

# Energy Efficiency and Measurement in Rolling Stock

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## EMRails 2019

Electrical Measurements for Energy Management  
in Railway Systems

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# 1. HRI Company

**Hitachi Rail Italy (HRI)** is specialized in manufacturing of technologically advanced rolling stock



Following the acquisition of AnsaldoBreda, the most important Italian brand with more than 160 years of history in the rail and metro sector, **Hitachi Rail Italy** owns a wide range of products, ranging from high-speed train to driverless metros

In the field of regional trains **Hitachi Rail Italy** has manufactured the double-deck train “Rock” which is characterized by energy consumption for passenger/km 30% less compared to the most recent electric trains circulating in Italy

# 1. HRI Company: Research & Test Facilities



**Experimental and Validation Circuit  
for Light Metros**

**Railway Test Track**



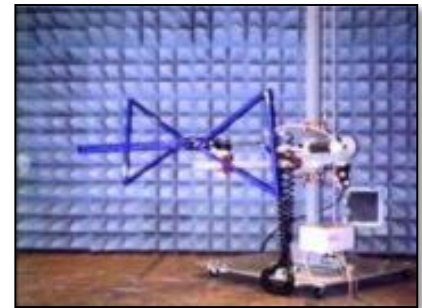
**Railway Vehicles Test Facility**

**Climatic Room**

**Structural Test Stand for  
Mechanical Components and  
Bogies**



**Electromagnetic Compatibility  
Test Room**



**Acoustic and Vibrations Laboratory**

## 2. Needs of Energy Efficiency in Rolling Stock

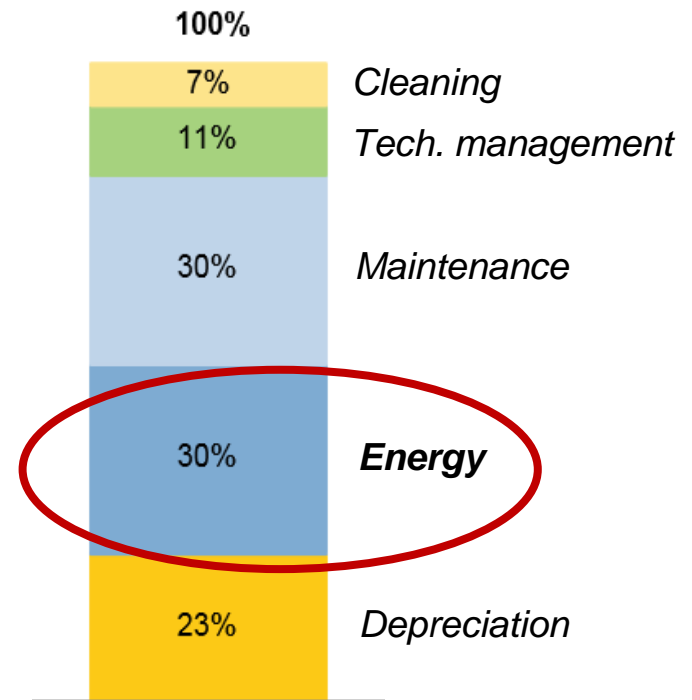
- An increase up to 2.6% per year in the **world rail market** is forecasted for next years, with significant investments expanding market volume up to about € 185 billion
- Different options are available for railway operators:
  - only purchasing,
  - purchasing + full service,
  - leasing
- For each of them, the most important issue is **the investment cost estimation** and the Life Cycle Cost (LCC) and the Net Present Value (NPV) are the most used methods

In order to improve their competitiveness in the market, **rolling stock manufacturers try to reduce the LCC** of the railway vehicles



