ECORailS –
Energy efficiency and environmental criteria in the awarding of regional rail transport vehicles and services

ECORailS

Deliverable 7:
Integration of technological feedback from the User Platform and the consortium into the guidelines

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Content

1. Executive Summary

The present Deliverable is structured to provide a description of the further results achieved within ECORailS WP2 activities to be included into the Guidelines and to integrate the feedback on the previous technological results from the User Platform.

In chapter 2, after an introduction and the definition of the project framework, including the link between WP2 activities and D7 aims, a synthetic overview of the database concerning technologies and operational measures, extensively described in D6, including information sources and related references, is presented.

In chapter 3 all the technologies and operational measures under evaluation are classified by clusters and the state of the art has been described, focused on the achievement of a consolidated methodology to define energy consumption for regional passenger transport, which is a critical aspect the Guidelines will have to face.

The energy consumption of a train (described in paragraph 3.2) strongly depends on the energy consumption of the traction system, of auxiliaries and of comfort function equipments, that, in their turn, depend on their real efficiency related to their instantaneous operational parameters and their maintenance conditions. Therefore the energy consumption of a train depends on characteristics of the train, characteristics and conditions of the line (i.e. service profile, see paragraph 3.2 for their definition), environmental conditions, comfort parameters, the planned operation of trains and different driving styles, that could cause high variation between different drivers (more than 49 %, see Fig. 5-1 and Fig. 5-2).

The following chapter 4 is dedicated to depict the technical context for the ECORailS Guidelines application, by describing quantitative elements, emerging issues and trends concerning operated fleets and services in regional transport. The influences of the composition of fleets have been highlighted which influence the starting point in different countries and related traffic parameters. Examples of best-practice of energy efficiency and environmental requirements in awarding and the TOCs perspective is depicted in paragraph 4.4.

A detailed description about the complexities implied by the energy consumption calculation and measurement is included in chapter 5.

In chapter 6 specific indicators are defined which are useful for qualifying specific solutions (technologies and operational measures) on the basis of their energy saving potential, potential for reducing emissions of pollutants, the economic potential and implementation time.

Chapter 7 anticipates a Pilot Catalogue with a first selection of the most promising technologies and operational measures evaluated and already integrated into the first draft of the guidelines as first results of the evaluation work.

Finally, in chapter 8 the general remarks emerging from the WP2 work are described.

Some of these remarks have been further synthesized and are summarised hereafter in the following resulting issues:

- limited availability of experimental data about energy efficiency technologies and operational measures which could prove the real potentials (savings for a single vehicle or a specific fleet) of many solutions;

- existence of different measurement systems (on board and at ground) to evaluate the keeping of the contract related to an awarding procedure;
  - the specification of a limit value for the KPI2 and KPI4 (Key Performance Indicator defined in D6 and synthetically carried out in paragraph 5.3) as a requirement to be fulfilled by the proposed rolling stock (as for Reliability Availability Maintainability - RAM - indicators) in a direct contract procedure (possibly with bonus/penalty clauses in case the effective value of the indicator will be less or more than this limit value);
  - requirements for the manufacturers or the TOCs for calculating and providing their best offered value for KPI2 and KPI4 (again as foreseen for the RAM indicator);

  in any case the PTAs have to specify all the characteristics and conditions defined in paragraph 3.2 with reference to the state of the art, moreover, in order to clearly measure in a common accepted and agreed (legal secure) way the energy consumption for the specified line or for the selected reference track, it could be performed an agreed combined test during the commissioning phase (acceptance by the customer of the prototype) in the following controlled (during the test) conditions:

  - respect of the driving style suggested by the manufacturer or the TOC and of the specified timetable;
  - no other trains disturbing the test (respect of timetable without any delay);
  - agreed (possibly in compliance with TSI and CENELEC standards) energy meters (see paragraph 5.4) to measure the energy consumption with: different payload; an agreed overhead contact line voltage and, where relevant, an agreed energy receptivity by the overhead contact line;
  - evaluation of KPI2 and KPI4 (on the basis of the simulated payload condition) and comparison with the offered values;
  - monitoring of the real operational performance of the rolling stock data provided by the energy meters in case the contract is with the TOC (not applicable in case of an awarding procedure for the procurement of rolling stock by a PTA) and verification of the possible bonus/penalties clauses specified in the contract taking into account the technologies and operational measure provided by the TOC for energy savings (e.g. the effectiveness of the used energy meters data, the real use of the technologies and their operating efficiency);

  combined tests for a new class series of vehicles are foreseen anyway for other purposes (for the authorisation process by the Safety Authority). The results of previous tests, related to previous contracts, could be evaluated by PTAs if made available by previous customers because they have the property of these results, as provided for by EN 17025;

- in the Railenergy project Standard Service Profiles (SSP) are being determined and some of them could be interesting for ECORailS in view of a possible integration in the awarding procedures. The energy consumption calculated referring to this service profile will not be compared in a real environment, thus these standard service profiles are not linked to a real test track;

- in order to assess the potential of specific solutions to save energy and reduce the emission of pollutants, manufacturers should provide on-off switching devices to allow the measurements with and without the new solutions and to ensure the availability of the train, although in a degraded operational mode, if the technology occasionally fails. It seems difficult to monitor the real operational performances of single solutions, nevertheless it could be possible to ask for the repetition of specific type, or combined, test at certain time intervals in order to verify the compliance to determined standards of specific technologies or of specific issues, e.g. noise emissions and pollutants (as provided for in the road sector where specific tests, at certain intervals of time, have to be performed to circulate within restricted area, e.g. the centre of the cities);
- there are positive approaches towards integrating environment-related criteria in tenders of regional rail services or the procurement of new rolling stock, but they are still rather exceptions than standard procedures. Economic criteria are still almost absolutely dominant for decisions.

2. Introduction and project framework

2.1. WP2 activities and D7 aims

The present Deliverable is the second document issued by ECORailS Work Package 2 (WP2): Technologies.

According to the description of the actions included in Annex 1 of the Contract, WP2 is expected to give a documentary overview of relevant technologies and related markets, to be identified in the participating countries and in the whole Europe.

The work is organised along a period of 22 months in the following Tasks:

1. Technologies:
    - 1.1. State of the art and foreseeable trends
    - 1.2. Comparison of available technologies and operational measures
    - 1.3. Future technological trends in awarding
2. Analysis of the environmental impacts.

D7 includes mainly the results of Sub Task 1.2, which developed its activities according to the working scheme in Fig. 2-1, and a synopsis of Task 1.1 results relevant for the development and the description of Task 1.2 activities.

In this context the main D7 aims are:

- to depict the guidelines application field from a technical point of view;
- to identify direct and indirect indicators to be used;
- to integrate the technologies feedback into the guidelines;
- to present a selected set of technologies and operational measures quantified and assessed on the basis of the selected indicators (Pilot Catalogue of technologies and operational measures);
- to integrate the feedback from the User Platform into the qualification process for technologies and operational measures.

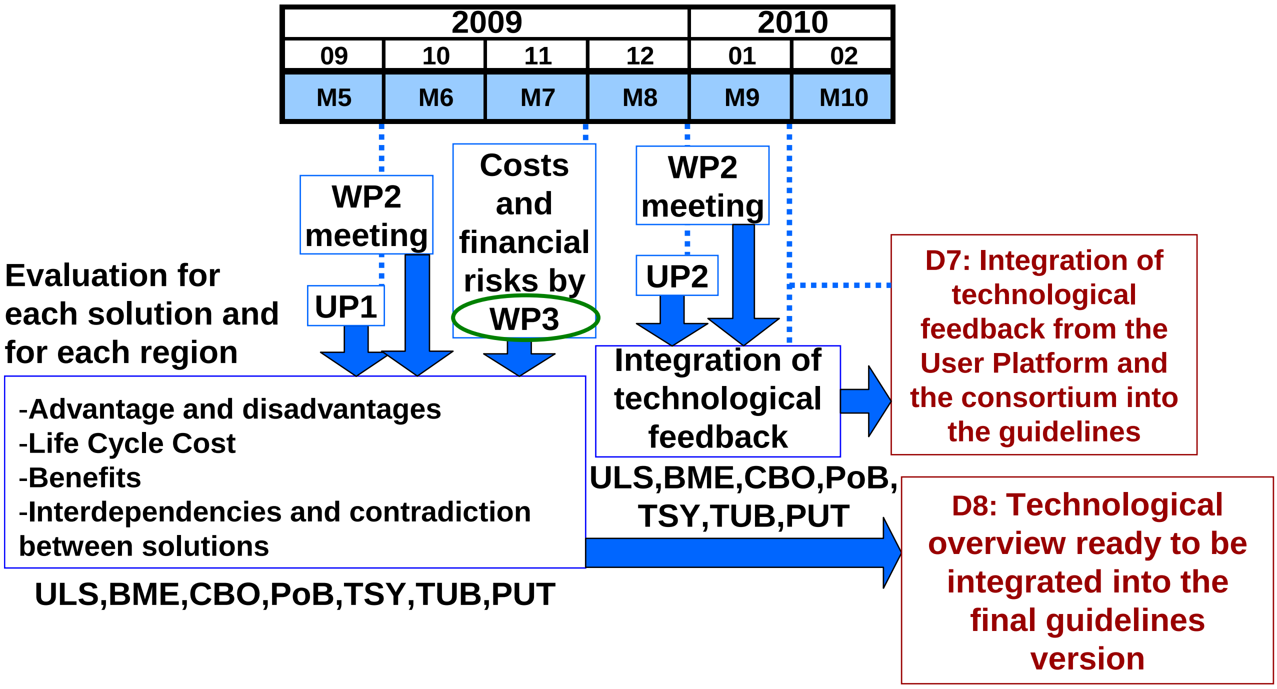

Fig. 2-1: WP2 Task 1.2 – Working scheme

2.2. Main references for ECORailS database

The collection of information and best practices about Energy Efficient (EE) and Environment-Friendly (EF) technologies and operational measures has been performed by the analysis of:

- the results of previous or ongoing European projects as EVENT, Railenergy and PROSPER,
- the technical literature,
- the advertise information provided by the manufacturers of subsystems or the industry (often systems integrator) on websites or in press releases.

The main source of information was the Database for energy efficiency technologies and operational measures made available on internet by UIC (EVENT Project) including about 90 technologies and an expert evaluation for almost each of them, though taking into account that the EVENT Final Report is dated 2003 and the potentials estimated are not verified by experimental data.

