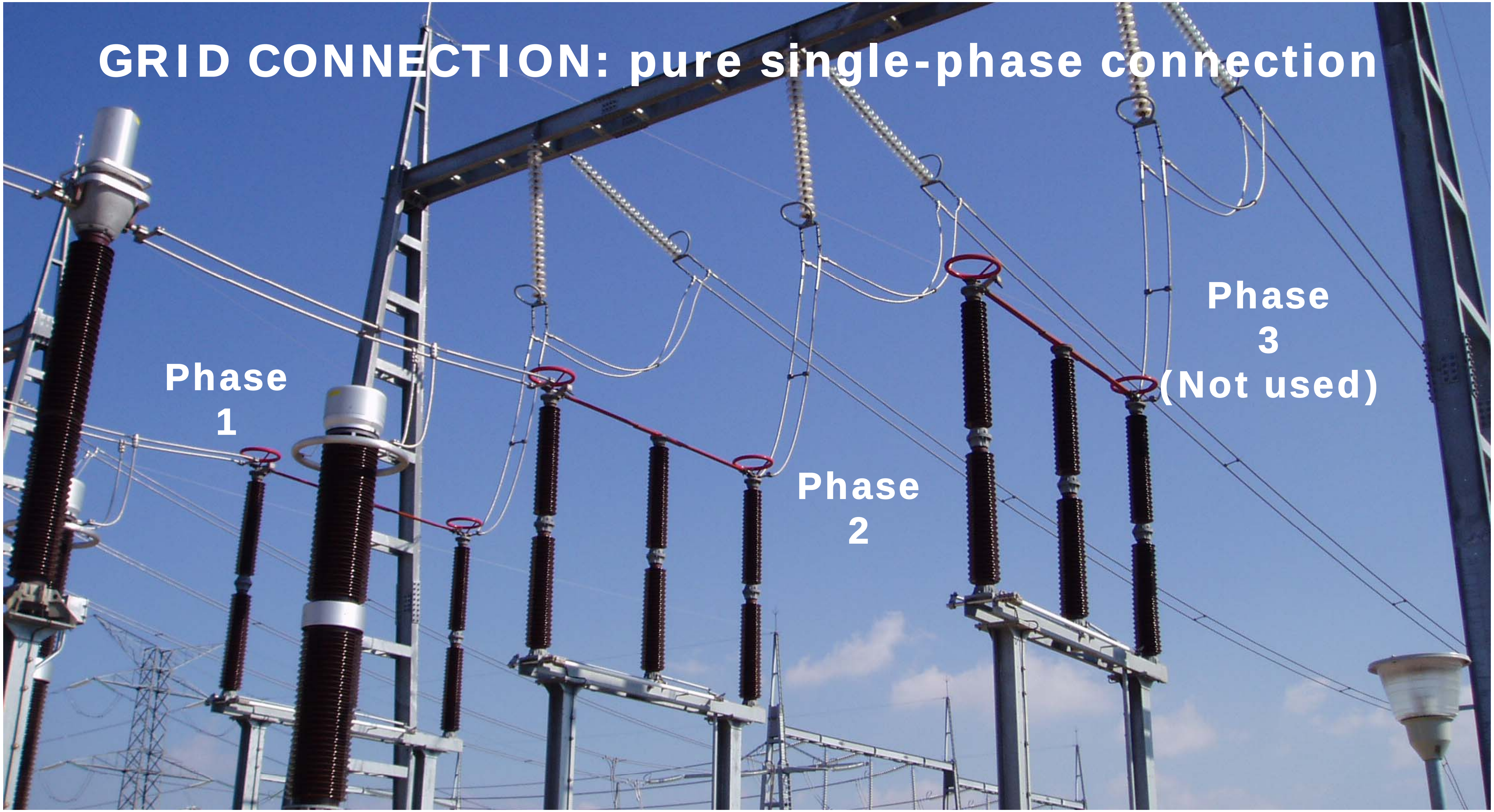
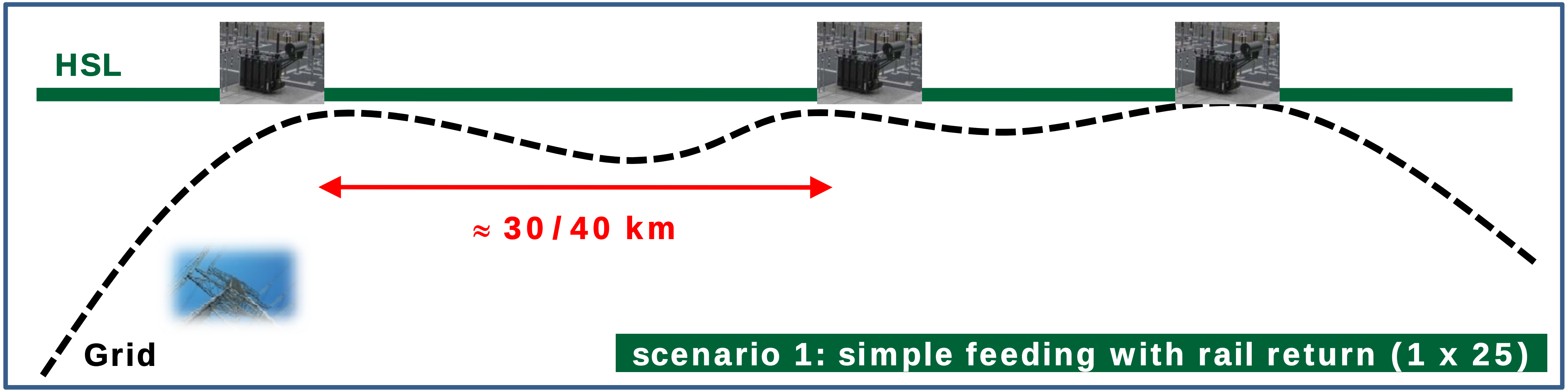
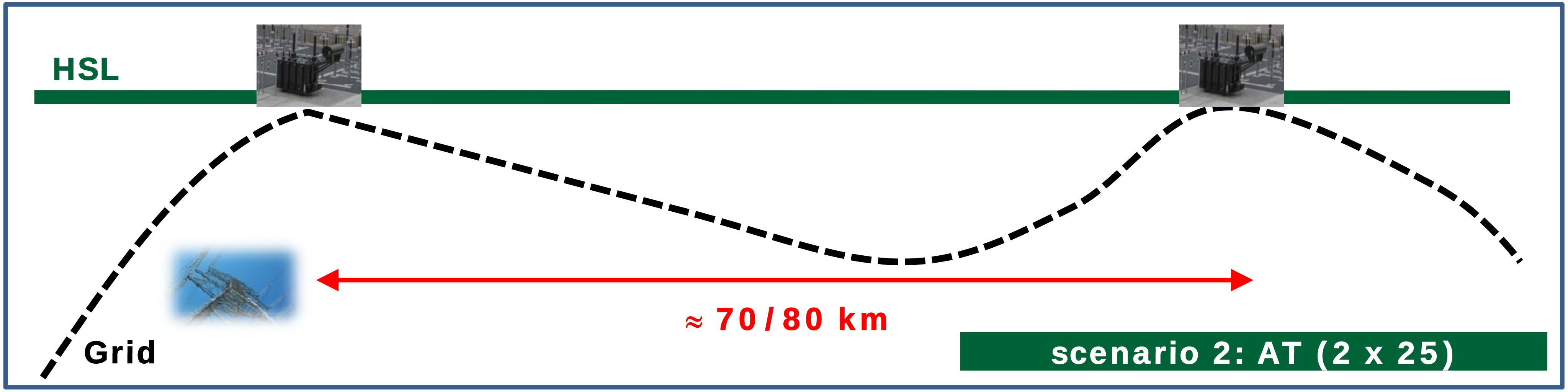
Traction Power System (TPS) used in Spanish High Speed network



Traction Power System (TPS) used in Spanish High Speed network

CATENARY CONNECTION: 1x25 kV & 2x25 kV





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Traction Power System (TPS) used in Spanish High Speed network

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Traction Power System (TPS) used in Spanish High Speed network

Traction Power System (TPS) used in Spanish High Speed network

Our approach: A sustainable TPS must optimize mainly the following three variables:

1. **Energy consumption.**
2. **Grid imbalance.**
3. **Catenary voltage.**

The incorporation of technologies (existing and new) is done analyzing these three variables

Traction Power System (TPS) used in Spanish High Speed network

Adif is developing different lines of work and technologies oriented to the efficiency of the TPS:

Energy consumption	Imbalance	Catenary voltage
• Eco Driving • Smart Grid • New AC substation concept	• New AC substation concept	• New AC substation concept

energy management & energy efficiency

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Energy consumption of High Speed trains. Case of Spain

Energy consumption of High Speed trains. Case of Spain

Total consumption of trains of electric traction in Spain *(average per year)* → **3.500 GWh**

Total consumption of electric traction trains in the Adif network *(average per year)* → **2.800 GWh**

1.600 GWh (DC network)
1.200 GWh (AC network)

→ **0,9%** of total demand in Spain

Energy consumption of High Speed trains. Case of Spain

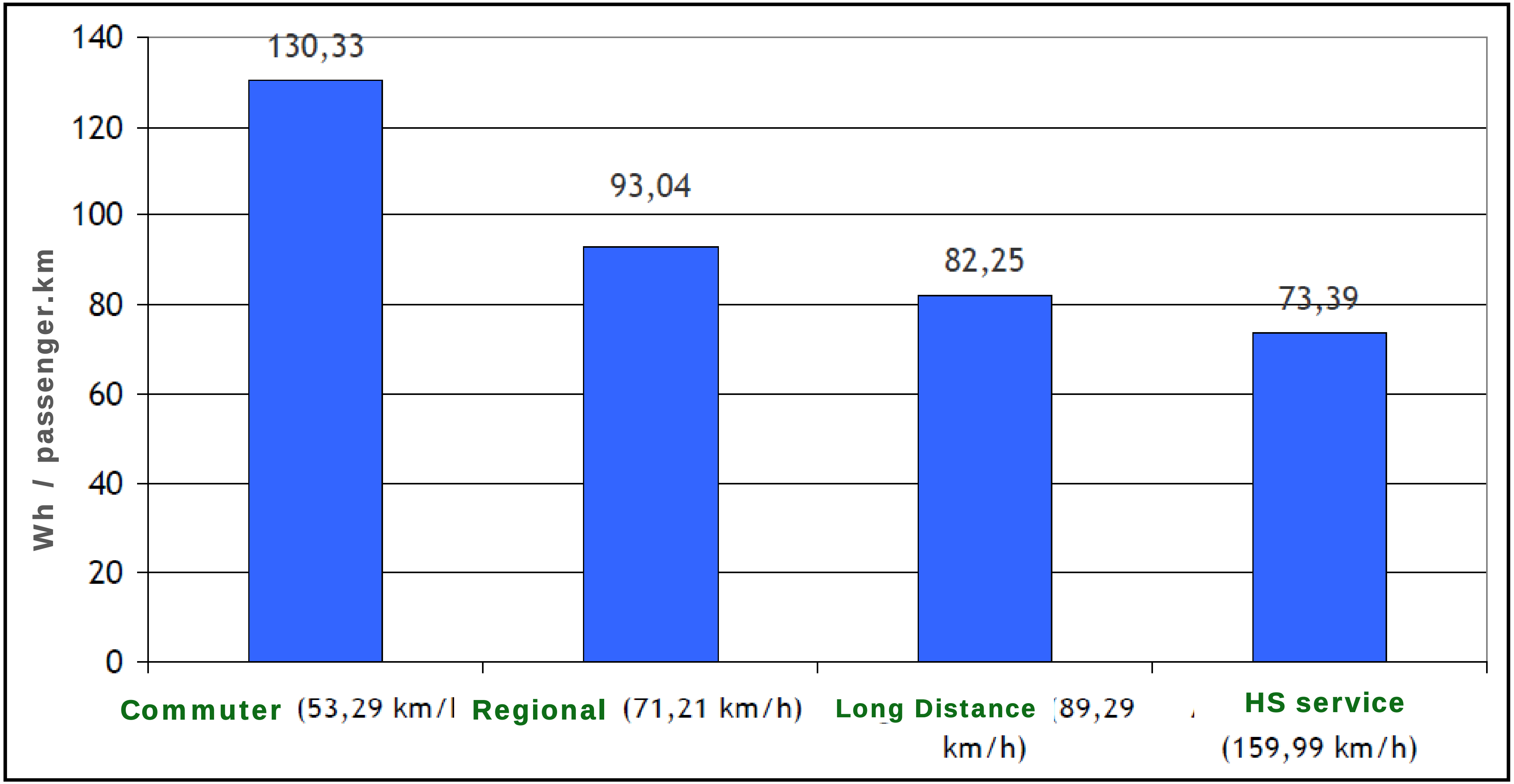
Two conclusions:

- The **energy consumption of HS trains** (per passenger) could be **similar to than in slower trains running between the same stations,** as a consequence of acceleration/braking processes. Main factor will be the degree of occupation of different trains, that in Spain is much higher for HS (around 90%) that for conventional trains (we will simulate for Thane-Nasik section, on Chapter 4, adapted to Indian conditions, with an high degree of occupation of Conventional Trains)

- The **energy consumption in HS trains is also the lowest of all the means of transport**. With the increase of their speed, passengers prefer HS trains to, for example, planes. The energy consumption and carbon emissions are lower with the HS trains (of course, with a big density of traffic) (we also will apply to Indian case on Chapter 4)