## 2. Needs of Energy Efficiency in Rolling Stock

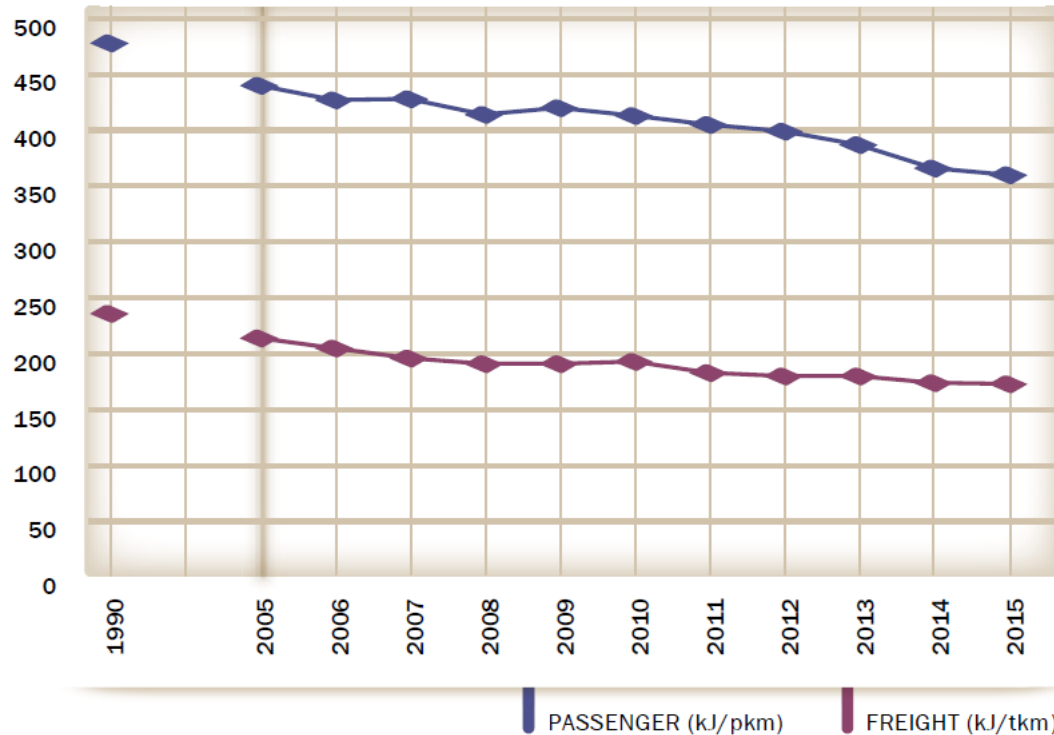
- LCC is used to **identify cost drivers**, allow the comparison of different rolling stock and deliver the necessary information for technical and **economic decisions to be made**
- However, rolling stock are very complex systems, and thus the **LCC cannot be easily and accurately estimated**
- For example, the major drivers of the costs for a high-speed train are:
  - Maintenance (30%)
  - **Energy (30%)**
  - Depreciation (23%)
- For other rolling stock typologies, this costs split **is about the same**, while reducing the total costs



Source: Oliver Wyman - Lean Rolling Stock Maintenance

## 2. Needs of Energy Efficiency in Rolling Stock

Railway specific energy consumption, 1990-2015



- Between 1990 and 2015, average energy consumption per transport unit **decreased by 22.2%** and CO2 emissions **decreased by 45.2%**
- Energy consumption per passenger-km **decreased by 18.2% between 2005 and 2015**, and energy consumption per freight ton-km decreased by 19.2% in the same period

Source: UIC IEA Railway Handbook 2017



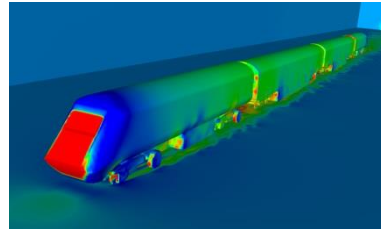
## 2. Needs of Energy Efficiency in Rolling Stock

### Strategies for Improving RS Energy Efficiency

In order to reduce the energy consumption of a fleet of railway vehicles it is possible to act on three main factors:

#### ➤ **Weight Reduction**

- Composite materials
- New bogie technologies

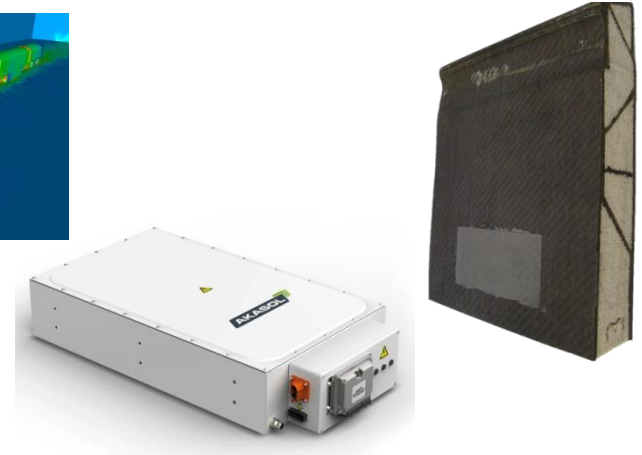


#### ➤ **Aerodynamic (and Noise) Improvement**

- Advanced simulation tools to design the train external surface

#### ➤ **Innovative Components for the Power Traction System**

- Silicon carbide (SiC) power semiconductors
- Permanent magnet synchronous motors
- On-board energy storage systems





### 3. Requirements of Energy Efficiency by Customers

Like the other leaders of the sector, **HRI is strongly committed** to design products with innovative technological solutions to adapt them to the needs of railway operators

Besides a reduction of the times and costs, customers are oriented towards:

- **products with high performance in terms of energy consumptions** to reply to the increasing attention towards the environment and the energy costs
- **products with low consumption and high reliability and availability**, in other words with low life cycle cost



### 3. Requirements of Energy Efficiency by Customers



- Currently, all tenders require the calculation of **the traction energy cost**, which is an important parameter on commuters and even more on high-speed trains

<p><b>Energy Efficiency</b></p>	<p><b>Energy Consumption</b> of the rolling stock calculated in accordance with the standard TECREC 100_001, on B.3 track section (defined on the Appendix B of the standard) and vehicle maximum speed (where the standard provides the side speed at 140km/h), in full load condition, HVAC switched-off and dynamic braking set only as "recover" with receptive track condition</p>	<p><b>kWh</b></p> <p><b>PMD</b> = Maximum Available Score  <b>W</b> = Energy Consumption  <b>VO</b> = Offered W value  <b>Wb</b> = minor W value corresponding to the best offer  <b>Ww</b> = minor W value corresponding to the worst offer  <b>P</b> = Scoring related to the item</p> <p>Calculation  <b><math>P = \text{PMD} * (Ww - VO) / (Ww - Wb)</math></b></p> <p><u>If the best and worst offer will be the same, the maximum available scoring will assigned</u></p>	<p><b>2/100</b></p>
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#### 1. Measurement related to power traction of Rolling Stock to:

- evaluate Losses reduction in the traction chain due to the deployment of new technologies
- price of the total energy absorbed by train and evaluating the energy returned to the grid by trains in the power supply system equipped with reversible substations

#### 2. Measurement related to auxiliary systems of Rolling Stock to:

- evaluate new technologies that allow decreasing the energy consumption in both the auxiliary systems on-board (as HVAC technologies or new lighting systems)

#### 3. Measurement related to energy management of Rolling Stock to:

- evaluate the introduction of ECO-Driving Systems or the driving style differences of existing drivers
- introduce Energy Storage Systems in order to smart manage the use of the on-board energy

### 3. HRI Contribution to MyRails Project

Hitachi Rail Italy is involved in:

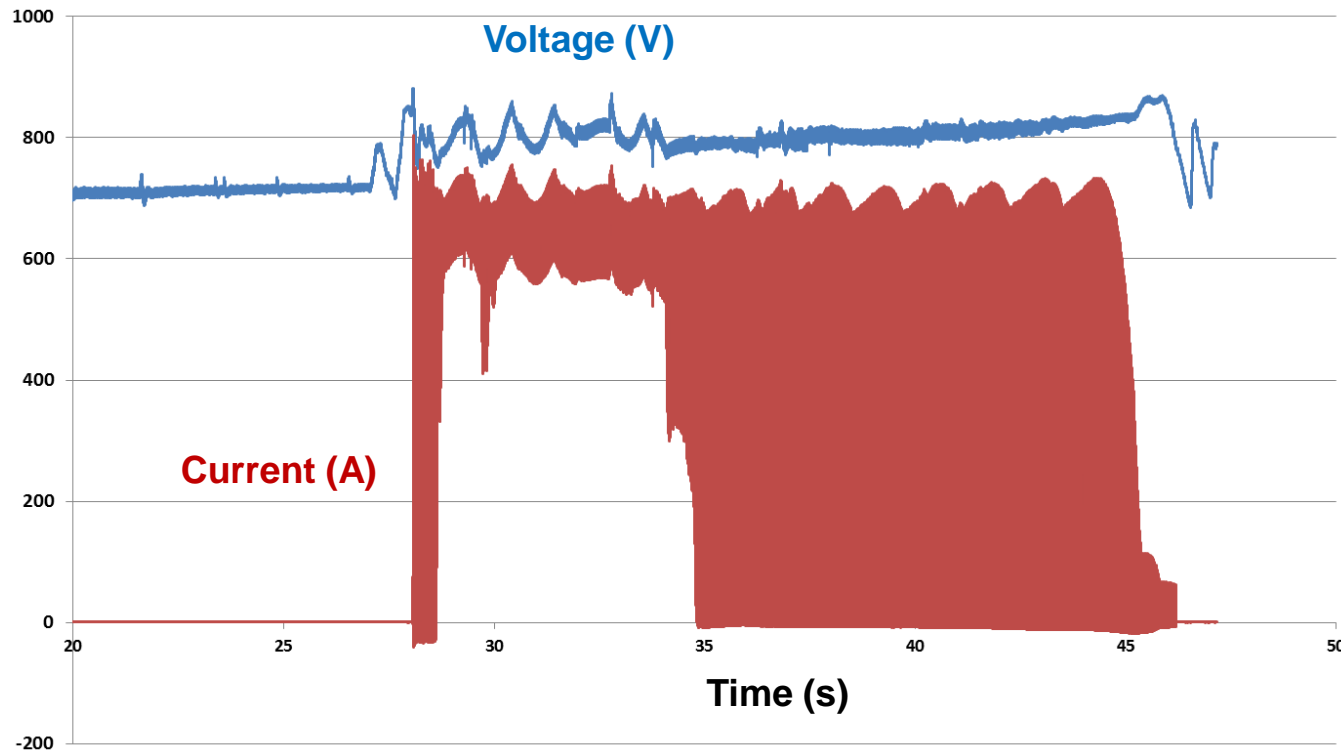


- **WP1 - Calibration of EMF working under AC and DC voltages**
  - *HRI has participated in defining use-cases, and has supplied data to other partners for off-line analysis*
- **WP2 - PQ in supplying railway system: means, methods and on-site applications**
  - *Task 2.1: HRI has contributed to analyze voltage/current waveforms measured at the traction unit pantograph for the 3kV, 1,5kV and 750V dc systems. The electrical characteristics of some vehicle rheostats were also provided*
  - *Task 2.4: HRI has contributed for the Summary report on the identification of advanced metrics for PQ events and on the measurement procedure for on-board assessment of PQ events*
- **WP3 - Measurement-simulation tools to underpin the dissemination of RSSs**
  - *Task 3.1: HRI has been involved to design and test of a measurement system for the braking rheostat losses*
- **WP5 - Creating impact**
- **WP6 - Management and coordination**

### 3. HRI Contribution to MyRails Project

#### Task 2.1 - Voltage/Current Acquisition

- A real section line has been reproduced inside of **HRI test facility** in order to acquire data related to the energy wasted during a rheostatic braking and properly size the energy meter
- **HRI acquired a braking rheostat current and voltage waveforms** of a metro railway vehicle: it is a very difficult measure to implement due to the high harmonic content of the waveforms