Other relevant source was the Railenergy project, though it is more oriented to investigate and validate solutions from the point of view of an integrated railway system and this aspect makes it more difficult to relate its results to a specified type of contract for services or for vehicles.

Moreover the Railenergy activities are ongoing and the evaluation or collection of the values for the identified key performance indicators are not yet available nor have the benchmark analyses of different simulation tools for the calculation of energy consumption and their validation by comparison with experimental data been performed yet. Railenergy intends also to specify standard service profiles for suburban and regional traffic in the near future (see paragraph 3.2).

In the UIC project PROSPER a leaflet was produced, in which all relevant aspects for the integration of environmental aspects into the procurement process were addressed.
The Leaflet ("Environmental specifications for New Rolling Stock") is aimed at contributing to the harmonisation of the environmental procurement framework in the rail sector to achieve a more efficient procurement process enabling railways to procure with higher effectiveness new rolling stock with sound environmental performances.
The ECORailS point of view deals with environmental specifications and energy efficiency from a Public Transport Authority (PTA) perspective. Therefore, an additional relevant source of information is the feedback from the stakeholders interviews (technological chapter) developed in conjunction with WP3, as well as the feedback from the first and the second User Platforms in Berlin.

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2.3. Abbreviation list

AC	Alternated Current
CR loc&pas	Conventional Rail Locomotives and Passenger Rolling Stock
D	Deliverable
DC	Direct Current
DMU	Diesel Multiple Unit
EE	Energy Efficient
EF	Environment-Friendly
HVAC	Heating, Ventilation and Air Conditioning
KPI	Key Performance Indicator
LCC	Life Cycle Cost

MU	Multiple Unit
PTA	Public Transport Authority
RAM	Reliability Availability Maintainability
SSP	Standard Service Profile
TOC	Train Operating Company
TSI	Technical Specification for Interoperability
UIC	International Union of Railways (Union des International Chemins de fer)
UNIFE	European Rail Industry Association

3. Technologies and operational measures

3.1. Synopsis and classification by clusters

In the first phase of WP2 work (see Deliverable 6) a checklist has been produced including 83 solutions (technologies and operational measures) grouped into clusters.

The clusters have been identified on the basis of the expected chapters/paragraphs to be included in the technical annexes of the possible awarding contracts for vehicles or for services.

Nevertheless some definitions have been adjusted to be more easily integrated into the Guidelines in view of a possible fruition by non-technical readers.

The selected clusters for the technologies are listed below.

Cluster T1 - Train formation or typology: This cluster includes all choices affecting the typology of the train, different combinations of components (e.g. bogies shared between two units) or, at an extreme case, the change of the whole traction system (e.g. magnetic levitation technology). Some choices refer to the particular shape of the car body (e.g. double-decked stock) to increase the seating capacity per train length leading to positive impact on energy efficiency and cost effectiveness by a minor weight per seat. A group of technologies in this cluster is related to different ways to compose a train by employing different kinds of vehicles or levering on the length of the train.

Cluster T2 - Noise and/or vibration reduction: This cluster contains the techniques aimed at reduced noise emissions. Obviously this technologies concern mainly the components that usually are the principal sources of noise because of the presence of friction, such as braking system and wheels.

Cluster T3 - Optimisation of comfort functions: This cluster includes all technologies concerning a new management of comfort functions oriented to avoid wasting energy. The term “comfort functions” refers to those elements that are important for on-board people (passengers and personnel) like lighting system or systems regulating the inner climate. The idea, on which these technologies are based, is adapting the energy consumptions to the different demand situations and avoiding the heat dispersions through the use of insulating materials.

Cluster T4 - Use of particular materials or structures for mass reduction: This cluster describes the employment of new lighter materials (e.g. aluminium for the car bodies, light interior coach equipment) and structures (e.g. sandwich structure) to reduce the total mass of the vehicle. In some cases the originality of the technologies contained in this cluster is to put on the railway market certain material which is already used in other fields.

Cluster T5 - Improvement of traction equipment efficiency: This cluster represents different attempts to increase energy efficiency taking action directly on traction systems. Obviously the technologies mentioned here are very different from each other due to the different possible traction typologies. Therefore such solutions give rise to changes on motors or on electricity equipments (e.g. transformers), and on auxiliary traction equipments (e.g. their demand-controlled operation).

Cluster T6 - Use of bio-materials allowing recyclability

Cluster T7 - Reduction of energy consumption by recuperation and storage of energy: Cluster 7 contains all the technologies generally aimed at reducing energy consumption. This goal can be achieved by re-using energy. Several ways to store (e.g. by super-capacitors) - on-board or in fixed installation - the recovered energy (e.g. the braking energy) are reported in this cluster but the final employments of the recovered energy are essentially two: traction purpose or auxiliary functions purpose. In this cluster there are also some practices based on consumptions recording to allow well planned changes aimed at exploiting eventual margins of energy consumption reduction.

Cluster T8 – Reduction of exhaust pollutants: This cluster groups technologies aimed at reducing gas emissions by filters, by optimisation within the engine or by new techniques already in use in other sectors.

Cluster T9 - Improvement of auxiliary efficiency: Some auxiliaries like air compressors for braking pneumatic system and other pneumatic actuators, or components of the braking system could consume less energy and produce less noise by new technological features (rotary compressors, compact braking units, …).

Cluster T10 - Reconditioning/revamping of vehicles that already exist: This cluster comprises some technical adjustments on already existing vehicles. In many cases, the high disposal costs and the elevated costs to acquire new rolling stock could justify changes on old fleets to reduce energy consumptions, noise and emissions. The actions on old trains can be substitutions of motors with more efficient ones (also unconventionally propelled motors), or their upgrading or substitution of other components (e.g. interior coach equipment, compressors …) that actually can be realized with better performances.

Cluster T11 - Unconventionally propelled locomotives or Multiple Units: The technologies included in this cluster involve new traction typologies (e.g. hybrid solutions) and exploit new propelling machinery.

The selected clusters for the operational measures are as follows.

Cluster M1 - Training program to raise awareness of personnel: In this cluster there are some measures that refer to energy efficient driving by studied driving strategies and eventually by driving advice systems. So these solutions implicate a planned analysis of the characteristics of each line (altimetric and planimetric features, speed limits, distance between stops, …) and of the recovery times in the timetable, the study of existing saving energy margins and then the definition of the most opportune driving strategies. Quite obviously, after this technical analysis, it is necessary to acquaint the drivers with the planned changes, to train them and often to stimulate them to do better.

Cluster M2 - Energetic optimisation of timetable: contains operational measures based on timetable optimisation. To do that, it is necessary to consider not only the characteristics of the lines (distances, signalling, speed…) but it is basic also to know what the constraints to satisfy the demand are.

Cluster M3 - Speed harmonisation: Speed harmonisation is a means to improve line capacity especially where demixing fails or has reached its limits. The measure consists of adapting the speeds of all trains which are running on the same track and thus achieving enhanced traffic fluidity. Increased traffic fluidity can have energy efficiency effects.

Cluster M4 - Optimisation of train operation by control centre: includes solutions relating to centralised control of circulation by optimisation software to support complex decision making and give driving recommendations from control centre to trains. In an extreme case, an automated driverless operation through centralised optimisation of driving style and traffic flows could be clearly more energy efficient.

Cluster M5 - Energy meters: presents only one measure which consists of energy measurement by installation of energy meters in railway vehicles and recording documentation. This solution provides consumption data for an exact energy billing system and for the assessment of energy saving measures (both technologies and operational measures) and their tuning (e.g. from consumption data it is possible to define changes about driving styles, operational measures in cluster M1).

Cluster M6 - Management and organisation: Solutions in this cluster are legal and administrative solutions. Some of them suggest the way to ask requirements for energy efficiency in the contracts (e.g. LCC driven procurement) as the keeping of limits on some parameters (e.g. LCC, energy consumption, weight) leaving the responsibility of finding the appropriate solutions to the supplier. These kinds of requirements (e.g. bonus/penalty rules) could also stimulate research and development by suppliers, also in the long term, to achieve better performance for well defined parameters (e.g. LCC, energy consumption, weight) to be evaluated during the awarding process and to be monitored during the operation time. Other agreements, based on incentive systems, involve the drivers by stimulating them to save energy.

Cluster M7 - Passenger information systems: This cluster involves also the final users in the energy-saving process by letting them know information about composition of the train approaching the platform. In this way the boarding time is decreased and the delays are reduced. This is relevant for energy efficiency because delays reduce the potentials for energy efficient driving.

Cluster M8 - Noise reduction: These solutions are mainly noise-reduction oriented. They consist of an evaluation of noise emissions during the awarding process (e.g. noise driven procurement) and/or during the operation time (e.g. identification of noise and wheel flats by trackside fixed measurement systems in strategic sections of the track).

All the solutions (technologies or operational measures) are furthermore classified:

1. for possible applications within 5 years (short term) or beyond (long term);
2. by dividing them into the categories “very promising” / “promising” / “interesting” or judgements according to a preliminary evaluation based on EVENT project results and additional expert evaluations.

The categories “very promising”, “promising” and “interesting” provide the “Overall rating potential” as defined in the EVENT project. This has been done according to a key taking into consideration the criteria in Table 3-1.

General criteria	Environmental criteria	Economic criteria
• Benefits • Barriers	• Energy efficiency potential throughout fleet	• Vehicle - fix costs • Vehicle - running costs • Infrastructure - fix costs

Table 3-1: Criteria for overall rating criteria according to EVENT

Details about the evaluation procedure are laid out in the EVENT Final Report – Appendix A [2].

In the case of solutions not included in the EVENT project analysis, a first rough evaluation of the "Overall rating potential" in the EVENT project meaning has been done by ECORailS WP2.

All the information about each solution and each technical context (included in D6 Electronic Annex II), already collected and analysed, will be involved in the ECORailS evaluation process.

Table 3-2 gives an idea of the amount of technologies and operational measures analysed. An interesting result is the fact that there are about 30 "very promising" solutions. The solutions included in the Pilot Catalogue, which is used for pilot testing in WP4 have been selected out of this group.

	Technologies		Operational Measures	
	short term	**long term**	**short term**	**long term**
Very promising	17	4	10	-
Promising	21	5	3	-
Interesting	16	4	2	1
TOTAL	**54**	**13**	**15**	**1**

Table 3-2: Distribution of solutions according to their preliminary evaluation

3.2. State of the art and future trends

The draft Guidelines (see Deliverable 19) include in Part I the synthetic (at clusters level) description of technologies and operational measures.