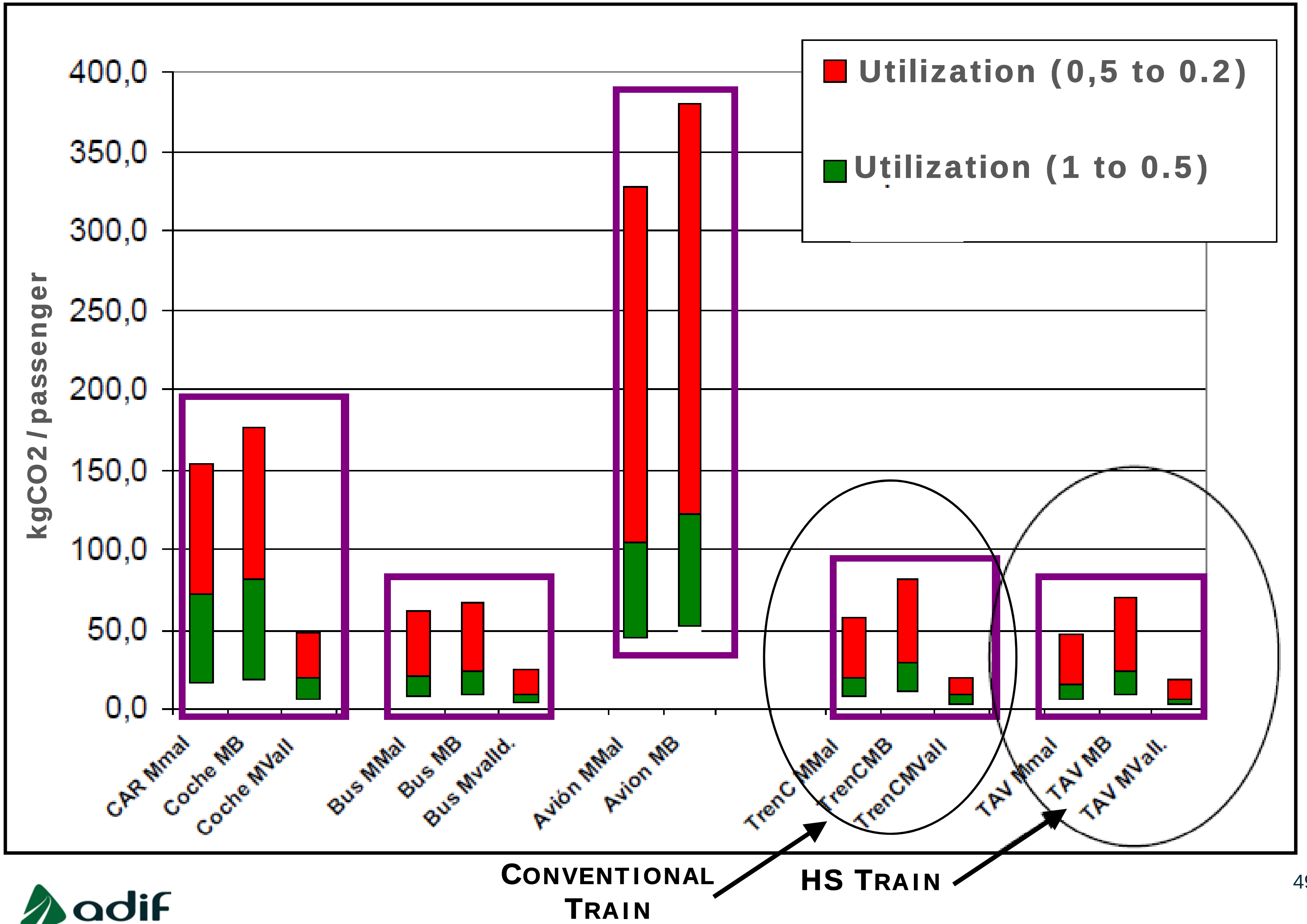
Energy consumption of High Speed trains. Case of Spain

Comparative between different types of trains



Energy consumption of High Speed trains. Case of Spain

Comparative between different modes/different cities/different degrees of occupation



Energy consumption of High Speed trains. Case of Spain

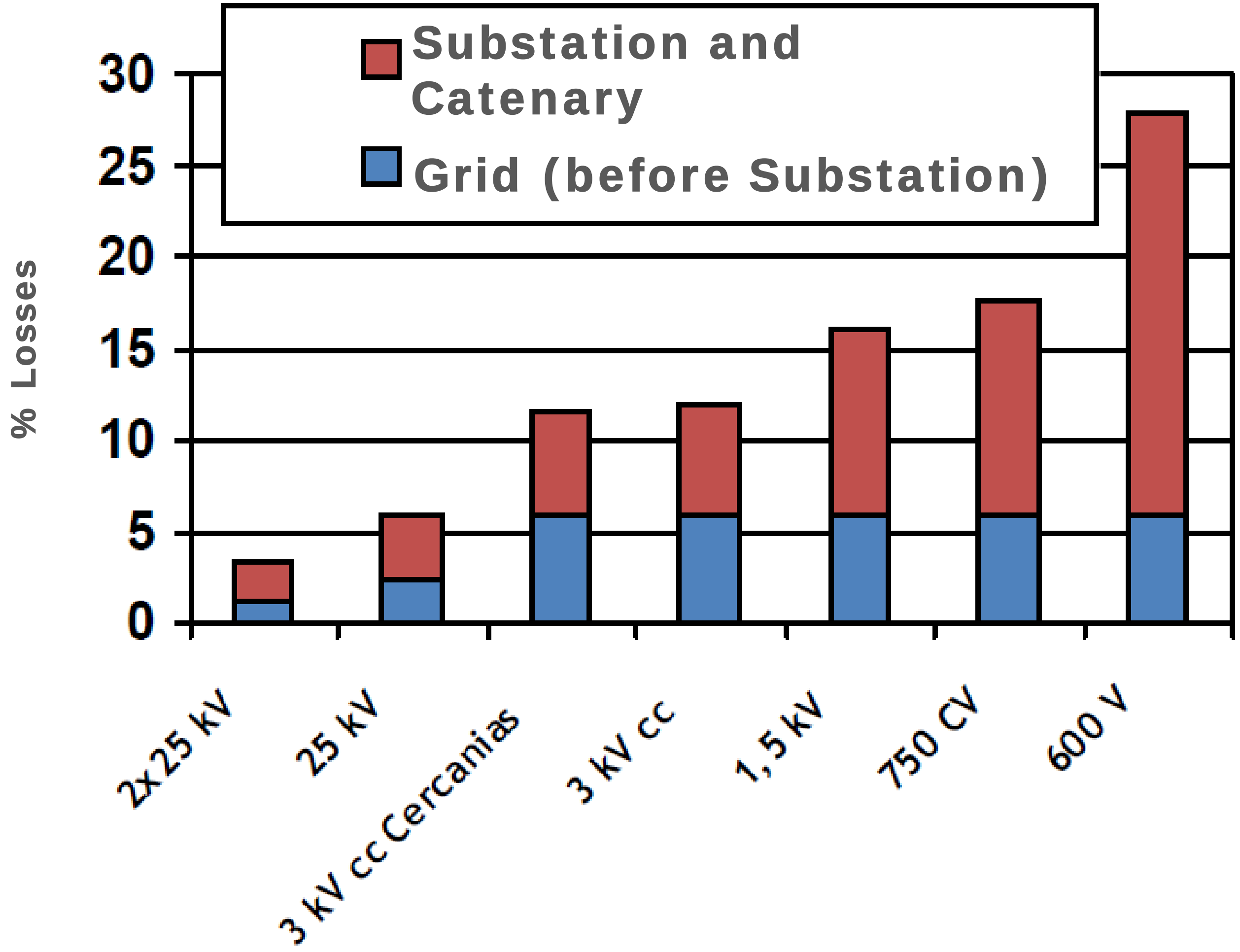
Some of the reasons of the efficiency:

- More homogeneous speed profile *(less speed variation)*.
- Less distance *(-23%)*.
- Lower ancillary services consumption *(less travel time)*.
- Less mass per seat and smoother trains.
- More efficient aerodynamic profile.
- Bigger trains.
- Better load factor.
- More efficient TPS.

Energy consumption of High Speed trains. Case of Spain

Some of the reasons of the efficiency:

More efficient TPS



Eco Driving

Eco Driving

- In the case of a HSL is the initial action to be used.
- Consists of consuming the minimum possible energy respecting the commercial time of the train.
- Putting it into practice, **the energy consumed can be reduced by around 20%** (our experience).
- It does not mean in principle a great economic investment.
- Pre-simulation process and subsequent application in service (1: Optimum manual driving; 2: ATO integration).

Eco Driving

Madrid-Seville HSL (example)

By applying a Eco Driving, it is possible, respecting the commercial timetable of the train, to travel approximately to 60% of the Madrid-Seville route in drift, and 50% in the return (since in this case the ramp proportion is greater, having to climb from the valley of the *Guadalquivir River* to the *Plateau of Castilla*)

⇨ **23% less energy**.

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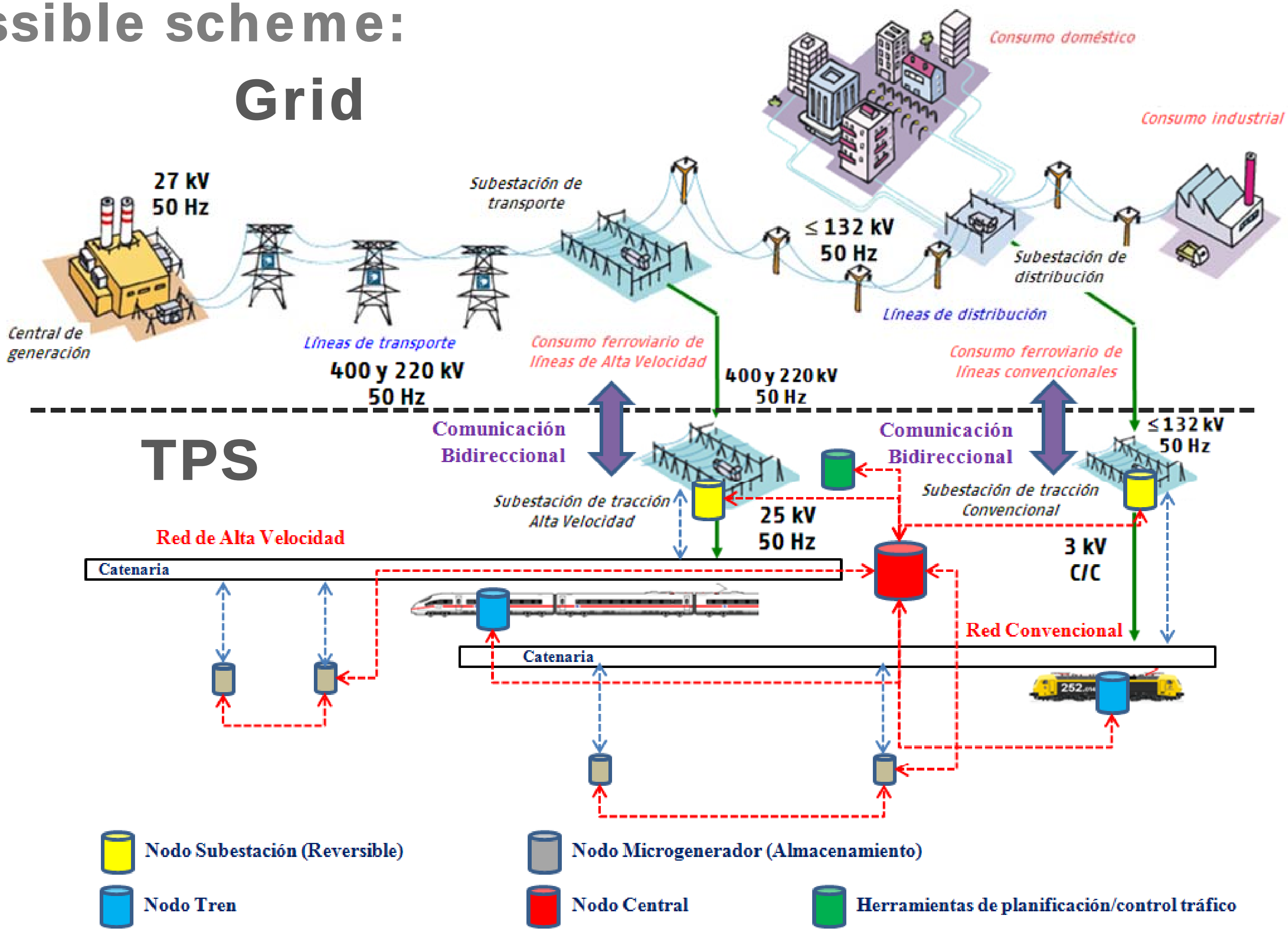
Smart Grid

Smart Grid

- A **Smart Grid** network is one that can efficiently integrate the behavior and actions of all users connected to it, so as to ensure a sustainable and efficient energy system with low losses and high levels of quality and security of supply, making intensive use of information technologies and telecommunications.
- Measure of application in High Speed TPS.
- Introduction of **new concepts***: e.g. distributed generation (e.g. renewable energy), Smart Metering, Storage, etc*.
- Important issue: **Vehicle-infrastructure interaction from an energy consumption point of view**.
- **Reductions in energy consumption of around 10%.**

Smart Grid

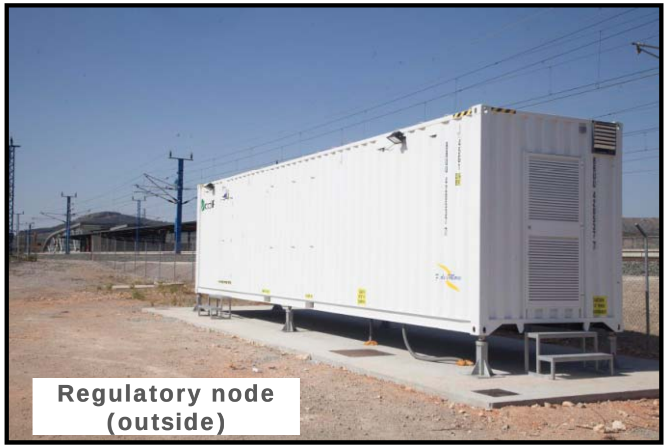
Possible scheme:



Smart Grid

Some internal tests:

Cordoba-Malaga HSL



Regulatory node (outside)

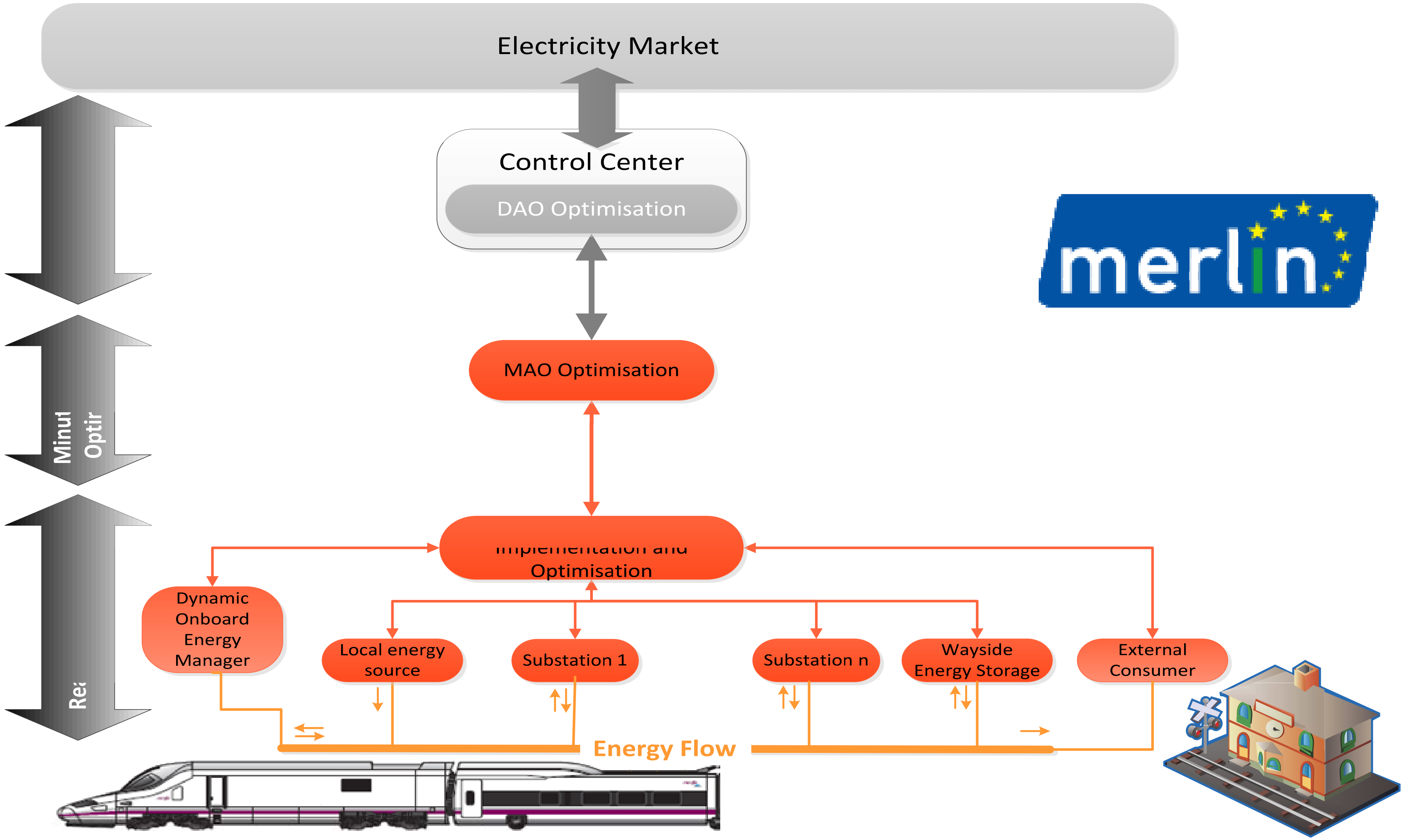
Regulatory node (inside)

Regulatory node (inside). Storage

Renewable generation

Smart Grid

Merlin Vision:



New AC substation concept

New AC substation concept

- A new concept of traction substation for High Speed lines is being developed. Although the reduction of **energy consumption is an objective (around 8%)**, this substation has other advantages directly related to the efficiency of the TPS.

- Specifically, the new substation will optimize the **imbalance** problems in those lines connected to moderate short-circuit power networks (considering a high traffic density). It is also planned to regulate the **voltage of the catenary** according to the operational needs, always optimizing the losses.

- It is not a viable solution for new High Speed lines (already in operation) because problems do not occur.

- On the other hand, Adif wants to develop this solution for old HSL where power requirements are important and operating problems can occur if traffic increases. It is also an applicable solution for the transformation of a DC line to an AC line (connection to distribution network with low short-circuit power).

New AC substation concept

Power Electronics as countermeasure (active methods)

Power Supply	Converter Power Rating (Per-Unit Load)	Neutral Sections	Catenary Voltage and Frequency Regulation	Harmonic Compensation	Catenary Short Circuit Protection
SVC	0.58	Compulsory	No	No	Passive
STATCOM	0.58	Compulsory	No	Yes	Passive
FULL-POWER CONVERTER	1.0	Can be omitted	Yes	Yes	Active
COPHASE SUPPLY	0.5	Can be omitted	No	Yes	Passive

New AC substation concept

Madrid-Seville HSL: New analyses

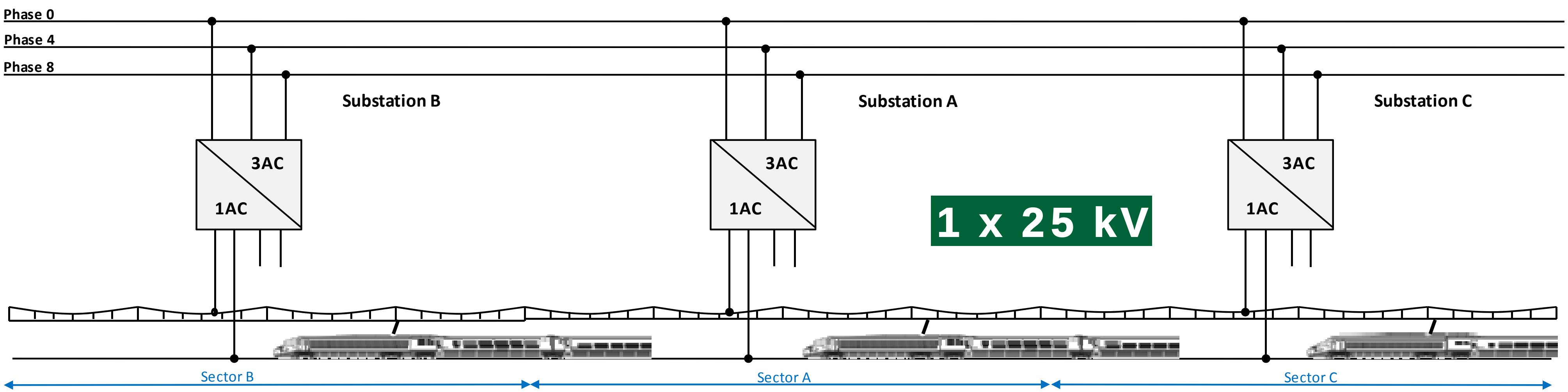
- Future scenario: Greater power demanded (*e.g. increased traffic (more trains) and trains in double composition*).
- Use of the existing grid and TPS (equipment and configuration).
- In this situation, the operation of this future scenario would become impracticable (greater grid imbalance, excessive voltage drop in catenary, etc.), mainly in a degraded operating situation.
- Need to use a new technical solution: *full-power converter*.

New AC substation concept

Madrid-Seville HSL: New analyses

full-power converter

TRANSPORT LINE **132/220 kV**

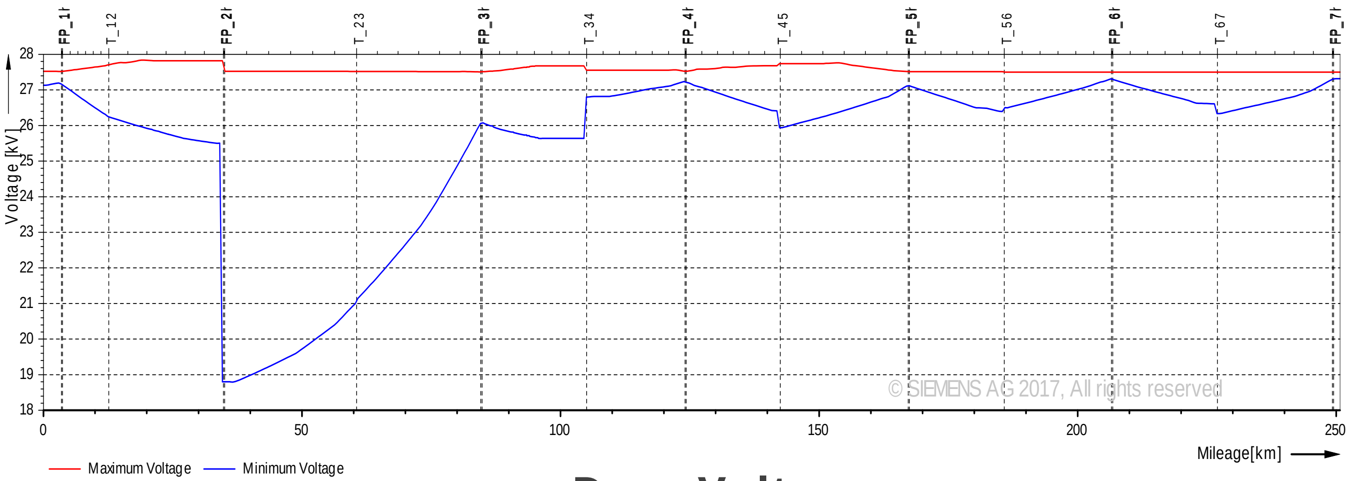


Madrid-Seville HSL

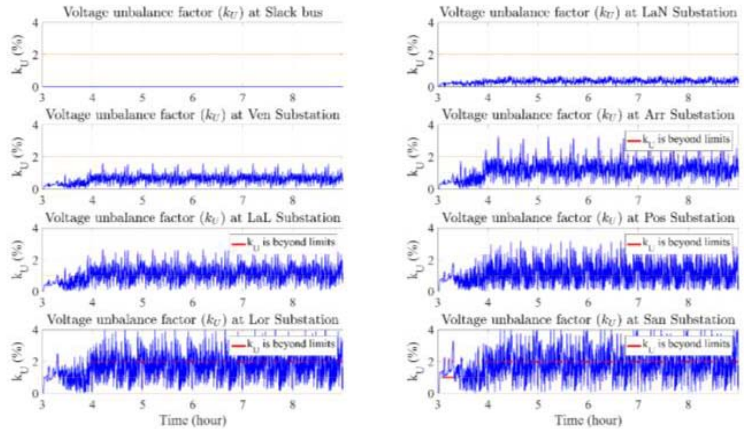
New AC substation concept

Madrid-Seville HSL: Some results (degraded operating situation)

without full-power converter

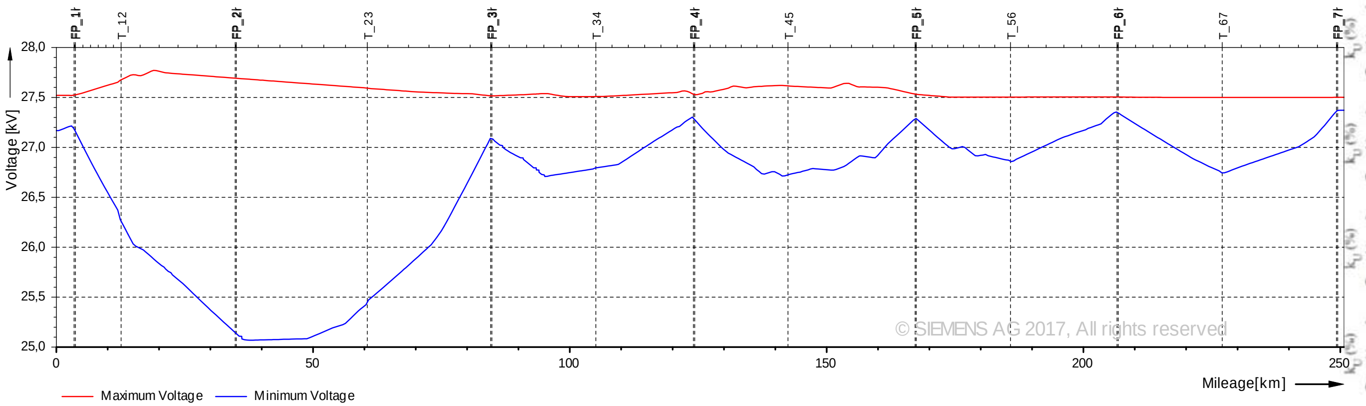


Drop Voltage

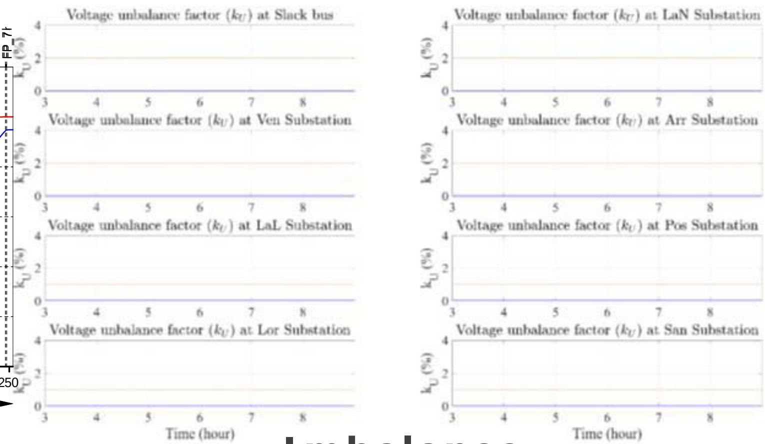


Imbalance

with full-power converter



Drop Voltage



Imbalance

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Conclusions

Conclusions

- If we consider the **energy efficiency of the HS system**, we do not just have to take into account the direct energy consumption. An efficient line is also one that does not produce affections about the environment. It is also that line that safely and optimally supplies the energy demanded by the train.