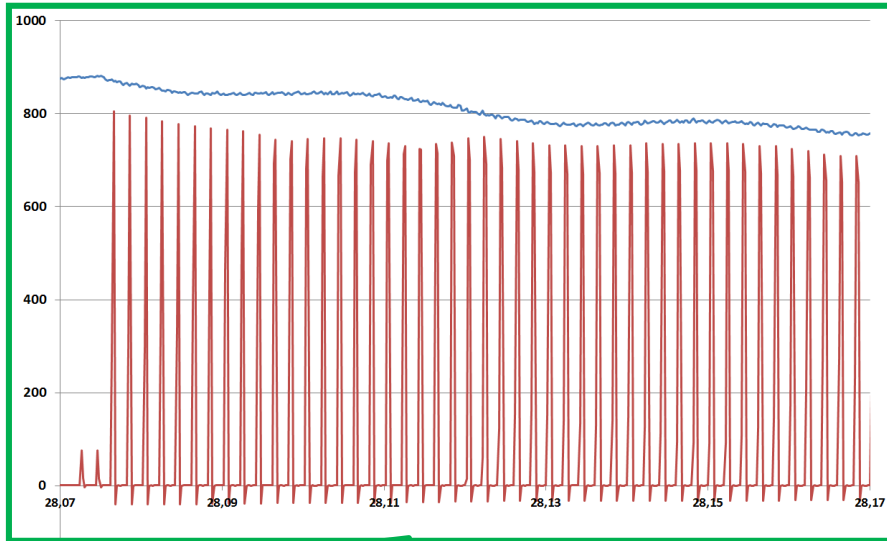


**Sample time = 200us**

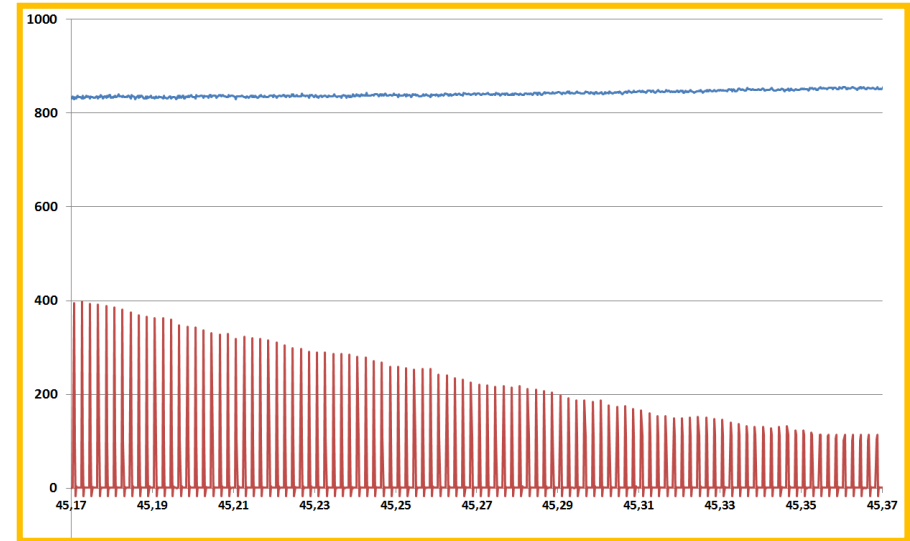
According to the standard TECREC 100\_001, up to **1.7 kWh** are wasted as heat during each single brake !!