On this basis the Guidelines will be ready to integrate also the corresponding state of the art in terms of procuring environmental friendly rolling stock, which will be based on the approach of UIC Leaflet 345 and similar projects.

Moreover the Guidelines will face the following additional critical aspects:

- the achievement of a consolidated methodology to define energy consumption for regional passenger transport;
- the inclusion of energy efficiency criteria/requirements in the awarding of regional passenger services or in the procurement of vehicles for this kind of services;

For the first aspect the energy consumption of a rail vehicle could be defined as the amount of energy that, through the diesel fuel tank or the electrical supply collector (pantograph), flows to the train, irrespectively of how that energy is used, minus regenerated energy that flows back, through the electrical supply collector (pantograph), to the overhead contact line.

The energy consumption of a train depends on the energy consumption of the following equipments:

- traction system (considered by Clusters T5 and T11), e.g. traction motors, transformers, converters, auxiliary traction equipments (mechanical fans and pumps, etc.), electrical line filters, gearboxes, axles and wheels, etc.; their energy consumption (dissipated energy) could be more than 45 % of the total consumed energy;
- auxiliaries (considered by Cluster T9), e.g. mechanical fans, air compressors for pneumatic brake systems and other pneumatic actuators, doors closing systems, etc.
- comfort functions (considered by Cluster T3), e.g. heating, ventilation and air conditioning systems (up to 10 % of traction power could be spent for air conditioning), etc.

In particular the energy consumption depends on the real efficiency of each of these equipments related to their instantaneous operational parameters and their maintenance conditions. Some of them consume energy also during standstill and parking phases (through pantograph or through a special heating terminal).

Basic parameters that influence the energy consumption for traction purposes are the **characteristics of the train**:

- length and weight (train fully equipped for service operation without passengers on board);
- pay load weight;
- wheel diameter at new and maximum wear values;
- factor for rotating masses or dynamic mass;
- maximum speed;
- service acceleration and deceleration rate;
- traction and electrical braking effort versus speed;
- resistances to forward motion versus speed;
- additional resistance (e.g. curves and gradients);
- braking energy recovery capability and its efficiency (where applicable);
- braking energy storage capability and its performance, e.g. see Fig. 3-2, (where applicable);
- tilt systems (where applicable);

Further parameters that affect energy consumption are the **characteristics and conditions of the line**:

- longitudinal profile (total length, mileage points and altitude of stations as well as start and final points of each section, with different gradient;
- speed profile (permanent speed limits and temporary speed restrictions);

- tunnels position, section and length;
- curve radius;
- nominal characteristics of the electrification systems (AC/DC, voltage, frequency);
- pantograph (line) mean voltage.

With reference to the real set of characteristics and conditions of the line it is possible to define a **specific service profile**.

The use of a reference service profile might be a possible alternative. For this purpose the most appropriate **standard service profile** out of the following ones can be selected:

- Suburban;
- Regional;
- Intercity.

These standard service profiles are currently being developed by the Railenergy project.

The concerned **ambient conditions** are:

- altitude (above sea level);
- air pressure;
- front wind velocity (average front wind in operation);
- temperature (mean value, minimum value in winter season and maximum value in summer season);
- relative humidity;
- equivalent solar load (intensity of sun light in W/m^2).

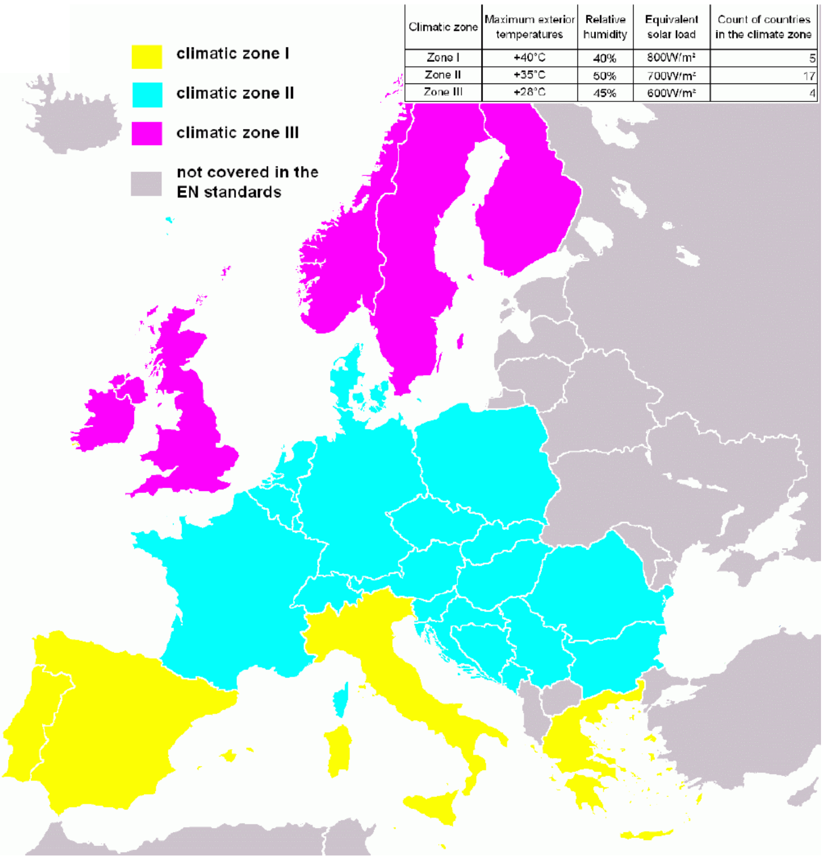
Parameters for the last three bullet points can be identified referring to the specifications of the European standards climatic zones (e.g. see Fig. 3-1) defined by the EN 14750 (urban and suburban rolling stock) and EN 13129 (main line rolling stock).

Comfort parameters (air temperature, air speed, relative humidity, temperature of interior surfaces, normal and extreme exterior operating conditions, pre-heating and pre-cooling conditions and performances, …), affecting HVAC performances and consumption, can be used as specified in the EN 14750 (urban and suburban rolling stock) and EN 13129 (main line rolling stock) for each climatic zone, or directly specified by the customer.

Other important factors for energy consumption are the **foreseen operational features:**

- timetable;
- operational safety rules (foreseen overtaking, imposed stops, etc.);
- empty running;
- total average duration of the pre-heating or pre-cooling period;
- load profile (electrical power consumption and voltage, interior temperature increase or decrease and time, etc.) for the pre-heating or pre-cooling period;
- total average duration of the cleaning period;

- load profile for the cleaning period;
- total average duration of the parking/hibernating period;
- load profile for the parking/hibernating period.



Climatic zone	Maximum exterior temperatures	Relative humidity	Equivalent solar load	Count of countries in the climate zone
Zone I	+40°C	40%	800W/m²	5
Zone II	+35°C	50%	700W/m²	17
Zone III	+28°C	45%	600W/m²	4

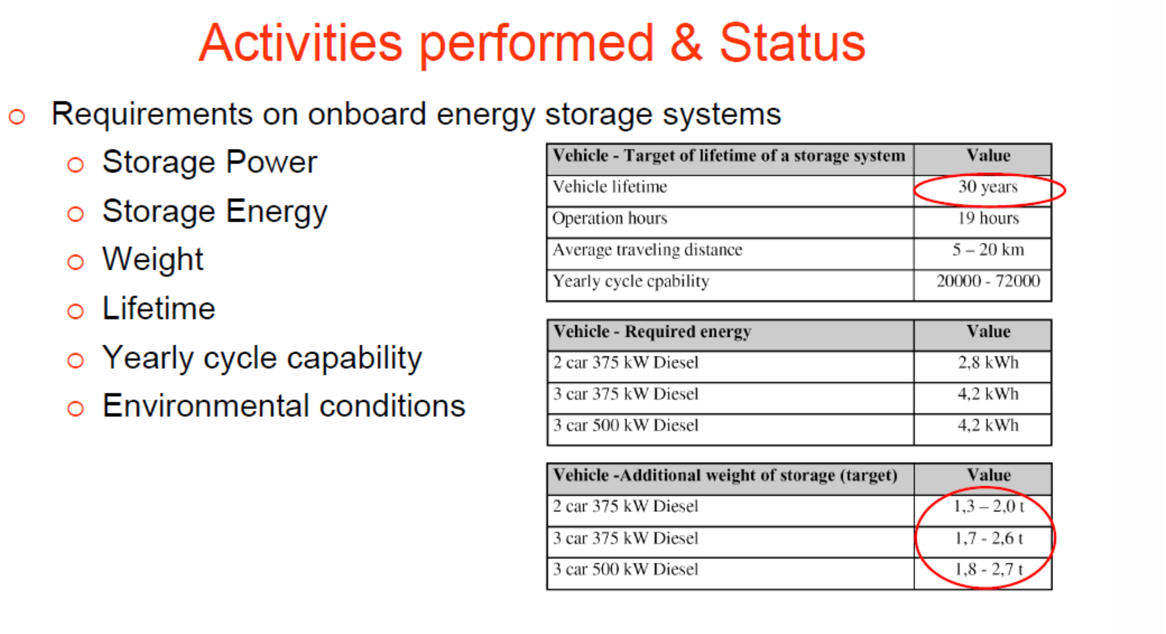
Fig. 3-1: European standard climatic zone [15]

From a general point of view one train on a network needs energy for the journey from A to B. If there are no trains disturbing it, it is possible to calculate the energy consumption considering the parameters and conditions above. For this purpose you may apply a clearly defined, measurable, calculable, verifiable and common accepted energy consumption evaluation for a specific service profile and a specific driving style.

If other trains are running on the same network the calculation is more difficult because other trains may disturb the run and cause delays, therefore the energy consumption is partly out of the control of the train itself.

The strong influences of ambient conditions and regional aspects (e.g. different costs of energy and power generation processes) let seem an approach being preferable which is based on target values to be granted by applicants to the bids.

The EU Railenergy Project is working to agree and propose specific sets of requirements (example for energy storage systems in Fig. 3-2) and global and single domain target values (example in Fig. 3-3). Similar target values were fixed by the Lombardy region in Italy. These target values might be used within a weighting process to be applied to the energy saving potentials defined in the Pilot Catalogue of technologies and operational measures.