- **Three variables for analysis**: *Energy consumption*, *imbalance* and *voltage in catenary* (drop voltage).

- The incorporation of technologies (existing and new ones) is done analyzing these three variables. **Eco Driving**, **Smart Grid** and **New AC substation** are the main technologies in which Adif works now.

- In any case **in Spain the energy consumption of HS trains (per passenger) is usually lower than in slower trains** running between the same stations. The energy consumption in HS trains is also the lowest of all the means of transport.

- Some of the reasons of the efficiency: More homogeneous speed profile, less distance, lower ancillary services consumption and more efficient electric system.

Conclusions (2)

- **Eco Driving**: In the case of a HSL is the initial action to be used. Putting it into practice, the energy consumed can be reduced by around **20%** (our experience).

- **Smart Grid**: Measure of application in HSL. Reductions in energy consumption of around **10%**. Introduction of new concepts: e.g. distributed generation (e.g. renewable energy), Smart Metering, Storage, etc.

- **Smart Grid**: Vehicle-infrastructure interaction from an energy consumption point of view.

- **New AC substation** (with full-power converters): Although the reduction of energy consumption is an objective (**around 8%**), this substation has other advantages directly related to the efficiency of the TPS. Specifically, the new substation will optimize the imbalance problems in those lines connected to moderate short-circuit power networks (considering a high traffic density). It is also planned to regulate the tension of the catenary according to the operational needs, always optimizing the losses.

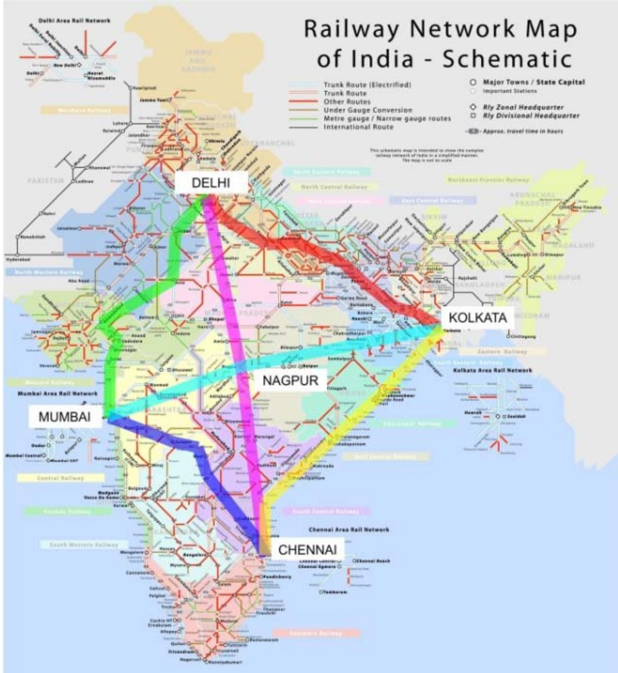
I. ADIF references, as Infrastructure Railways Manager in Spain

II. Relevant results on Energy and Environment management

III. Energy Management technologies for High Speed

IV. Sharing Spanish experience with Indian HS projects: Simulation of Energy savings over Thane-Nasik strecht
(feasibility study of New HSL Mumbai-Kolkata / phase 1: Mumbai-Nagpur)

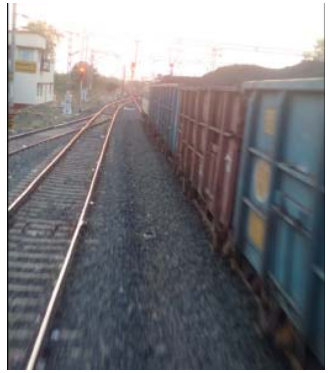
A RELEVANT COOPERATION WITH HSRC OF INDIA



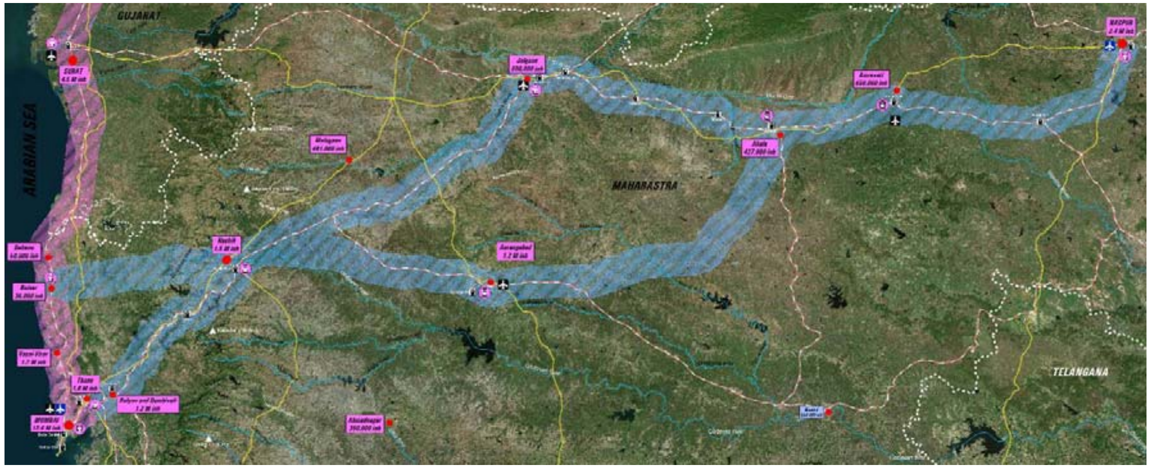
Feasibility Study for a future High Speed Rail (HSR) between MUMBAI and KOLKATA (PHASE I Mumbai - Nagpur).

Its main objective is to evaluate if the project is feasible, minimizing all technological risks link to a HSR project, reaching the best cost effectiveness and studying all the financing requirements.

As main reference for this Feasibility Study it has been considered the Spanish proven technology on High Speed Lines, adapted to India´s specific conditions

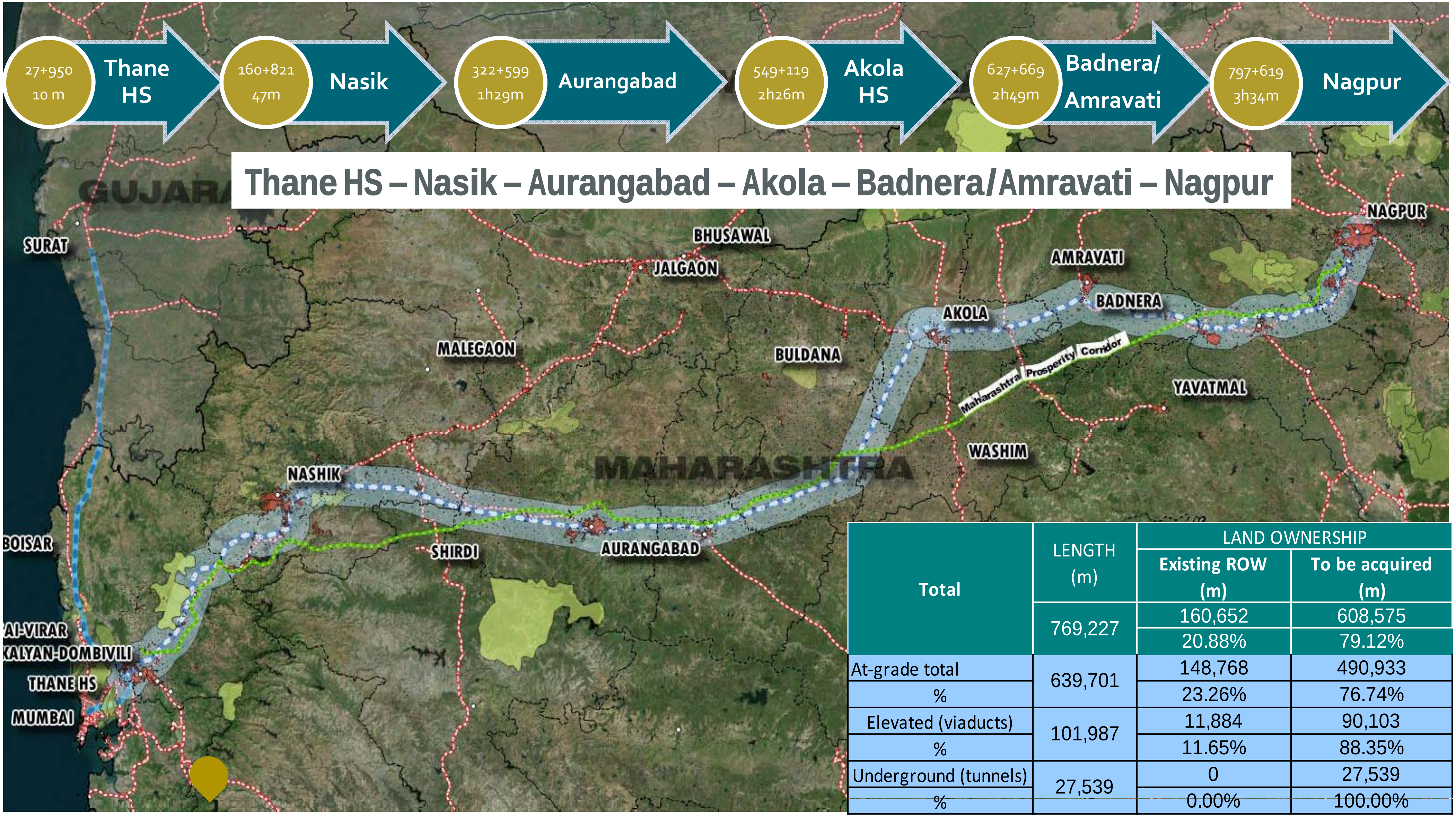


- ➢ Collaboration Agreement signed by HSRC and ADIF
- ➢ ToR agreed by HSRC with ADIF
- ➢ G2G support by Spanish Ministry of Economy and Competitiveness



HSRC

SELECTED ALTERNATIVE: 769.67 km of New Line 3h 34 min from Mumbai BKC



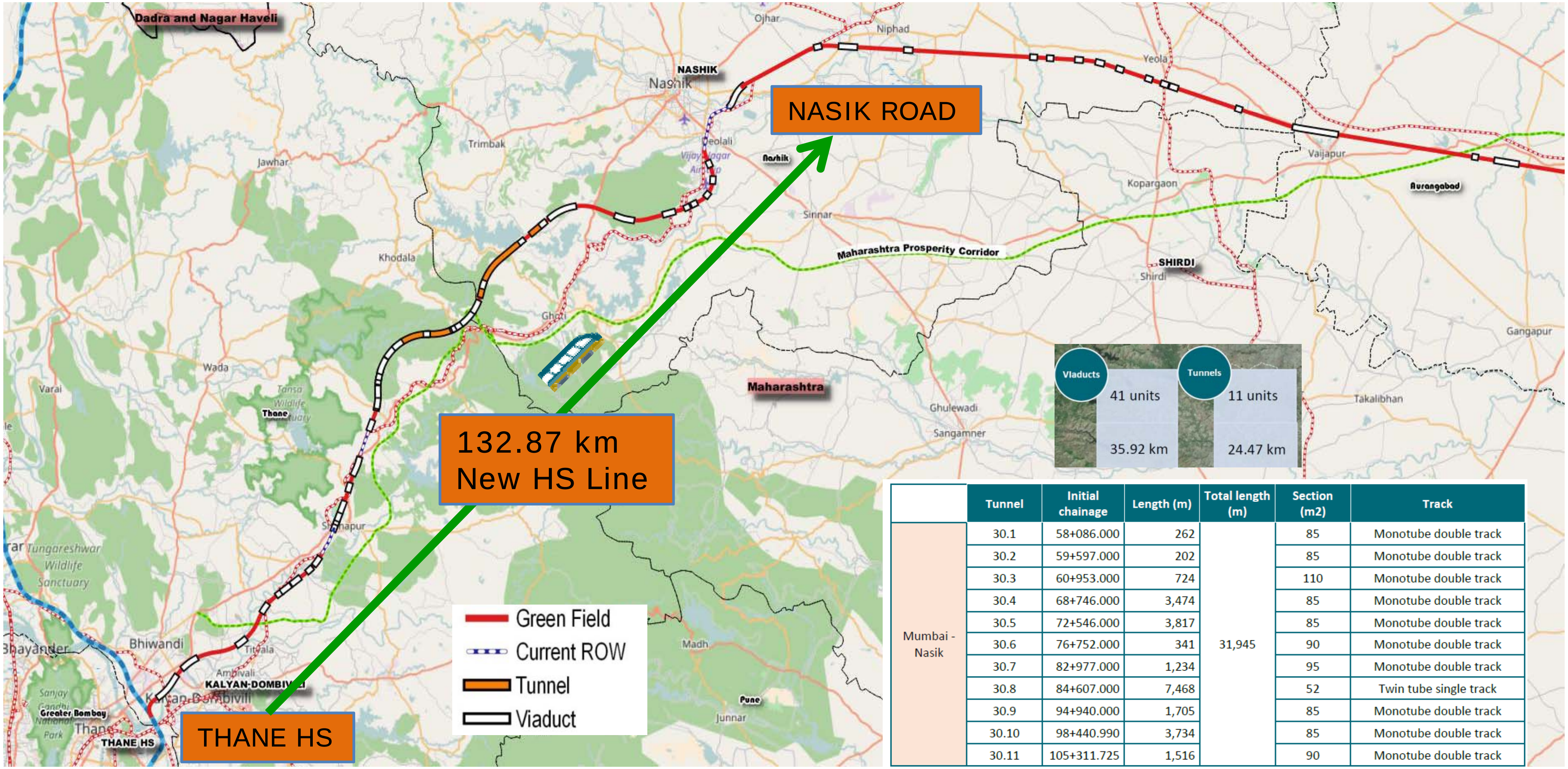
Total	LENGTH (m)	LAND OWNERSHIP	
		Existing ROW (m)	**To be acquired (m)**
	769,227	160,652	608,575
		20.88%	79.12%
At-grade total	639,701	148,768	490,933
%		23.26%	76.74%
Elevated (viaducts)	101,987	11,884	90,103
%		11.65%	88.35%
Underground (tunnels)	27,539	0	27,539
%		0.00%	100.00%