# 3. HRI Contribution to MyRails Project

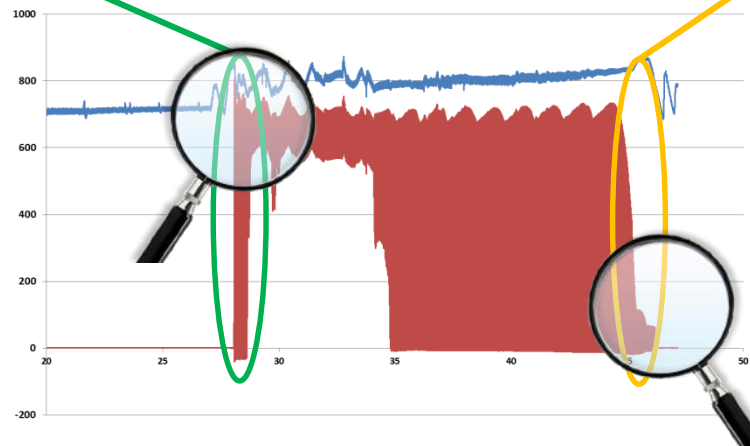
## Task 2.1 - Voltage/Current Acquisition



100ms time interval



200ms time interval



# 3. HRI Contribution to MyRails Project

## ➤ According to the **TECREC 100\_001** standard:

### 6.2.5 Regenerative braking

For electric trains, the regenerative brake (if available) shall be used as preferred braking system, within the constraints of capability of the brake, timetable, and applicable rules for safe operation of the train.

The calculation of the energy consumption shall be done as follows in cases where the electric traction equipment allows for regenerative braking

- For AC electrified railway systems: net energy at pantograph, i.e. fed back energy counted as negative without any other reduction factor than the one possibly imposed by the electric traction system itself (if for example a part of the braking energy is systematically consumed in resistors even in regenerative mode)
- For DC electrified railway systems, two calculations shall be made: the first one in the same conditions as for AC railway systems, the second one with the total braking energy consumed in the vehicle without any consideration of fed back energy. These two extremes correspond to fully regenerative and fully rheostatic braking respectively. The consumed and fed back energy at pantograph shall be identified separately for both AC and DC railway systems. It may depend on the individual project or economic rules in different countries how consumed and fed back energy is taken into account for life cycle cost (LCC) considerations.

The calculation of the energy consumption shall take into account the effect of any on-board energy saving systems, e.g the amount of braking energy stored in batteries or other devices for later use by traction or auxiliary systems or the possible use of the diesel engine losses for train heating.

- However, **in real operating conditions, we do not have only fully regenerative braking or fully rheostatic braking !!**



# 3. HRI Contribution to MyRails Project

## Task 3.1 - Measurement System Characterization

### ECOmeter

Nominal Voltage ranges Available	750Vdc, 1.5kVdc, 3kVdc, 15kVrms@16,67Hz, 5kV@50Hz
Maximum Input Current	4000 Adc and 1000 A rms
Accuracy Class:	0.5% (according to EN50463)
Nominal Battery supply	Extended range from 24V to 110V
Weight	40kg
IP Protection level	IP 66
Storage temperature	from -40°C to +85°C
Class of altitude range (EN 50125-1)	A1 (up to 1400m)
Mechanical Stresses	Load of 2000N for 1h on the top of the Insulator Torque 100Nm
Rolling Stock Category (NF F 16-101 and NF F 16-102)	A1