Vehicle - Target of lifetime of a storage system	Value
Vehicle lifetime	30 years
Operation hours	19 hours
Average traveling distance	5 – 20 km
Yearly cycle cpability	20000 - 72000

Vehicle - Required energy	Value
2 car 375 kW Diesel	2,8 kWh
3 car 375 kW Diesel	4,2 kWh
3 car 500 kW Diesel	4,2 kWh

Vehicle -Additional weight of storage (target)	Value
2 car 375 kW Diesel	1,3 – 2,0 t
3 car 375 kW Diesel	1,7 - 2,6 t
3 car 500 kW Diesel	1,8 - 2,7 t

Fig. 3-2: Requirements on onboard energy storage systems by Railenergy [16]

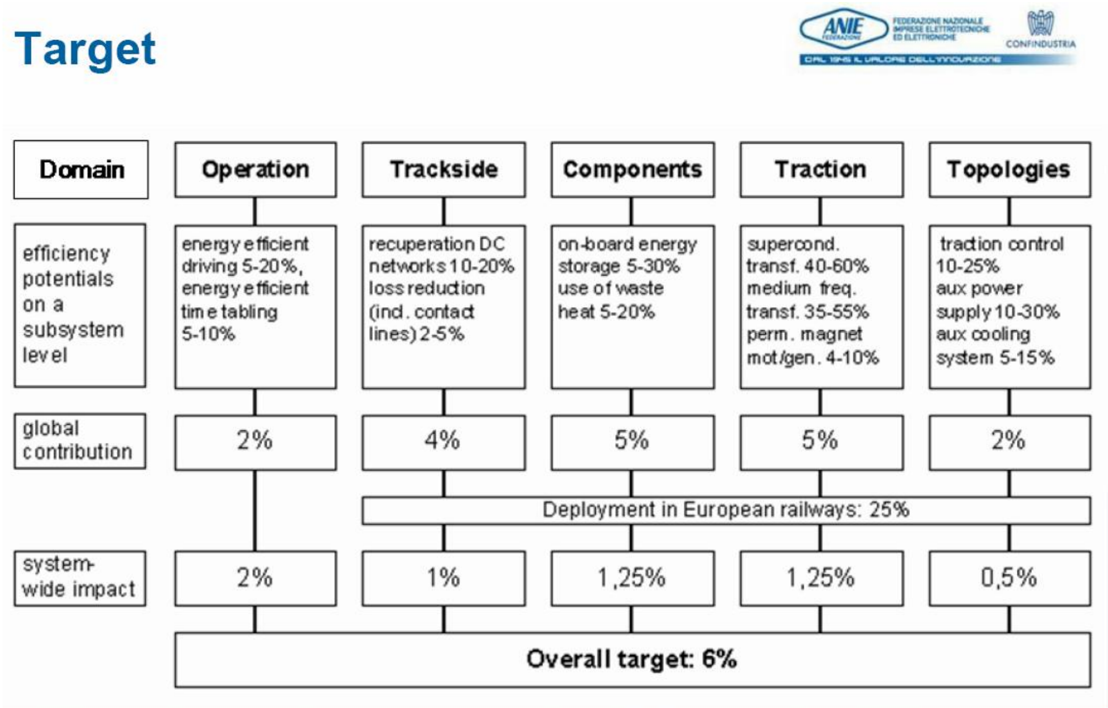


Fig. 3-3: Target values fixed for various technical domains by Railenergy [17]

3.3. Barriers encountered by PTAs to ask for requirements

The User Platforms provided some well defined highlights and warnings about the potential difficulties that could be encountered by PTAs when they want to implement Energy Efficiency and Environment-Friendly requirements in their awarding procedures. The identification of these barriers, when definitely identified after the Pilot Tests, could feed a SWOT analysis that could help to define possible options (as used in many Impact Assessment Analyses for the selection of different Transport Policy options). The results of this analysis are planned to be included in the final version of the guidelines.

From the User Platform 1 resulted that the PTAs are generally well aware of the possibility to acquire new rolling stock or to modernize the existing trains, as well as of the capability of the manufacturers to supply technologies with the right reliability, availability, maintainability and safety performances. Nevertheless the most relevant feedback from User Platform 1 shows that infrastructure bottlenecks, speed restrictions and intense capacity demand by freight operators, particularly when they are expression of incumbent companies linked to Infrastructure Managers, restrict the effectiveness of the implementation of operational measures.

Therefore the involvement of the Infrastructure Manager or at least the warranty of a neutral behaviour within the market dynamics becomes a key success factor, particularly for operational measures implementation. In this context the PTA should act with pressure and sensitisation on the Infrastructure Managers to create the most effective premise for a fruitful implementation of the required performances. These conflicts are of course les prominent on lines where regional passenger trains do not (or only to a minor extent) compete with freight or fast passenger trains for capacity.

The most relevant feedback from User Platform 2 concerns the expected possible instruments capable to enforce or stimulate the TOCs' and manufacturers' virtuous behaviours.

For this scope different options have been identified up to now:

- strict requirements:
  - applicable by PTAs after they have checked that these requirements can be fulfilled by TOC and manufacturers;
  - mainly recommended for detailed monitoring system for energy consumption, eco-driving and driver training, parked train control systems, onboard equipment for energy recovery/storage, maintenance procedures;
- weighting, target values
  - applicable for assessing and selecting offers (e.g. additional scores for offers with good environmental quality);
  - used when availability and costs are unclear and the reliability of technologies is to be checked;
  - recommended for advanced energy consumption limits/objectives and mainly for innovative technologies (e.g. onboard energy storage);
- bonus/malus

- optionally used as incentive for good real life performances;
- penalties, requiring a rigorous monitoring of the operator's actual performance.

4. Fleets and services implementation context

4.1. Operated fleets review

In order to assess the different technical starting points in the European countries, within the starting phase of WP2 activities the available information about rolling stock fleets was collected and summarised in Deliverable 6.

The amount of diesel locomotives, electric locomotives, Diesel Multiple Units (DMU), Electric Multiple Units (EMU), unconventionally propelled Multiple Units and passenger coaches dedicated to regional services has been estimated.

The collection of information by desk research covers only 11/25 railway operating European countries due to the lack of specific information for the remaining 14/25.

A larger amount of specific data is available for a very limited set of countries (e.g. the age of the rolling stock employed for a regional service was available for Italy and Portugal only).

In the meantime the start of WP4 activities allowed the collection of additional data concerning the regions involved in the pilot tests and the concerned countries.

In general terms it is possible to remark that:

- no unconventionally propelled locomotives neither unconventionally MUs are used for regional or suburban transport services;
- some TOCs do not employ locomotives for regional transport (e.g. in Germany, Sweden, Poland and Spain) but only MUs, as well as, on the contrary, other TOCs (e.g. Italy and Portugal) prefer to use already available locomotives and coaches, though they aim to standardize their locomotive fleets and vary the composition of their trains;
- the trend to use electric locomotives and EMUs instead of diesel locomotives and DMUs is going to be consolidated in almost all the countries in the last 30 years, though different starting points are self-evident, particularly for Eastern and Western European countries. Anyway there will in the mid-term perspective be non-electrified lines because in some regions electrification does not seem suitable from an economical point of view.

In Table 4-1 and Fig. 4-1 some synthetic data are presented.

Countries	D-Loco	E-Loco	DMU	EMU
CZ	1383	938	794	270
DK	36	6	217	203
DE*	2733	3326	4162	4162
HU	484	439	357	68
IT	140	743	805	678
PL	2501	1811	187	1115
PT	79	49	98	190
RO**	150	93	68	no data
SK	54	148	153	59
ES	0	0	no data	760

Table 4-1: fleets composition in several European countries; * total DMU + EMU = 8324 conventionally fifty-fifty split; ** data not including all RO regions

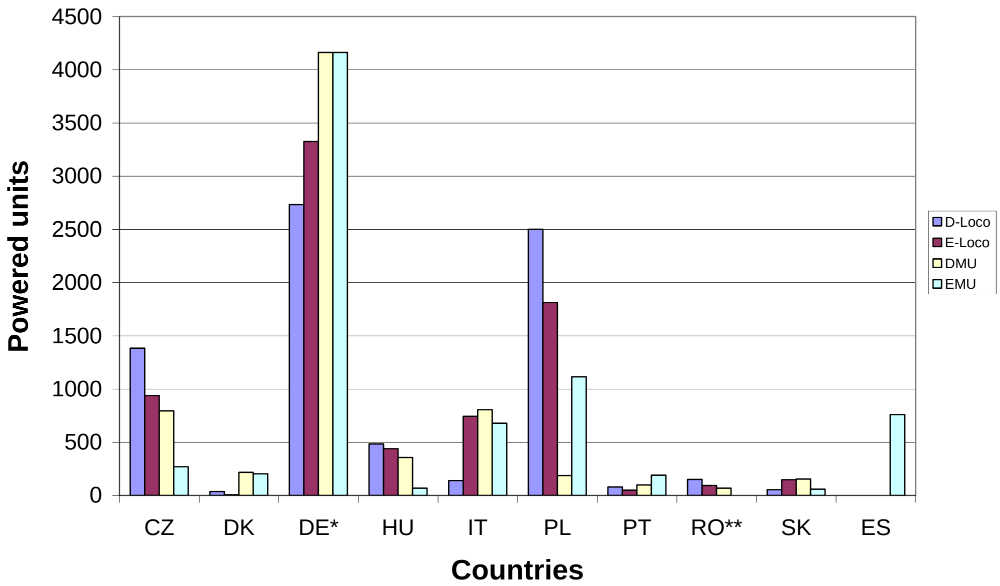


Fig. 4-1: fleets composition in several European countries

They integrate the D6 data.

4.2. Operated services review

Similarly to fleets, in order to assess the different technical starting point in the different European countries, information about operated services was also collected and summarised in Deliverable 6.

The database includes operated lines and traffic (total and by electrification system), frequency of services (min/max headways), transport capacity and satisfied demand (total and by electrification system), accessibility (called stops at stations), areas and populations served by the services.

Also for the services the start of WP4 activities allowed the collection of additional data concerning the regions involved in the pilot tests and the concerned countries.