(*) Jouney Time from Mumbai BKC

A SECTION OF HSRL SELECTED TO ANALYSE ENERGY AND ENVIRONMENTAL EFFECTS

THANE HS TO NASIK ROAD : A FIRST STRECH WITH MAXIMUM BENEFITS

- **Mumbai - Nasik Conventional Train** — **3h 35m**
- **Mumbai BKC - Thane HS – Nasik High Speed Services** — **47m**



	Tunnel	Initial chainage	Length (m)	Total length (m)	Section (m2)	Track
Mumbai - Nasik	30.1	58+086.000	262	31,945	85	Monotube double track
	30.2	59+597.000	202		85	Monotube double track
	30.3	60+953.000	724		110	Monotube double track
	30.4	68+746.000	3,474		85	Monotube double track
	30.5	72+546.000	3,817		85	Monotube double track
	30.6	76+752.000	341		90	Monotube double track
	30.7	82+977.000	1,234		95	Monotube double track
	30.8	84+607.000	7,468		52	Twin tube single track
	30.9	94+940.000	1,705		85	Monotube double track
	30.10	98+440.990	3,734		85	Monotube double track
	30.11	105+311.725	1,516		90	Monotube double track

Exploitation

Possibility of extending service typology to increase high speed line use

- Apart from the trainsets to be used in the core service, other trains could use the line…
  - Offering low cost travel to attract new passengers
  - Extending their journey through conventional network to reach new destinations
  - Variable Gauge trains HS EMUs (TALGO or CAF)to be used to set exploitation plan.

- Trailed high speed rolling stock could offer new (and attractive) possibilities
  - Locomotives would remain inside the line and only the less-expensive part of the train would continue beyond
  - As much as 1400 quality standard class seats per train (although beds are also possible)

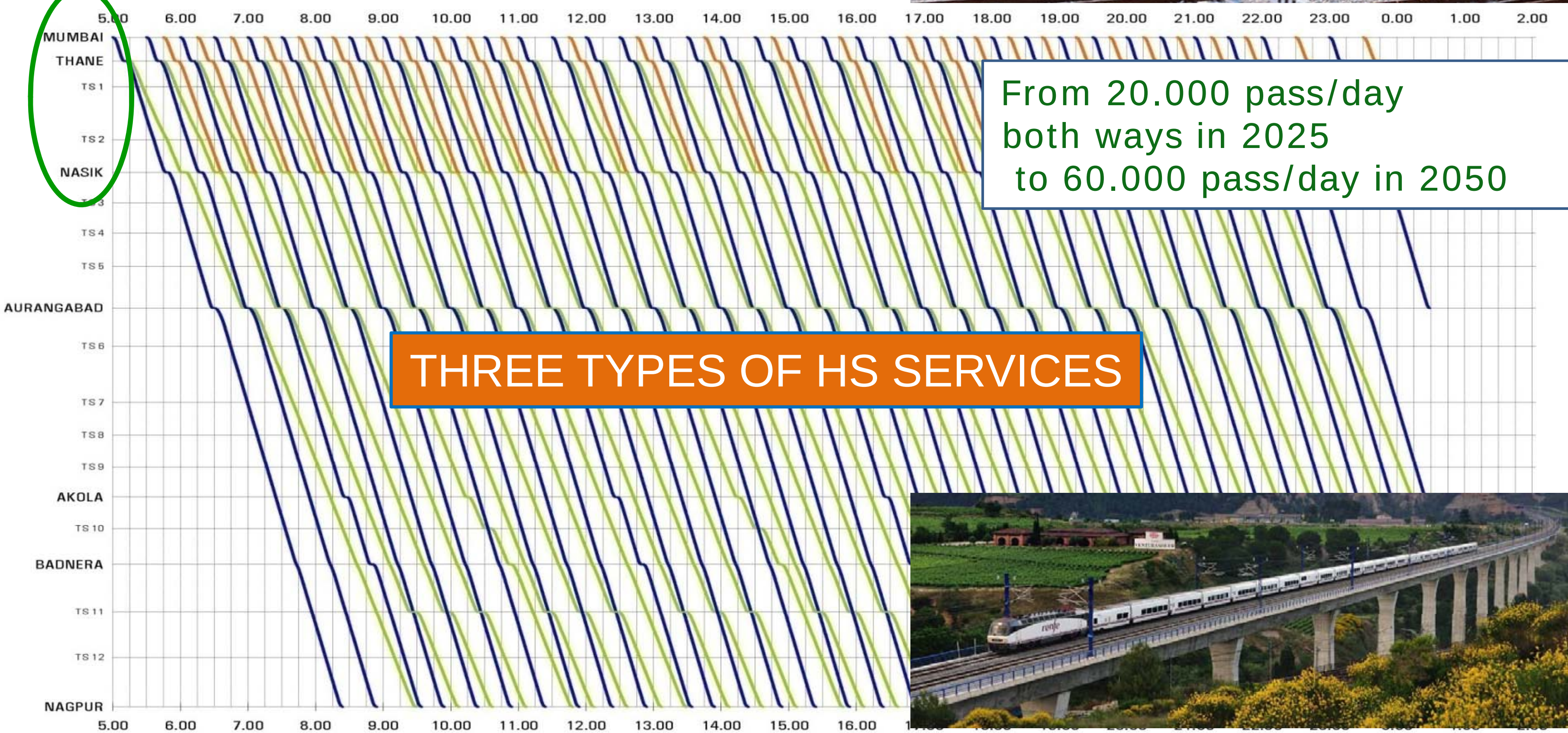
Talgo Avril awarded by Renfe

22,5 M€ / train
(additional -10% if order extends)
521 seats (103+2 1st / 416 2nd)
200 m / 12 cars (3+8+1)
-43% operation cost per pax

Exploitation

– 'Extended' pattern

(initial approach)



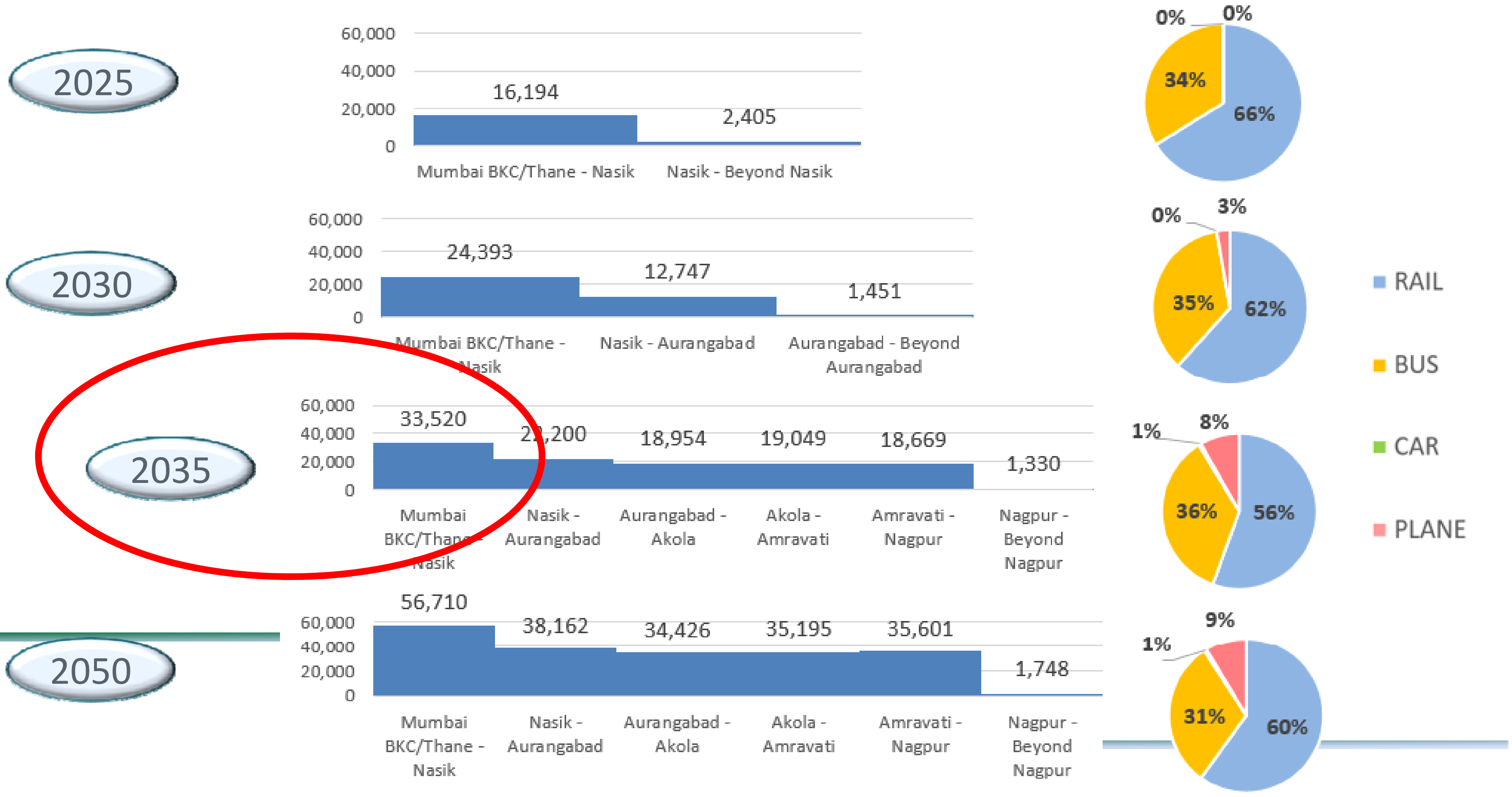
From 20.000 pass/day both ways in 2025 to 60.000 pass/day in 2050

THREE TYPES OF HS SERVICES

HS 350 trains — HS 250 Regional trains — HS 230 LD trailed trains

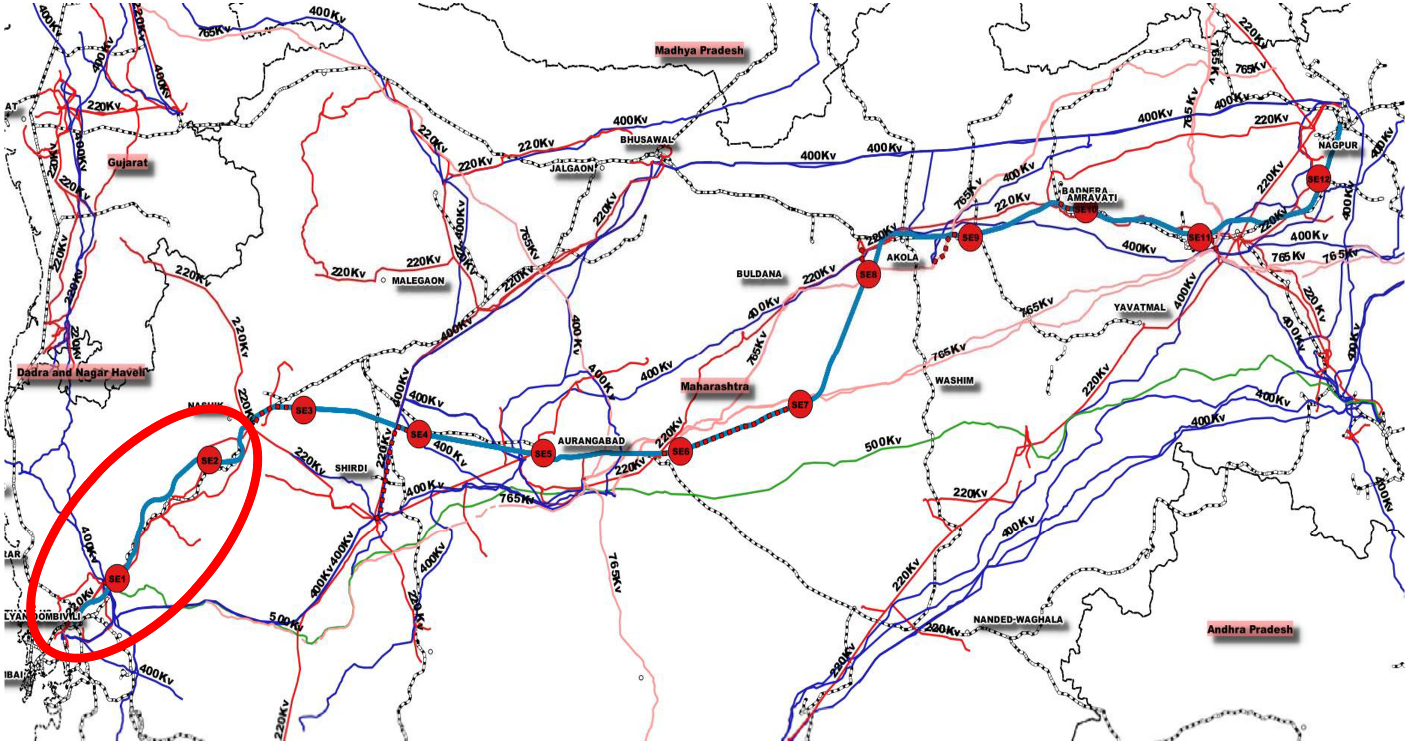
Demand forecast for the Mumbai-Nagpur HSRL
Thane HS – Nasik as priority for a progressive operational timing
2035 Scenary as base for the Energy and Environmental effects simulation