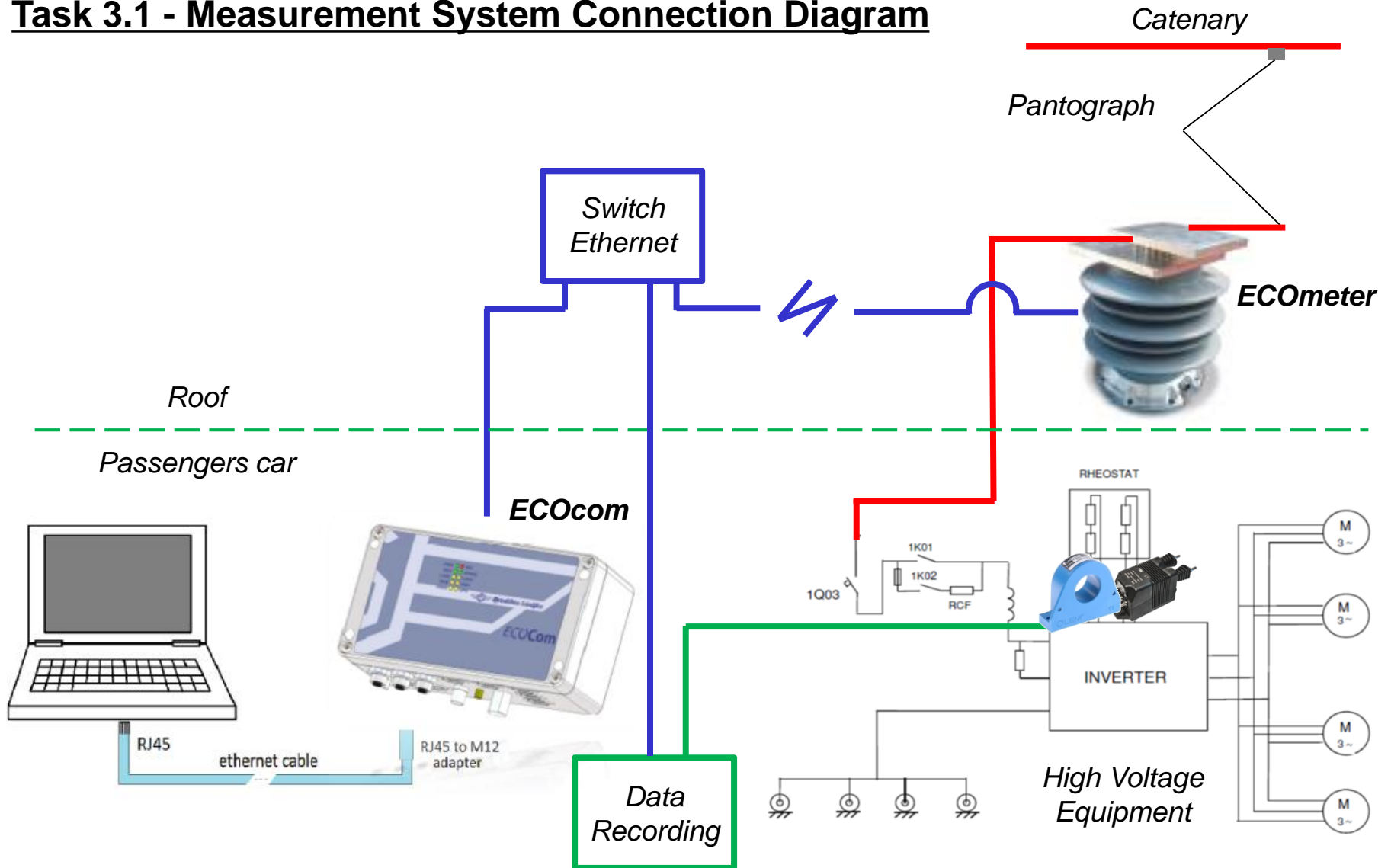


- HRI has carried out **preliminary laboratory tests** for the energy measurement system consisting of **ECOmeter** and **ECOcom** devices
- The **ECOcom** device collects data coming from different devices installed on the vehicle, elaborates them with complex algorithm and **displays them on a PC laptop** via Ethernet bus connection
- The voltage and current are measured and the energy value is calculated **in compliance with the standard EN 50463**



### 3. HRI Contribution to MyRails Project

#### Task 3.1 - Measurement System Connection Diagram



- Tests will be performed on **Metro de Madrid** to evaluate the total energy of the railway vehicle during both traction and braking phases, and to estimate the accuracy of the native on-board measuring systems
- The energy meter will be tuned in the **INRIM laboratory** (Turin - Italy) before being installed on the roof of a Metro de Madrid for tests in normal operating conditions
- Metro de Madrid is a railway vehicle **designed and manufactured by HRI**, which have a full service contract and then will be involved in the set up of the on-board ECOmeter and during the experimental test activities



# Thanks for Your Attention

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**HITACHI**  
**Inspire the Next**