In general terms it is possible to remark that:

- different service profiles may be identified (sometimes operated by different TOCs, national incumbent operator and local or new entrant operators, sometimes by a single TOC): a) with many stops (mean distance between stations of 2 km) and dense transport demand typical of suburban services; b) with limited stops (mean distance between stations of 5 km) and more limited demand typical of a regional service profile;
- high capacity coaches or MUs are employed for the suburban service profiles but problems could arise for passengers accessibility (e.g. for most series of double-deck trains when in the pick hour many passengers have to get in and get off) and lower capacity coaches or MUs for regional service.

In Table 4-2 and

Fig. 4-2 some synthetic data are presented.

Country	Suburban	Regional	Million seats x km	Million passengers x km
CZ	x		no data	1
CZ	x		17500	6500
DK	x		no data	555
HU		x	19396	6517
IT		x	71800	21800
IT	x		3400	1200
PL		x	no data	12747
PL	x		no data	39
RO*		x	66	8
SK	x		14600	2300

Table 4-2: operated services in several European countries; *data not including all RO regions

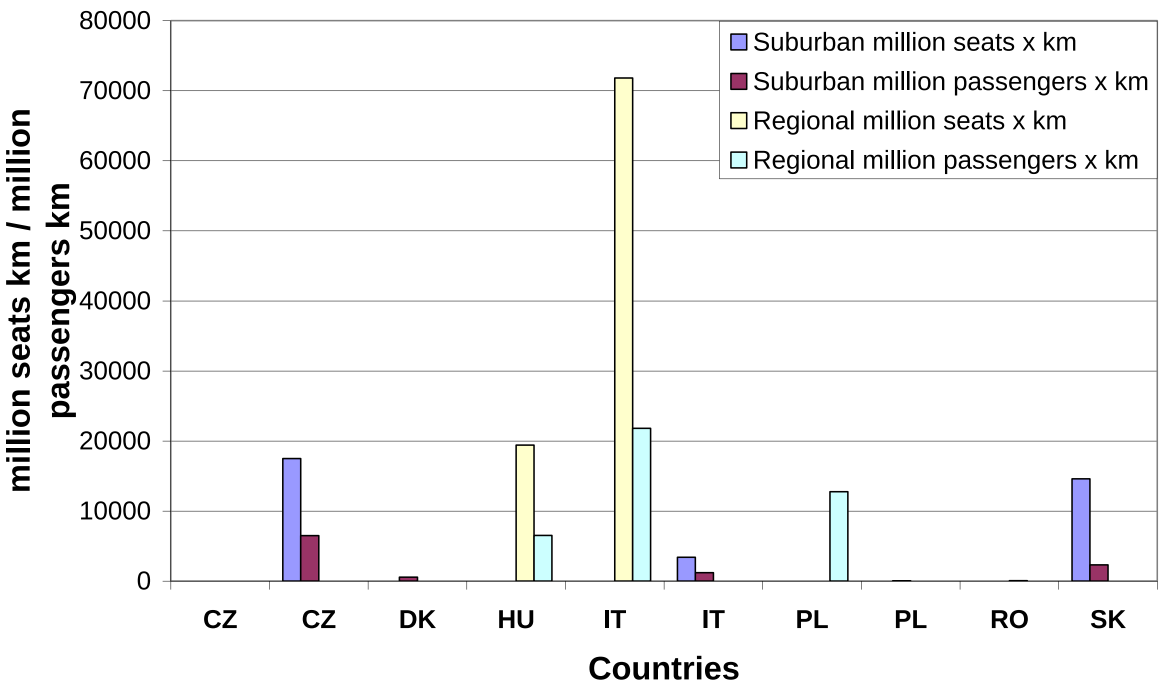


Fig. 4-2: operated services in several European countries

They integrate the D6 data.

Moreover, as previously anticipated, the Railenergy Project is working to define standard service profiles which are intended to be made available by a UIC leaflet.

Some of them could be interesting for ECORailS scopes and they will be eventually selected just on the basis of the collected data and the needs of the PTAs involved in the pilot applications.

4.3. Application to different operational contexts

The main feedback concerning the operational context of vehicles and services allows to identify a set of 8 possible combinations between conditions defined by traction systems and trains composition on one side and by service profiles on the other side.

The resulting operational conditions are summarised in table …

	D-Loco	*DMU*	*E-Loco*	*EMU*
Suburban				
Regional				

Table 4-3: operational contexts definition

The Guidelines should be in principle applicable to all these operational contexts.

4.4. Best-practice of energy efficiency and environmental requirements in awarding

There are currently only limited experiences of awarding including EE and environmental standards. Moreover, where considered, the environmental criteria have normally only marginal weight in comparison with economic criteria. Nevertheless they may be considered as initiations of good practices, on which more extended EE- and eco-awarding processes can be built on.

Netz "Stadtbahn" of Berlin and Brandenburg, Germany

In May 2009 the so-called 'Netz Stadtbahn' in the Berlin Capital Region was awarded in a tender to two bidders: Deutsche Bahn (state-owned) and ODEG (an indirect subsidiary of the federal state-owned Hamburger Hochbahn and Arriva).

The tender was managed by VBB on behalf of the Federal states Berlin and Brandenburg. Some of the lines cross the border to the federal states 'Saxony-Anhalt' and 'Mecklenburg-West Pomerania'.

The tender of the overall 16 regional lines was divided into four lots and each bidder won two lots with a contract period of 12 years from 2011 to 2022.

The main awarding criterion was the price (weighting 70 %), while the remaining 30 % was assigned to quality criteria, including environmental performance (weighted for 6 % within all quality criteria or respectively 2 % only in general). The environmental performance includes values concerning noise and pollutants as well as environmental concepts (including citizens information, technical measurable achievements, e.g. for energy recovering, environmental management, recycling).

Regional rail network of Lombardy, Italy

The regional IM of the rail network of Lombardy region – Ferrovie Nord – was responsible for the procurement of new rolling stock, acting on behalf of the regional government. The rolling stock was manufactured by Stadler and the first vehicles were delivered in 2009. The aim of the awarding was to order new DMU for the regional passenger transport.

Energy efficiency criteria were considered in the awarding, which included a lowered weight per seat, as well as the on-board use of recovered braking-energy. Furthermore, the European emission standard ("stage IIIa") for diesel engines was required, but improvements above that standard were not rewarded.

The main awarding criterion was the price (weighting 60 %), while the remaining 40 % were assigned to quality criteria (weighting 18 %), technological criteria (weighting 12 %), environmental performances (lowered weight – measured by the weight/seat rate – weighting 3 %; On-board use of braking energy weighting 3 %), time to deliver the rolling stock (weighting 4 %).

Swedish part of Öresundtrafiken, Skånetrafiken

The Swedish part of the contract for the railway services in the Öresund area included the environmental requirements concerning the use of renewable energy sources, the recycling of waste disposal and the vehicle washing.

Moreover the staff is supposed to be educated in how to reduce the environmental impacts during operation for onboard services and vehicle maintenance.

To check the compliance to these environmental demands the TOC has to annually deliver an environmental report and the PTA has the right to monitor the compliance through an external inspector and to change the environmental requirements during the contract under compensation of the TOC for the increasing costs.

ARRIVA Experiences and suggestions of a private TOC with environmental criteria in railway tenders[1]

ARRIVA with a fleet of 570 train sets has asked for environmental criteria in railway tenders in 12 different countries (DK, DE, NL, PL, PT, SE, UK,…) aiming at acquiring modern fuel efficient and less polluting trains by solutions as: brake energy recovery, low noise emissions, energy savings, drivers training, bio fuels supply. ARRIVA reasons are: fuel cost savings, clean and modern image, long term sustainable fleet to be used in various markets, collect experiences with eco-friendly rolling stock.

The main criteria used in tenders were: trains meeting defined EU emission criteria (in tenders in DE, CZ, NL, SE, UK); requirements on energy efficiency in general; requirement in tenders of energy-consuming components (air-conditioning systems); noise emission compliant with standards; environmental proposals as part of the qualitative bid evaluation.

[1] As presented on the 2nd ECORailS User Platform, 19th Feb. 2010 in Berlin.

ARRIVA's experience and observations are: strict environmental requirements are in fact applicable to new trains only because if second hand vehicles are allowed, usually the emission classes do not match the requirements and much stricter requirements for new rolling stock than legal requirements complicates the use of second hand vehicles.

Partial modernisation of second hand rolling stock according to tender requirements may lead to refusing the participation in bids because of the risks which might arise with regard to authorisation of the modernised fleet.

Development costs are affected by depreciation time and maintenance costs could raise. The residual value of new components of uncertain life is another risk as well as the risk of bad technical compatibility with conventional components. Best way to include EE/EF criteria in tenders is:

- Not being too prescriptive
- Having realistic expectations
- Use lessons learnt from road sector
- Environmental requirements level to be decided at local level according to willingness to pay of passengers and focusing on new vehicles instead of requiring mandatory changes to existing vehicles.

Modernisation of existing rolling stock could become a more suitable solution in the future if authorisation procedures in the EU were standardised and simplified (e.g. "cross-acceptance").

Conclusions

The mentioned examples show that there are positive approaches towards integrating environment-related criteria in tenders of regional rail services or the procurement of new rolling stock.

Anyway such good practices are still rather exceptions than standard procedures; indeed the necessity and usefulness of environmental measures are generally accepted, nevertheless economic criteria are still almost absolutely dominant for decisions concerning the procurement of rolling stock and the awarding regional rail services. Thus the potential, even on the economic side, of the environmental measures could have positive effects on the environment and the public opinion, but it should be clarified to PTAs and TOCs.

5. Direct and indirect indicators and methodological approach for technologies and operational measures qualification

5.1. Needs and preferences of PTAs

During User Platform 1 PTAs suggested the adoption of requirements about the calculation of the values of some parameters (e.g. LCC, train weight, consumption) by manufacturers, to be evaluated in the tender processes or during the operation time, in defined operational conditions.

In the awarding procedures for services PTAs should also ask for requirements for EE and/or EF solutions in terms of operational measures.

In the awarding procedures for vehicles PTAs should also ask requirements for EE and/or EF solutions in terms of technological solutions.

5.2. Baseline Indicators

According to the definition already posed in chapter 3, the energy consumption of a rail vehicle can be defined as the amount of energy that, through the diesel fuel tank or the electrical supply collector (pantograph), flows to the train, irrespectively of how that energy is used, minus regenerated energy that flows back, through the electrical supply collector (pantograph), to the overhead contact line. In the same chapter details on different internal and external parameters affecting the energy consumption are listed.