Time horizon | *Load chart (Daily passengers, two ways)* | *Origin of demand for HSRL*



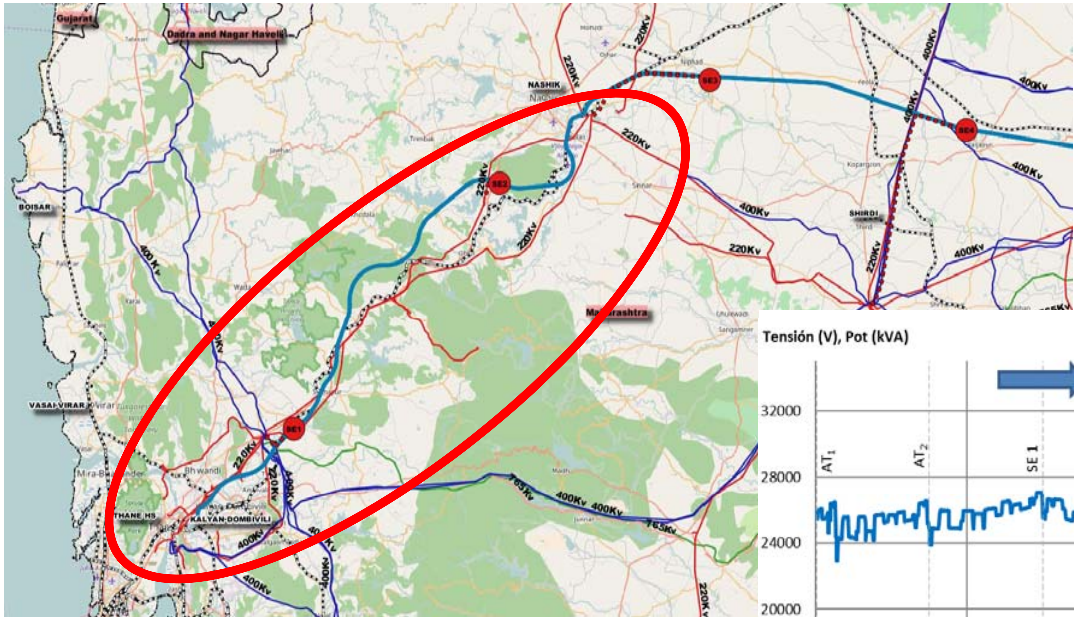
HSRC

Traction Substation Distribution

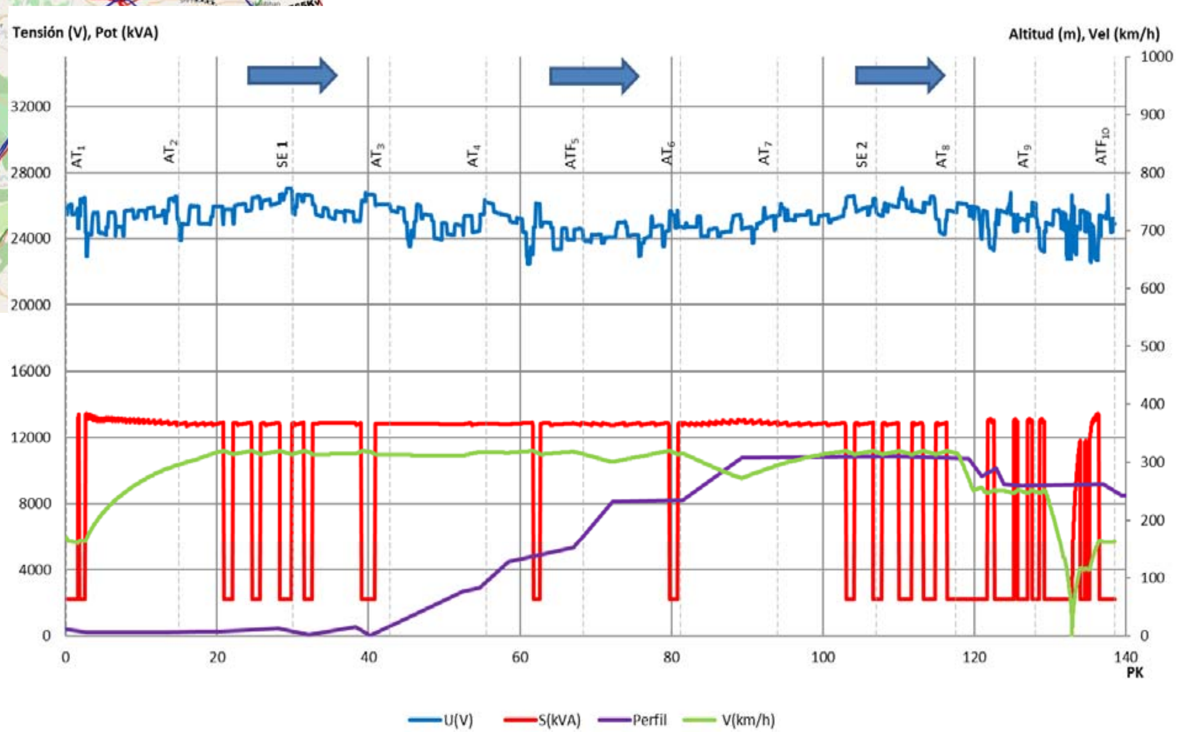


K.P.	SUBSTATION / AT	LINK TO	LINK LENGTH (m)
0+000	AT_1		
[illegible]	AT_2		
30+000	SE1	POWER SUBSTATION PADGHE	9.259,[illegible]
44+000	AT_3		
57+000	AT_4		
72+400	AT_5		
84+900	AT_6		
96+800	AT_7		
107+000	SE2	POWER SUBSTATION	6.452,00
120+000	AT_8		
[illegible]	AT_9		
145+500	AT[illegible]		
157+500	AT_{11}		
170+000	SE3	NASHIK THERMAL POWERSTATION	29.669,00
185+000	AT_{12}		
200+000	AT_{13}		
215+000	AT_{14}		
229+500	SE4	POWER SUBSTATION BABLESHWAR	53.179,00
242+000	AT_{15}		
255+000	AT_{16}		
267+000	AT_{17}		
279+500	AT_{18}		
292+250	SE5	POWER SUBSTATION PADEGAON	3.637,00
305+000	AT_{19}		
320+000	AT_{20}		
335+000	AT_{21}		
349+000	AT_{22}		
362+000	SE6	POWER SUBSTATION JALNA II	11.744,00
375+000	AT_{23}		
387+500	AT_{24}		
400+000	AT_{25}		
412+500	AT_{26}		
425+000	SE7	ACOMETIDA PARALELA	
440+000	AT_{27}		
455+000	AT_{28}		
467+500	AT_{29}		
480+000	AT_{30}		
493+500	SE8	PARAS THERMAL POWER STATION	12.122,00
506+000	AT_{31}		
518+000	AT_{32}		
530+000	AT_{33}		
542+000	AT_{34}		
555+000	SE9	POWER SUBSTATION AKOLA	25.025,00
570+000	AT_{35}		
585+000	AT_{36}		
600+000	AT_{37}		
615+000	SE10	POWER SUBSTATION BADNERA	13.156,00
630+000	AT_{38}		
645+000	AT_{39}		
660+000	AT_{40}		
675+000	SE11	POWER SUBSTATION WARDHA	13.895,00
688+000	AT_{41}		
702+000	AT_{42}		
715+000	AT_{43}		
730+000	AT_{44}		
745+000	SE12	BUTIBORI THERMAL POWER STATION	6.257,00
760+000	AT_{45}		

Typical Section Power Calculation



Thane HS – Nasik
2 Substations
Pk 30 Pk 107



2 x 30/60 MVA each

Calculated for the worst degradated situation of trains run

THANE – NASIK ROAD INFRASTRUCTURE

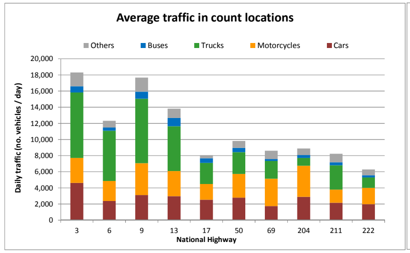
National Highway 160 **147 km**

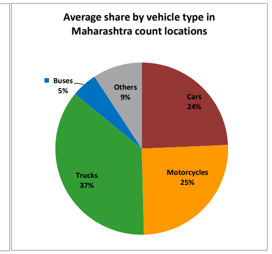
38.000 veh/daily

22.000 car & motorcycles

4.000 buses & other type of vehicles

12.000 trucks





Travel time & average speed from Greater Mumbai	h	km/h
to Thane	1.5	49.4
to Nasik	2.9	58.1

Buses operated by Maharastra State Road Transport Corporation MSRTC

to Nasik	round services / daily	
from Mumbai	33	4 – 5 h
from Thane	35	3 – 4 h

RAILWAY INFRASTRUCTURE

Mumbai Suburban Rail Network (Central)

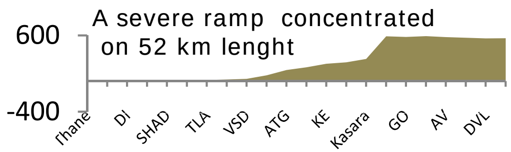
Mumbai CST – Thane km 33.02 – Kasara km 120.83 (293 m over sea level)

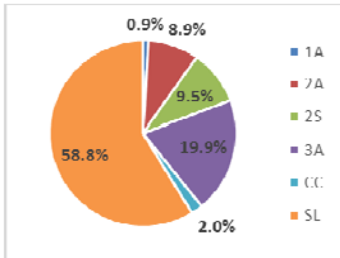
Indian Railways 154 km

Mumbai CST – Kasara - Igatpuri km 136,76 (589 m o.s.l.) –

- Nasik Road km 187,08 (564 m o.s.l.)

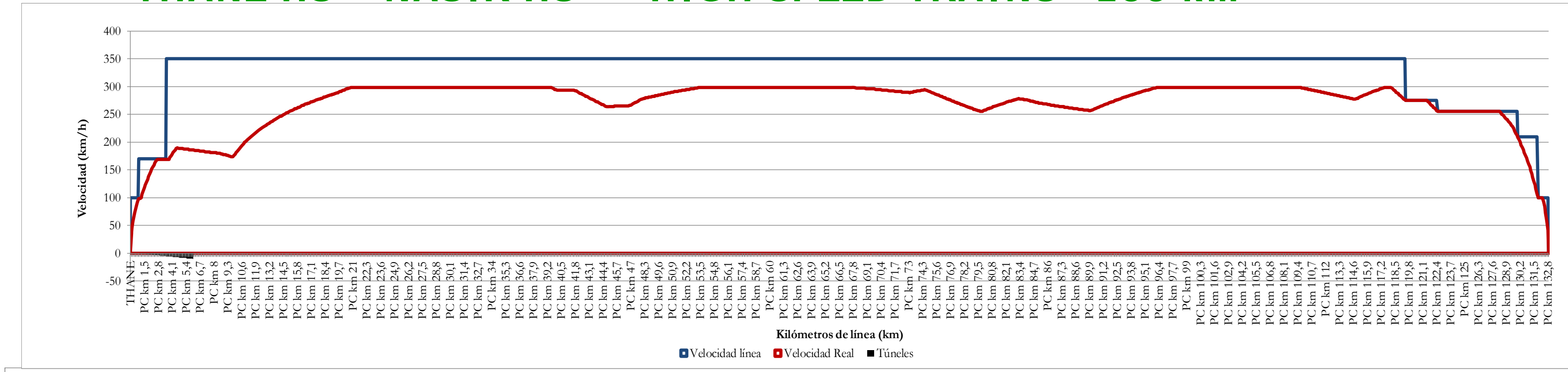
Travel time Mumbai CST – Nasik Road 3h 30 min

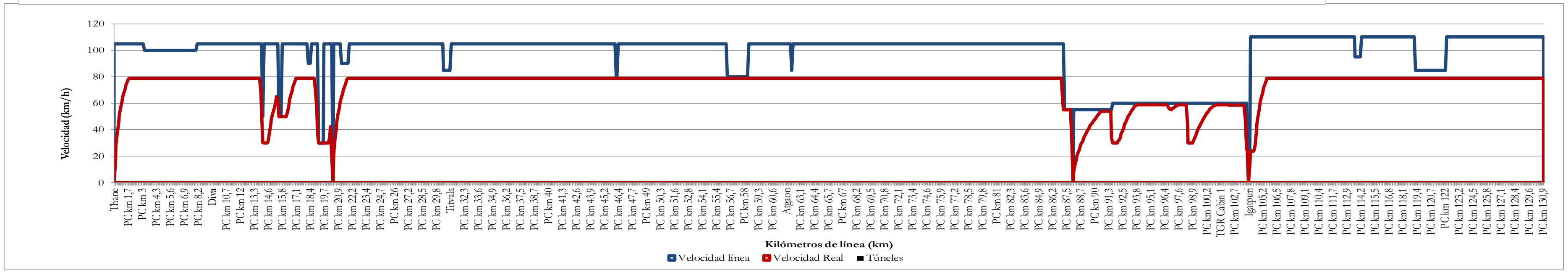




Split of the rail demand using the ticket reservation system

THANE HS – NASIK HS HIGH SPEED TRAINS 133 km





THANE – NASIK ROAD CONVENTIONAL TRAINS 154 km

Simulation of Energy Consumption show us that **for HS Train is 0,0361 kWh / pass-km**, just double that those for Conventional Trains