A similar approach is possible for the preliminary definition of the baseline scenario. It should be referred to a consolidated database, whose construction procedures should be as much as possible integrated into the routine monitoring activities to be carried out by PTAs. In this context direct indicators for preliminary evaluations should be selected to be used for:

- the preparation of awarding documents (draft text for invitation to tender (ITT))
- the evaluation and score of offers according to various possible and/or sequential approaches:
    - Yes/no,
    - evaluation,
    - calculation.

The best option would be to have measured data about the direct indicators (KPI as already defined in D6 and synthetically carried in the following paragraph 5.3). The direct indicators can be measured dependent or non-dependent on the load factor starting from the real energy consumption (kWh or l) measurement for which can be referred to paragraph 5.4.

Alternatively the present energy consumption could be estimated by using data about the vehicle classes, their relevant features in terms of EE/ENV criteria and their share of the operational performance. In this case the database should include (where available):

- train km;
- locomotive classes used for which amount of train km (or gross tkm);
- DMU/EMU classes used for which amount of train km;
- real energy consumption on the operated lines;
- data by vehicle classes:
  - energy consumption of existing traction units (locos, MU),
  - carriages in operation,
  - measured noise emission,
  - measured exhaust emission of diesel vehicles (fulfilled norm if not available);
- data about CO_2 emissions (sources and energy mix of traction electricity);

Therefore for each transport service (suburban, regional, etc.) and for each traction unit series, in addition to the measured values of the energy consumption, it is required to know the following parameters about the traffic:

- passenger km;
- seat km;
- gross tkm hauled in regional passenger operation.

It is also important to monitor the operation regularity or the average commercial speed, to take into account the effects of unforeseen speed restrictions that are under the responsibilities of IM or other irregularities modifying the planned operation. In many cases it may be possible to use the data which are collected by the IM for the assignment of the responsibilities for delays.

5.3. Applicability of indicators

According to the EU Project Railenergy a set of Key Performance Indicators (KPI) has been identified and considered for the possible application to the proposed technologies and operational measures included in the respective clusters. Three possible criteria have been applied to relate KPI and clusters:

- *Applicable*: the indicator may be used for the technology without any problems.
- *Not Reasonable*: the usage of a special indicator for the specified technology may be misleading.
- *Not Applicable*: the indicator cannot be used to judge the energy efficiency of this special technology/operational measure.

The KPI selected for ECORailS are (numbers and definitions refer to the suggestions of Railenergy):

- KPI1: Energy consumption per traction effort (kWh / gross tkm);
- KPI2: Energy consumption per offered capacity (kWh / seat km) with the specification about the number of passenger per m^2 considered to calculate the standing seats;
- KPI4: Energy consumption per passenger km (satisfied demand) (kWh or l / passenger km);
- KPI5: Share of energy consumption for parked trains related to the final energy consumption (%);
- KPI6: System wide realized energy recuperation rate related to the final energy consumption (%).

In Deliverable 6 the results of an evaluation were reported expressing the applicability of these indicators to the different technologies and operational measures contained in each cluster. Normally one or more KPI can be applicable to each solution (see D6 Electronic Annex II for the KPI applicability to each solution).

5.4. Energy consumption measurement systems

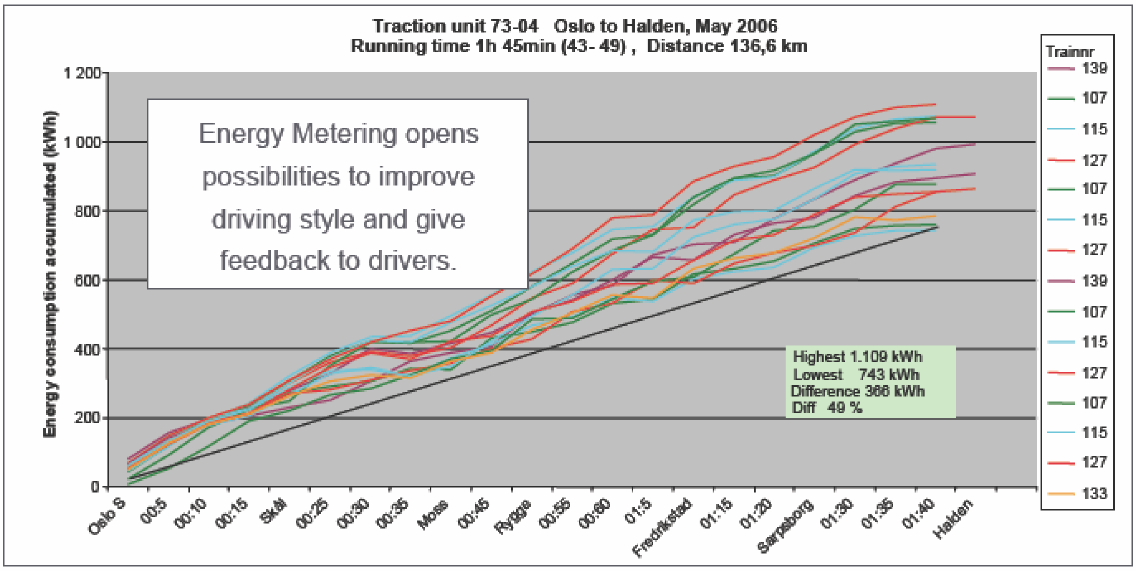
In order to approach the measurement of energy consumption in a systematic way, two main cases can be identified:

- The network is technically unlinked with other networks and the awarded services are the unique on this network.
- The network is linked to other networks or used by many trains with different characteristics or operated by different TOCs.

In the first case the measurement could be managed by fixed energy meters installed in the electrical power supply substations. The ease of the measurement systems contrasts with the rare occurrence of the case circumstances, which often are valid for underground services only. In this latter case the data acquired could be profitably stored and used for the specification, in the energy balance sheet of the transport company, of the two indicators KPI2 and KPI4 as suggested by the Energy Manager of the ATM urban public transport company of Milan some years ago [14].

These two indicators provide a very helpful baseline about the energy consumption and make possible the evaluation of the actual energy saving potentials of different technologies/operational measures adopted during the real operation.

Even in this particular case it is not advisable for a PTA to use these two performance indicators in an awarding procedure for the procurement of own rolling stock as requirements. The variability of the energy consumption due to different driving styles can cause variation between different drivers during the real operation of the rolling stock (Fig. 5-1 and Fig. 5-2) on the same line, with the same traction unit and timetable. This would certainly cause problems for the evaluation whether the contract is kept or not. The drivers are not under the responsibility of the manufacturer of the train.



Data supplied by ERESS and analysed by NSB AS

Fig. 5-1: Example for different energy consumptions measured on the same line but with different drivers (Norwegian example, 15 kV 16,7 Hz AC operation) [18]

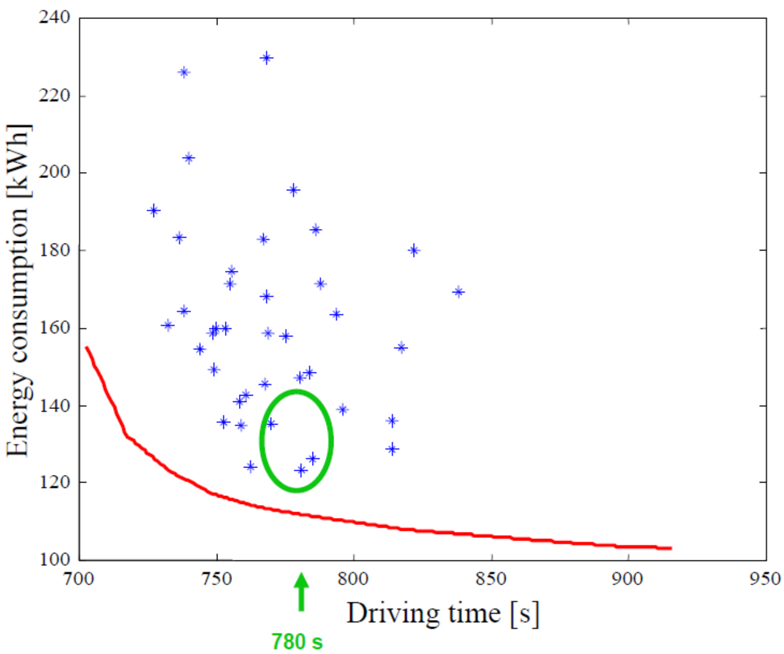


Fig. 5-2: In blue the energy consumptions measured on the same line but with different drivers [19]

In the second case the most promising solution seems to be the use of energy meters on board of each train of the fleets.

RFF (French IM) imposed traction units' equipment with energy meters starting on the 1st of January 2010 [22].

The Direction Committee of SNCB/NMBS (Belgian TOC) agreed on May 5th 2009 to install on board Energy Metering Systems on all new Traction Units. The accuracy shall be in compliance with the Conventional Rail Locomotives and Passenger Rolling Stock TSI in approval (CR loc&pas TSI). After approval of TSI, the conformance shall be tested by a Notified Body.

SNCB/NMBS will use the existing ATLAS (EBI star and ground from Bombardier) to store the data on board and transmit the data to ground. Infrabel (Belgian IM) will order an external audit to check the integrity on this data flow. The ground server of ATLAS will transfer the data format to the UTIL-TS messages defined in the UIC-leaflet 930. Infrabel shall use the recorded consumption starting from January 2011. A coefficient will be added to take into account the losses in the substations and on the Overhead Contact Line.

TSI and CENELEC rules will impose the requirements for the energy meters and their accuracy (about 2 % for those available in the market) levels (see Fig. 5-3 and Fig. 5-4).