This coincides with Unitary Values used on Macro approach

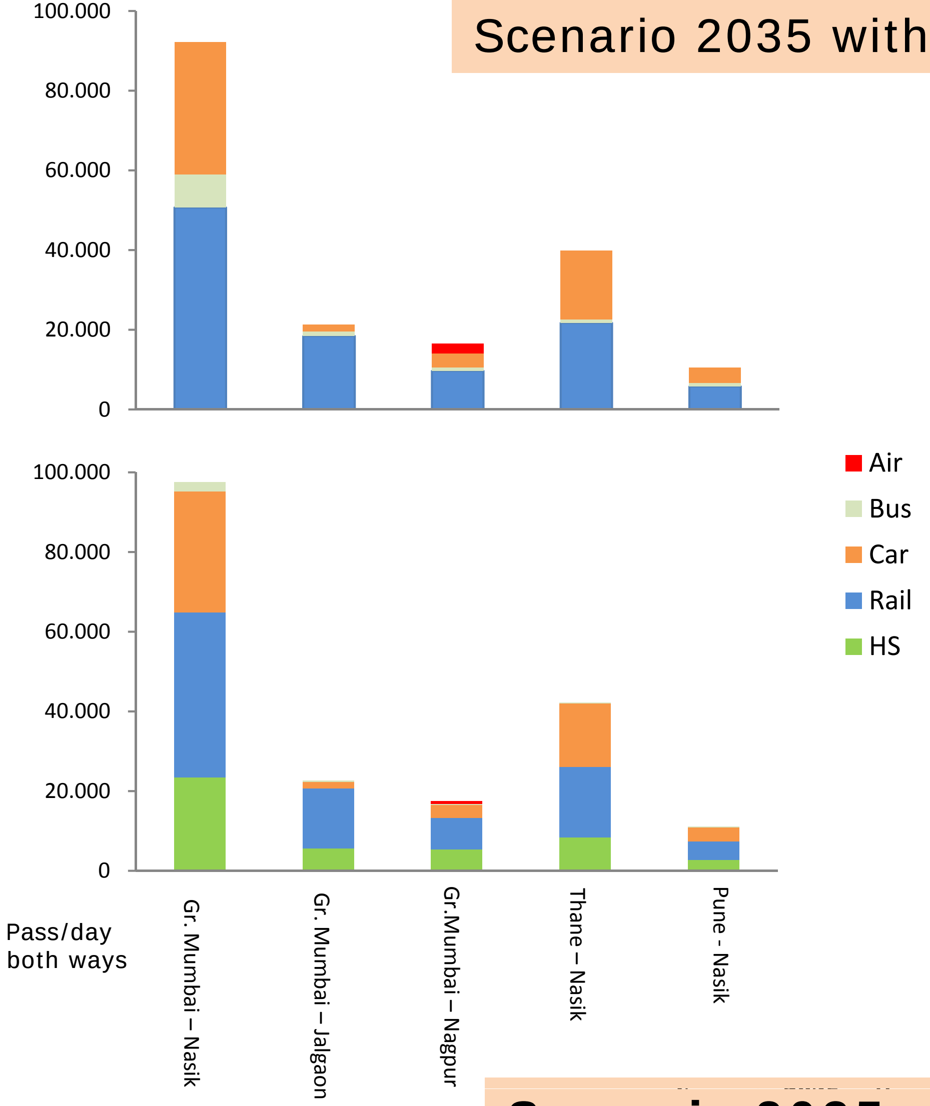
Train	Line	Max. Speed	Passengers / train (aprox.)	INCOME OF ENERGY FROM ELECTRICITY NET (kWh)	**NET CONSUMPTION OF ENERGY (kWh)**	NET CONSUMPTION OF ENERGY BY KM (kWh/km)	**NET CONSUMPTION OF ENERGY BY PASS-KM (kWh / pass-km)**	TRAVEL TIME (hh:mm:ss)
Loc WCAM3 + 18 Coaches	Thane-Nasik Road	80	1.440	4.014,0	**4.014,00**	**26,10**	**0,0181**	2:23:44
Talgo Avril	Thane-Nasik AV	300	1.042	5.466,8	**5.002,80**	**37,60**	**0,0361**	0:31:23

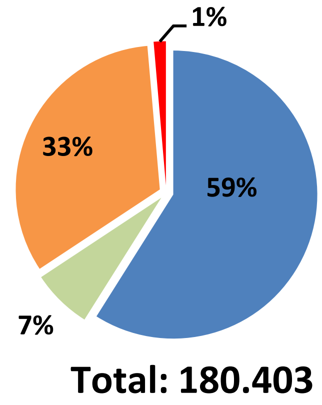
ENERGY AND ENVIRONMENT: A “MACRO” APPROACH

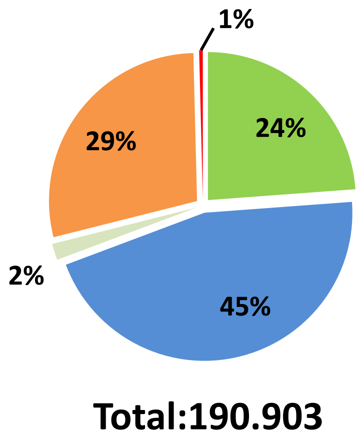
FROM CURRENT SITUATION TO SCENARIO 2035

Main traffics from Great Mumbai, Thane, Pune towards Nasik, Jalgaon & Nagpur

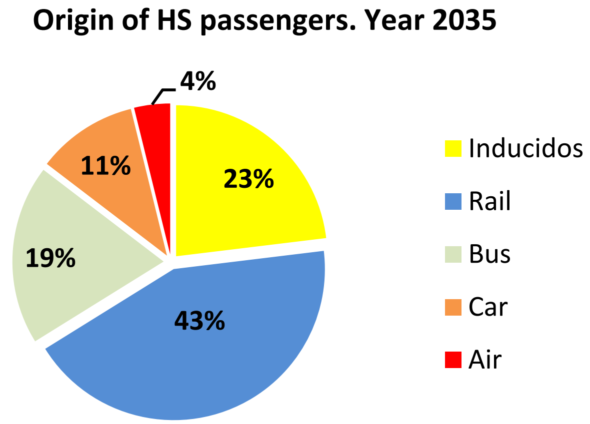
Scenario 2035 without Project







Total Passengers/day 180.403
Railway 106.366



Total Passengers/day 190.903

Railway 132.266
Conv. Railway 86.766
HSR 45.500
From Rail and other modes 35.000
Induced HS passengers 10.500

From GM, Thane, Pune
to Nasik 34.494 76%
to Nagpur&Jalgaon 11.006 24%

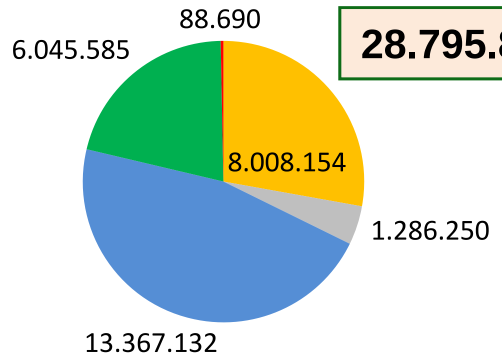
Scenario 2035 with Project

THE IMPORTANCE OF INCLUDING TRAFFICS "BEYOND"

Pass-km **Only Thane - Nasik** stretch	Without Project	**With Project**
Road Car	8.728.454	8.008.154
Road Bus	1.789.126	1.286.250
Rail	16.386.708	13.367.132
HS	0	6.045.585
Air	298.690	88.690
TOTAL	**27.202.978**	**28.795.811**

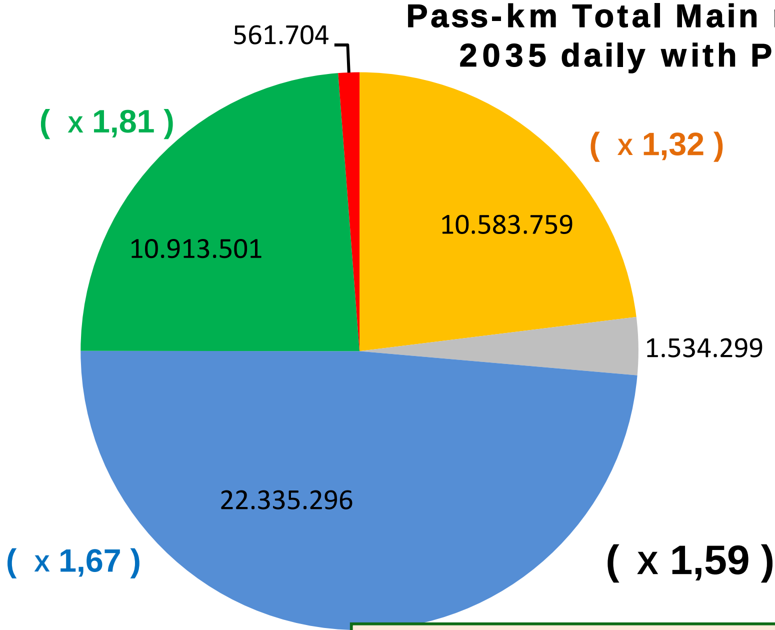
Pass-km Thane-Nasik 2035 daily with Project

28.795.811 pass-km / day



Total pass-km Main relations	Without Project	**With Project**
Road Car	11.535.724	10.583.759
Road Bus	2.671.632	1.534.299
Rail	27.380.741	22.335.296
HS	0	10.913.501
Air	1.891.704	561.704
TOTAL	**43.479.800**	**45.928.559**

Pass-km Total Main relations 2035 daily with Project



45.928.559 pass-km / day

DISTANCES

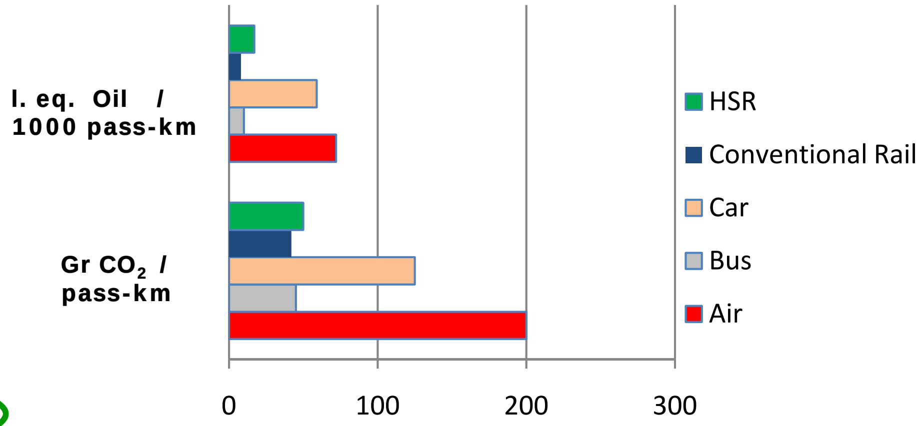
	HS	Rail	Road	Air
Thane – Nasik	133	154	147	120
Nasik – Nagpur	637	649	687	760 (from Mumbai)

UNITARY VALUES OF GAZ EMISSION, ENERGY CONSUMPTION AND OTHER EFFECTS

A

PASSENGERS EMISSION & CONSUMPTION		
	Gr CO2 / pass-km	l. eq. petroleo / 1000 v-km
Air	200	72
Bus	45	10
Car	125	59
Conv. Rail	42	8,1
HSR	50	17

Source: Socio Economic Effects of Railway in Spain, FFE 2004



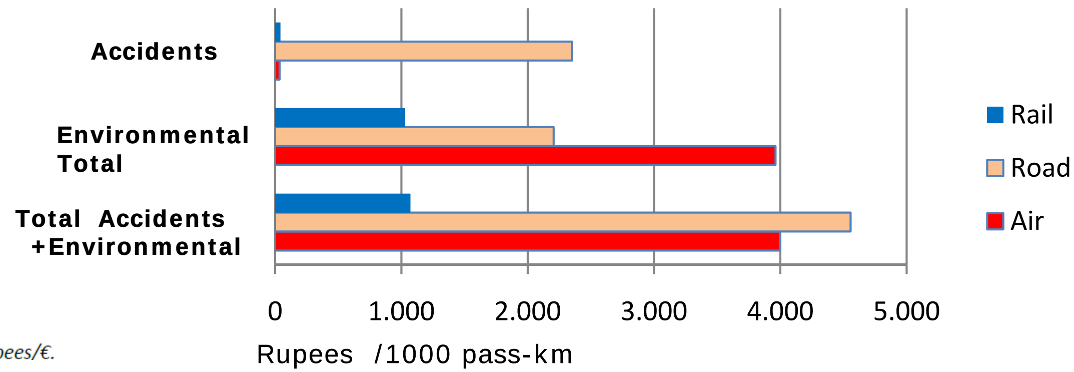
Even having higher emission and consumption figures in relation with Conventional Rail **HSR stands out** its relevant advantages over other transport modes in terms of **reduction of accidents** and total **environmental effects**

Passenger transport (Rupees/1.000 passengers-km)			
Cost Category	Road Passenger Transport	Rail Passenger Transport	Aviation Passenger Transport
Accidents	2352	42	35
Air Pollution	399	182	63
Climate change			
High Scenario	1141	105	3283
Low Scenario	196	21	560
Noise	140	84	70
Up and downstream processes			
High Scenario	378	567	497
Low Scenario	224	273	273
Nature & urban effects	105	56	42
Biodiversity losses	14	0	7
Soil & water pollution	28	35	0
TOTAL HIGH SCENARIO	2205	1029	3962
TOTAL LOW SCENARIO	1106	651	1015

Source: INECO based on the study "External Costs of Transport in Europe – 2011" with an exchange rate of 70 Rupees/€.