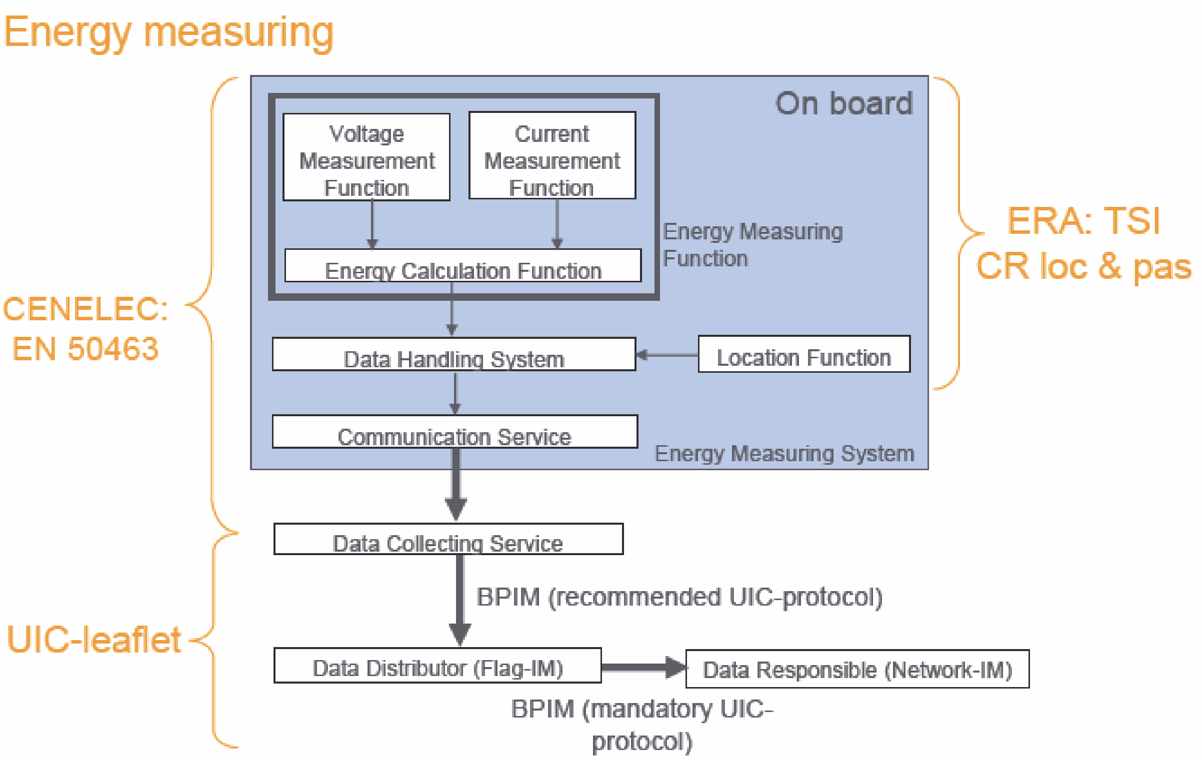


Fig. 5-3: On board energy measuring systems [18]

Energy meters can be used for:

- billing purposes (reference time of 5 minutes) in order to calculate the real energy consumption of each TOC and let them pay what they really consume;
- saving purposes, which implies functioning in real time (reference time of about 30 s) and possibility to exchange information with ground equipments able to send information to the driver in order to optimise the driving parameters by comparing the actual data of consumption with reference values for that position along the line.

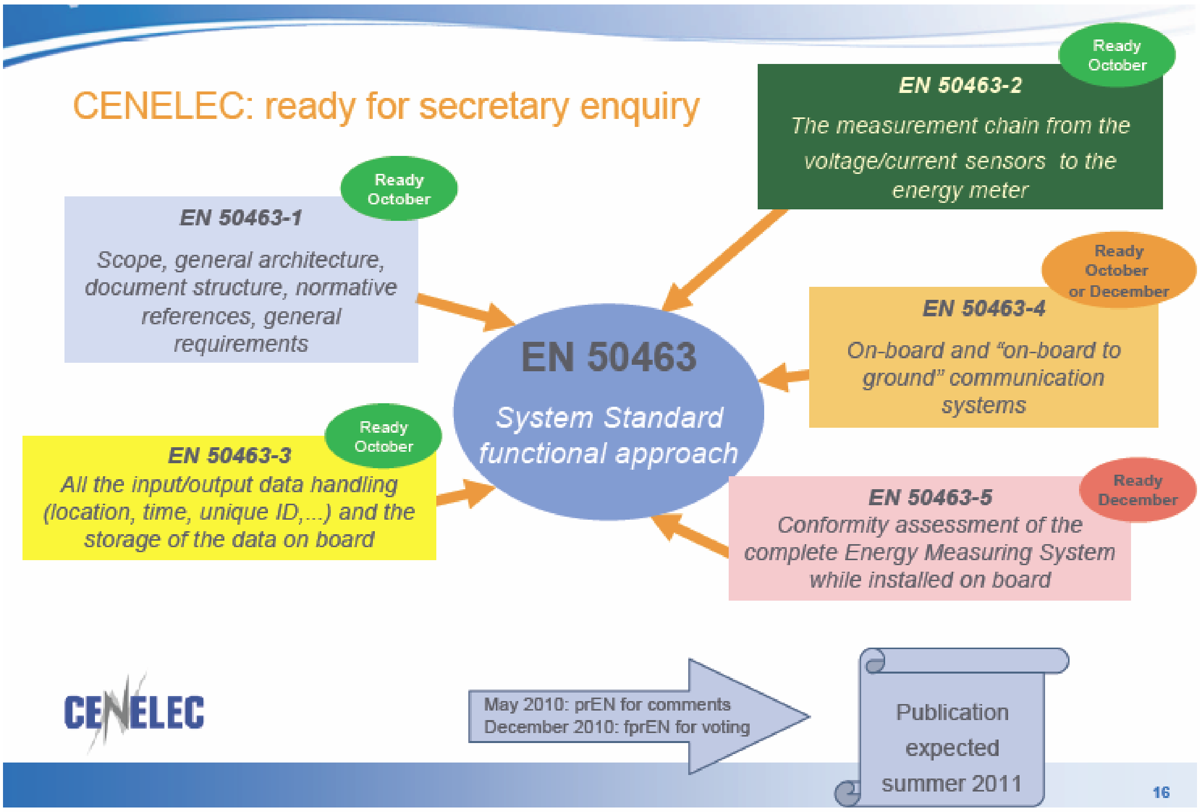


Fig. 5-4: CENELEC prEN 50463-1 contents developed in 2009 and definition process

Business case for Belgium (hypothesis)

Onboard equipment	
Number of engines to be equipped	1400
Unitary investment & installation cost per metering equipment (€)	12.000 €
Rythm of equipment (% per year)	15%
Annual maintenance cost per equipment (€)	500 €
Metering equipment lifetime (in years)	8
Metering equipment replacement cost (€)	6.000 €
Unitary driving assistance system cost (€)	2.000 €

Drivers' training & management	
Ratio of the number of drivers / engine	3
Rythm of drivers training (% per year)	20%
Total training cost per driver (€)	2.000 €

Software & Communication	
Initial software investment costs (€)	2.000.000 €
Annual software maintenance & operating costs (€)	500.000 €
Annual communication costs per metering equipment (€)	200 €

Economic parameters	
Potential of energy savings per trained driver (%)	5%
Number of years to achieve potential (training time included)	4
Potential of energy savings through schedule optimization	3%
Number of years to achieve potential	6
Unitary annual consumption per engine (MWH)	2000
Actualisation rate	4,00%
Electricity price per MWH (including transport)	100 €

Business case for Belgium (results)

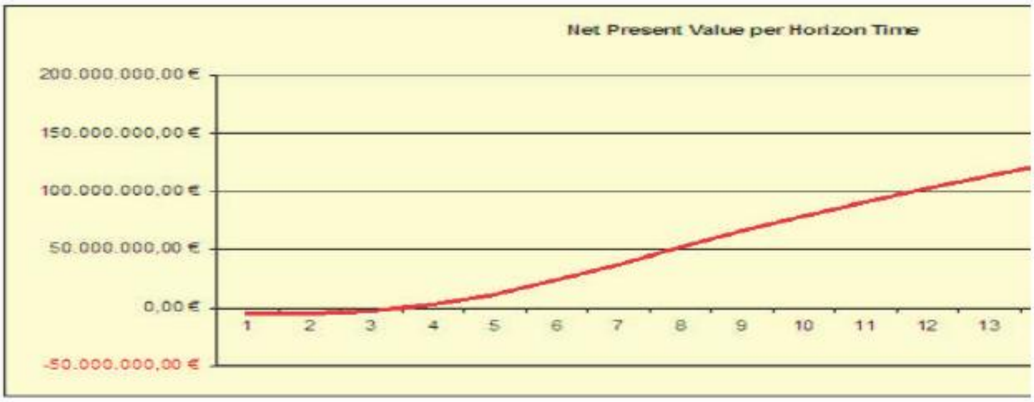


Fig. 5-5: Belgium Business case for retrofitting 1400 engines with energy meters [18]

The nomination of a correspondent responsible for Energy Savings (e.g. in Italy the Energy Manager) in each transport company is recommended by the French incumbent SNCF for each of its Business Units [22].

Moreover the rolling stock department of the French SNCF recommends not creating sub-parks equipped with energy meters within traction unit series to keep an easier maintenance of traction units [22].

5.5. The monitoring system evaluating the keeping of the contract

The description of the monitoring system should also refer to the cases identified above:

- network technically unlinked with other networks and the awarded services are the unique on this network;
- network linked to other networks or used by trains with different characteristics and/or operated by different TOCs.

In the first case for an awarding procedure for the procurement of the own rolling stock by a PTA it is not advisable to use performance indicators as requirements in order to evaluate the keeping of the contract during the real operation of the rolling stock because of the already cited variability of the energy consumption due to different driving styles (see Fig. 5-1 and Fig. 5-2 above).

In the second case the variability of the energy consumption is due to the different driving styles but also to the delays of trains due to other TOCs or due to the IM.

In both cases a monitoring system to evaluate the keeping of the contract should foresee:

- the specification of a limit or reference value for the KPI2 and KPI4 to be fulfilled by the proposed rolling stock (as for RAMS indicator) in a direct contract procedure (possibly with bonus/penalty clauses in case the effective value of the indicator will be less or more than this limit value);
- to ask the manufacturers or the TOCs for calculating and providing their best offered value for KPI2 and KPI4 (again as foreseen for the RAMS indicator).

In any case the PTAs have to specify all the characteristics and conditions defined in paragraph 3.2 with reference to the state of the art.