B

ACCIDENTS & ENVIRONMENTAL EFFECTS			
Rupees/ 1000 pass-km	Accidents	Environm. Total	Accidents +Environm. Total
Air	35	3.962	**3.997**
Road	2.352	2.205	**4.557**
Rail	42	1.029	**1.071**



SAVINGS ON CO_2 EMISSION AND ENERGY CONSUMPTION

RESULTS → SAVINGS

YEARLY SAVINGS ON 2035 SCENARY		Thousands Ton CO_2	Million l. equiv. Fuel
ESTIMATED YEARLY SAVINGS MAIN TRAFFICS (Mumbai/Pune/Thane - Nasik)	Savings with HS (without Induc. traff.)	17,9	2,9
	Savings with HS Induced	-7,6	-5,7
YEARLY SAVING FROM MAIN TRAFFICS OVER LINES BEYOND NASIK (Jalgaon, Nagpur)	Savings with HS (without Induc. traff.)	61,9	18,3
	Savings with HS Induced	45,0	12,5
ESTIMATED YEARLY SAVINGS TOTAL MAIN TRAFFICS	Savings with HS (without Induc. traff.)	**79,8**	**21,2**
	Savings with HS Induced	**37,4**	**6,8**

A

We have considered **two categories of main traffics:**

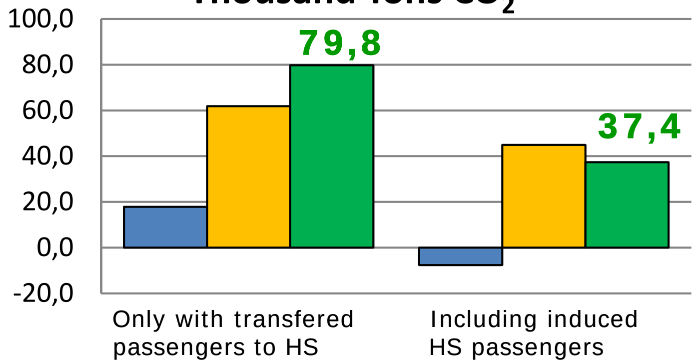
- Main traffics to/from Nasik
- Main traffics to/from beyond Nasik

Only in one year, we have estimated:
savings of 79,8 thousand Ton C02 and
21,2 Million liter equivalent of Fuel,

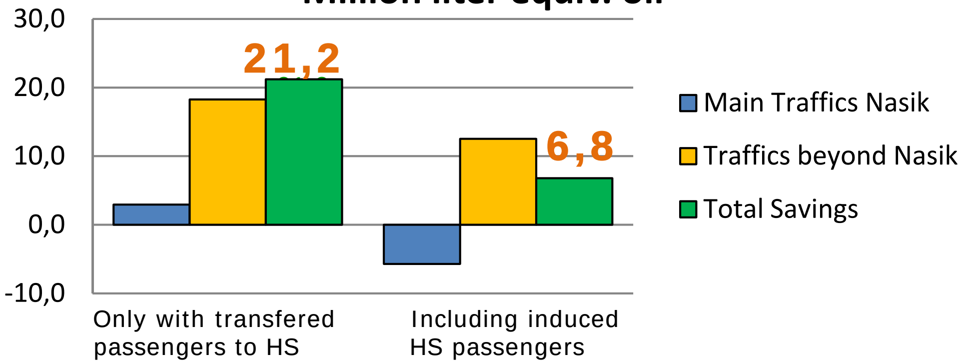
in both cases with a high relevance of savings from traffics beyond Nasik (by conventional trains, more economic in terms of this two characteristics).

Negative savings originated by induced HS passengers are **well recuperated by effects from passengers beyond Nasik**, with a final result of **21,2 thousand Ton CO_2 and 6,8 Million liter equiv of Fuel saved**

YEARLY SAVINGS 2035 SCENARY
Thousand Tons CO_2



YEARLY SAVINGS 2035 SCENARY
Million liter equiv. oil



SAVINGS ON ACCIDENT COST AND ENVIRONMENTAL ITEMS

HSRC

B

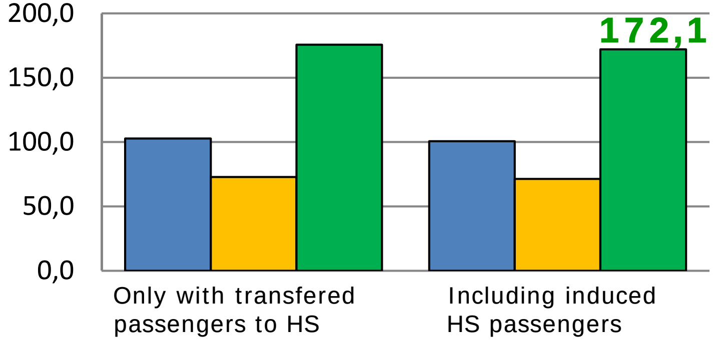
SAVINGS ON 2035 SCENARY (Crores)		Accidents	Climate Change	Environment Impact	TOTAL SAVINGS
ESTIMATED YEARLY SAVINGS MAIN TRAFFICS (Mumbai/Pune/Thane - Nasik)	Savings with HS (without Induc. traff.)	102,8	69,9	67,6	170,3
	Savings with HS Induced	100,6	64,5	15,2	115,8
YEARLY SAVING FROM MAIN TRAFFICS OVER LINES BEYOND NASIK (Jalgaon, Nagpur)	Savings with HS (without Induc. traff.)	72,9	162,9	159,8	232,6
	Savings with HS Induced	71,4	159,4	124,9	196,4
ESTIMATED YEARLY SAVINGS TOTAL MAIN TRAFFICS	Savings with HS (without Induc. traff.)	175,6	232,8	227,3	**403,0**
	Savings with HS Induced	**172,1**	223,9	**140,1**	**312,2**

Reduction of Accidents cost owing to introduction of HSR will reach **172,1 Crores on year 2035**, with a minor impact from induced traffic (as the very low accident index of HSR).

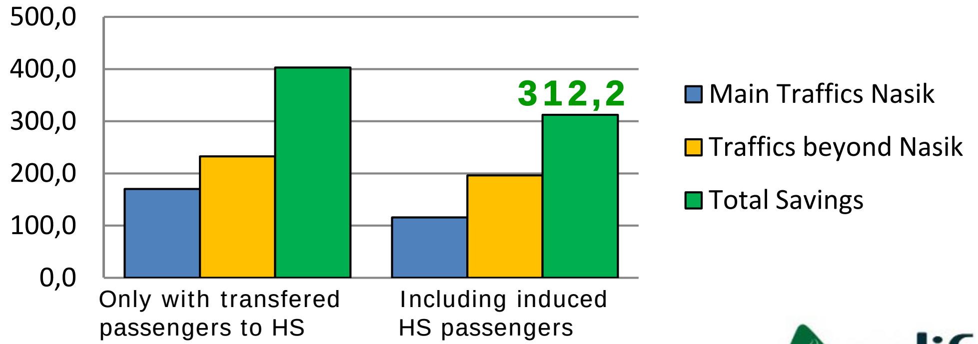
Among Savings related with **Environmental items**, highest value belongs to **Climate Change** (Greenhouse Gases emissions into the atmosphere through fuel combustion directly or indirectly), with **223,9 Crores/year**.

Taking into account the whole set of **Environmental items**, this saving is reduced to **140,1 Crores**, but **Total Savings for all concepts** reach **403 Crores** without consideration of Induced traffic and **312,2 Crores** if we include it

YEARLY SAVINGS 2035 SCENARY Accidents (Crores)



YEARLY SAVINGS 2035 SCENARY Accidents + Environmental Impact (Crores)



Application on Conventional Line CL / section Nasik-Bushaval

Spreading High Speed Rail Benefits through actions on Conventional Lines in Indian Railways network

KEY STRATEGY

Current state of Infrastructure

* Good alignements and Track quality
* Good quality of Electrificaction / Energy
* Maximum Speed 110 km/h
* Degree of use of capacity around 130%

Our performance proposals (PILOT OPERATION):

#: Enhance safety

#: Increase capacity

#: Increase speed

acting on

Signalling,
Optimized Traffic Control Operations
Train Protection ERTMS
Level Crossings Protection

A MAIN CONCLUSION

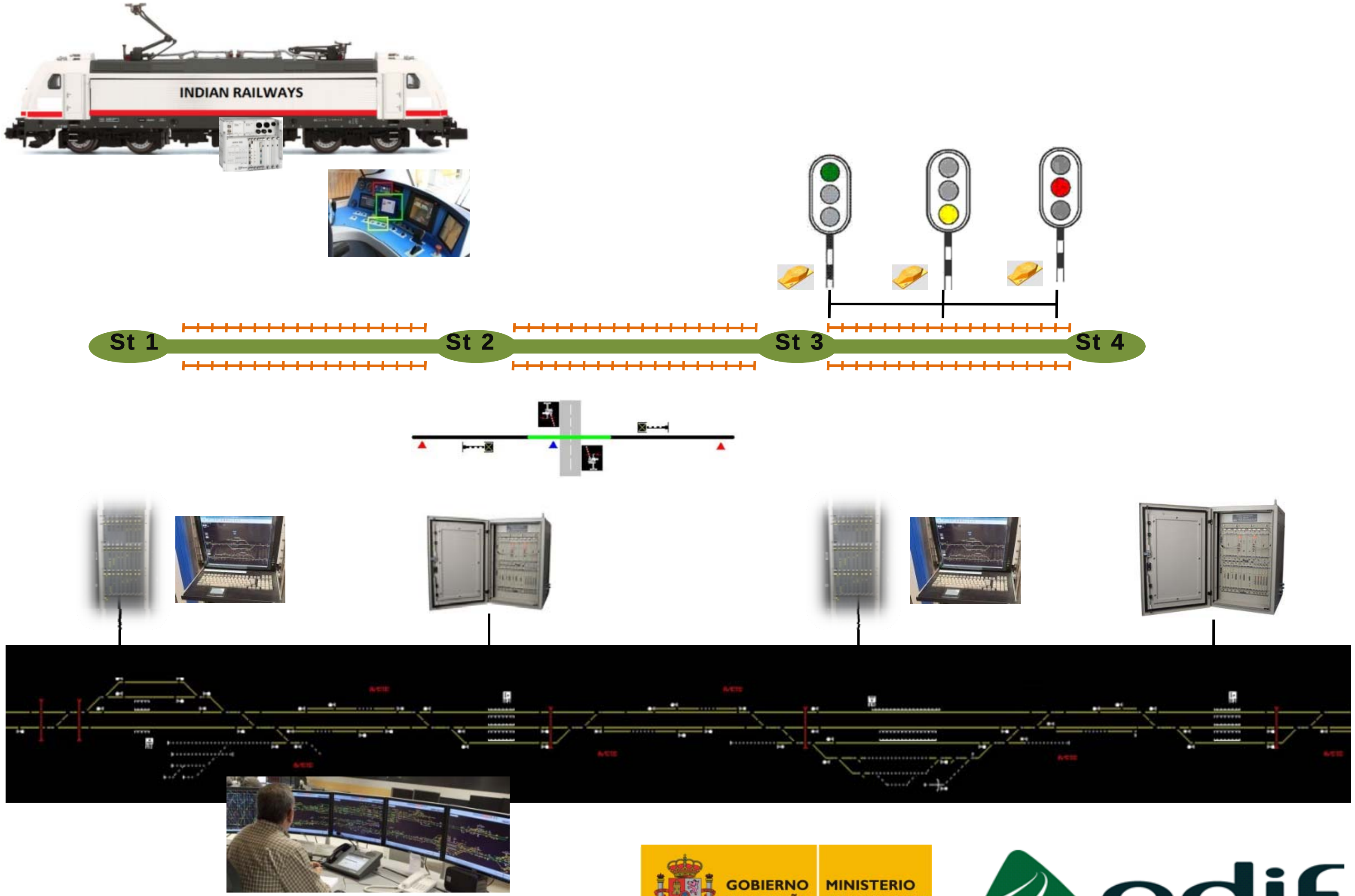
The relevant importance that HSR reaches in terms of **Energy and Environmental savings**, around 400 Crores/year over the section Thane HS – Nasik, but also the weight that traffic coming from connected conventional lines reaches, so the importance of acting over them to get the full benefit HSR can obtain

EXPECTED RESULTS FROM TECHNOLOGICAL ACTIONS OVER CONVENTIONAL LINES

Spreading High Speed Rail Benefits through actions on Conventional Line Nasik – Bhusaval

Updates in Signalling, Train Protection, Level Crossing, Communications & Track Access

- Automatic Train Protection
- OCC – Train Communication System
- New Track Sections
- Fencing
- Automatic Level Crossing Protection
- Electronic Interlocking
- Centralized Traffic Control Center



GOBIERNO DE ESPAÑA | MINISTERIO DE FOMENTO

adif

HSRC

Application on conventional line CL / section Nasik-Bushaval

Total length of CL to be improved 255,04 km

Travel time

Mumbai BKC – Nasik Road	CL 3h 25 min	55,34 km/h		
	HS 47 min	205,3 km/h		
Nasik Road – Bushaval	CL 3h 05 min	82,72 km/h	*Bushaval from Mumbai BKC*	
For Max Speed 160	*2h*	*127,52 km/h*	*2h 50 min*	*146,8 km/h*
Max Speed 200	*1h 30 min*	*170 km/h*	*2h 20 min*	*178,2 km/h*

GOBIERNO DE ESPAÑA MINISTERIO DE FOMENTO

adif ineco

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