In order to clearly measure in a common accepted and agreed (legally secure) way the energy consumption for the specified line or for the selected reference track, a combined test could be performed during the commissioning phase (acceptance by the customer of the prototype) in the following controlled (during the test) conditions:

- respect of the driving style suggested by the manufacturer or the TOC and of the specified timetable;
- no other trains disturbing the test (respect of timetable without any delay);
- agreed (possibly in compliance with TSI and CENELEC standards above) energy meters to measure the energy consumption with: different payload (train fully equipped for service operation but without passengers on board, maximum payload, estimated payload); an agreed overhead contact line voltage (e.g. minimum and/or nominal value); where relevant an agreed energy receptivity by the overhead contact line (e.g. completely receptive and/or not receptive overhead contact line, to consider the extreme conditions);
- evaluation of KPI2 and KPI4 (on the basis of the simulated payload condition) and comparison with the offered values;
- monitoring of the real operational performance of the rolling stock using data provided by the energy meters in case the contract is with the TOC (not applicable in case of an awarding procedure for the procurement of rolling stock by a PTA or a TOC) and verification of the possible bonus/penalty clauses specified in the contract taking into account technologies and operational measures provided by the TOC for energy savings (e.g. the effectiveness of the used energy meters data, the real use of the technologies and their operating efficiency).

Combined tests for a new class or series of vehicles is anyhow foreseen for other purposes (e.g. the authorisation process by the National Safety Authority in case of a network linked to the national network or from the Ministry of Transport or other local authorities in case of railway infrastructure which is not under national control). The results of previous tests, related to previous contracts, could be evaluated by PTAs if made available by previous customers because they have the property of these results, as provided for by EN 17025.

The use of a reference profile it will be possible by selecting an appropriate standard service profile, e.g. Suburban, Regional, etc., (see paragraph 3.2). The energy consumption calculated referring to this service profile will not be compared in a real environment, thus these service profiles are not linked to a real test track, but describe realistic conditions for the respective type of operation.

In order to asses the energy and pollutant saving potential of specific solutions, in Deliverable 6 a full set of possible parameters to be used for the implementation of the monitoring system has been defined (see D6 Electronic Annex II for the detail for each solution); it includes:

1. Average axle weight;
2. Vehicle weight;
3. Diesel consumptions with and without the technology/operational measure (or before and after the modernisation);
4. Energy consumptions with and without the technology/operational measure (or before and after the modernisation);
5. Efficiency of traction system;
6. Electric energy at the pantograph during the service braking from specified initial speeds (where applicable);
7. Efficiency of the transmission system;
8. Weight per seat;
9. Noise emissions;
10. K-factor to measure the transmittance (ratio between radiant energy transmitted and total radiant energy incident on a given body);
11. Medium value of power required from electric sub-station;
12. Pollutants: particulate matters (PM), nitrogen oxide (NO_x) and, with somewhat less relevance, carbon monoxide (CO) and hydrocarbons (OH).

These parameters can be grouped into three significant sets:

- Weight-based (parameters 1,2,8)
- Consumptions-based (parameters 3, 4, 6,10,11)
- Others (parameters 5, 6, 9, 12).

In Table 5-1 and Table 5-2 the correspondence between the most suitable monitoring parameters and the clusters of technologies and operational measures is summarised.

CLUSTERS OF TECHNOLOGIES	MONITORING PARAMETERS
T1: Train formation or typology T4: Use of particular materials or structures for mass reduction	• Weight per seat • Average axle weight • Vehicle weight
T2: Noise and vibration reduction	• Noise emissions
T3: Optimisation of comfort functions	• Energy consumption with and without the technology • K-factor (e.g. as specified by EN 14750 or EN 13129)
T5: Improvement of traction equipment efficiency T7: Reduction of energy consumptions	• Efficiency of the transmission system • Average value of power required from electric substation • Energy consumption • Electric energy at the pantograph during the service braking from specified initial speeds (where applicable)
T8: Reduction of exhaust pollutants	• Pollutant emissions • Energy consumption in a specified service profile
T10: Revamping of existing vehicles T11: Unconventionally propelled locomotives or Multiple Units	• Energy consumption before and after the modernisation • Noise emissions • Weight per axle or vehicle weight • Pollutant emissions

Table 5-1: Monitoring parameters suitable for clusters of technologies

CLUSTERS OF OPERATIONAL MEASURES	MONITORING PARAMETERS
M1: Training program to raise awareness of personnel M2: Energetic optimisation of timetable M4: Optimisation of train operation by control centre	• Energy consumption before and after the application of the measure
M5: Energy meters M6: Management and organisation	• The measures in these clusters are monitoring systems on their own
M8: Noise reduction	• Noise Emissions

Table 5-2: Monitoring parameters suitable for clusters of operational measures

5.6. Final remarks

The differences in applicability of KPI2 (energy consumption per offered capacity) and KPI4 (energy consumption per passenger kilometre) are very small.

They are limited to cases in which a reduction of the transport capacity (offered in seats) combined with a reduced energy consumption leads to a worse value of the indicator, although there is a total reduction of energy consumption due to reduced traffic.

The applicability of KPI5 (share of energy consumption for parked trains related to the final energy consumption) and KPI6 (system wide realized energy recuperation rate related to the final energy consumption) is quite small, nevertheless they are almost interesting for the tendering process, although only under specific circumstances.

In order to assess the saving potential for energy and pollutants of specific solutions, all the comparisons about energy consumption or system efficiency between two different situations (before and after the change) need to be related to a specified service profile. In order to make these monitoring systems easier, the manufacturers should provide on-off switching devices to: allow the measurements with and without the new solution; ensure the availability of the train, although in a degraded operational mode, if the technology occasionally fails.

Some monitoring systems to evaluate the keeping of the contract should be applied as type tests referred to specified rules and to agreements between the contracting parties. They may be performed on a single component of a given design. Supplementary type tests shall be required if they have been specified in the customer specification and after agreement with the supplier.

Other monitoring systems consist of combined tests, which can only be carried out in an operating environment. They shall take into account the type of vehicle to be used, its speed and direction of travel. They shall be carried out using the track and/or overhead line system defined in the customer specifications. In particular it is possible to assert that:

- systems based on parameters 1, 2, 8, 9, 10 and 12 can be applied as type tests.
- systems based on parameters 3, 4, 5, 6, 7 and 11 generally consist of combined tests.

It seems difficult to monitor the real operational performance of single solutions, nevertheless it could be possible to ask for the repetition of specific type, or combined, test at certain time intervals.

The repetition of specific type, or combined, test at certain time intervals (e.g. the general maintenance overhaul of engines, other maintenance intervals, …) could be useful in order to verify the compliance to determined standards of specific technologies or of specific issues, e.g. noise emissions and pollutants. Up to now only homologation tests were provided, in contrast with some experience in the road sector where specific tests at certain intervals of time have to be performed to circulate within restricted area (e.g. the centre of the cities).

6. Specific indicators and methodological approach for technologies and operational measures qualification

6.1. Definition

The specific indicators are not suited to provide the total energy consumption of the train but to evaluate the energy efficiency of a specific solution (technology or operational measure).

Therefore they have been systematically employed for the assessment and qualification section within the Pilot Catalogue (chapter 7) and are proposed to be employed also in the final full version of the Catalogue itself.

The single indicators are qualified and described below.

6.2. Potential for saving energy

This item refers to the energy saving potential for a single vehicle.

It has been estimated, by specifying a range of possible values (without using fixed values and fixed ranges) from worst to best case taking into account the different foreseeable application contexts.

The estimations of the potential are based on the evaluations already available in technical literature, on partners' expert judgements and on evaluations in previous projects (EVENT, TRAINER, Railenergy).

Also the results of a simulation tool, based on the Railenergy guidelines, have been used.

6.3. Potential for saving emissions of pollutants

This item refers to the potential of reducing emissions of pollutants for a single vehicle.

It has been estimated by specifying a range of possible values (without using fixed values and fixed ranges) from worst to best case taking into account the different foreseeable application contexts.

The estimations of the potentials are based on the evaluations already available in technical literature, on partners' expert judgements and on evaluations in previous projects (EVENT, TRAINER, Railenergy).

Also the results of a simulation tool, based on the Railenergy guidelines, have been used.

6.4. Economic potential

Economic potentials (on LCC basis) have been evaluated by the following approach:

- Implementation Cost (IC): it represents the initial investment for onboard equipments and/or for infrastructure changes required by the technology or operational measure:
  - High: > 1 % of initial investment of the vehicle,
  - Medium: 0,1 % ÷ 1 % of initial investment of the vehicle,
  - Low: < 0,1 % of initial investment of the vehicle;
- Operational Cost (OC): it is represented by vehicle running costs directly caused or influenced by the technology or operational measure (energy cost and costs for operating personnel):
  - Higher in comparison with a situation without solution implementation,
  - Similar in comparison with a situation without solution implementation,
  - Lower in comparison with a situation without solution implementation;
- Maintenance Cost (MC): this category includes all kinds of cost to repair failures and/or to prevent potential problems that could compromise operational service; they include materials and technical personnel costs:
  - High: > 1 % of initial investment of the vehicle,
  - Medium: 0,1 % ÷ 1 % of initial investment of the vehicle,
  - Low: < 0,1 % of initial investment of the vehicle;
- Disposal Cost (DC): costs related to the end-of-life of technical equipment; it includes demolition, disposal and selling off costs:
  - High: > 1 % of initial investment of the vehicle
  - Medium: 0,1 % ÷ 1 % of initial investment of the vehicle
  - Low: < 0,1 % of initial investment of the vehicle

6.5. Implementation time

The implementation is a global estimation of:

- *development time* for the availability in the railway market;
- *administrative time* for the procedures to issue purchase orders to acquire specific equipments involved by a technology or by an operational measure; in particular it involves:
  - financial time, availability of financial sources,
  - technical time, procedures exploitation,
  - legal time, integration into the set of regulations, (clarification of safety issues with Safety Authority and working rules with trade unions to be verified in advance),
  - management, acceptance of environmental responsibility;

- *construction time* for the specific equipments involved by a technology or by an operational measure;
- *installation time* to assembly the specific equipments.

The proposed ranges for the total time horizon are:

- Short time: < 1 year;
- Mid time: 1÷5 years;
- Long time: 5÷10 years;
- Perspective: > 10 years.

This latter category should refer to good solutions in general for various reasons, anyway they have to be handled separately in the guidelines because they are not contributing to the general objectives of ECORailS project.

7. Pilot Catalogue of solutions

7.1. Selection of clusters and solutions

According to the first selection proposed by ULS and to the selection of clusters agreed by ECORailS Consortium, the technologies and Operational Measures included into this Pilot Catalogue are listed here below.

CLUSTER	SOLUTION
Optimisation of control functions	Control of comfort functions in parked trains
Energy recovery	On-board use of braking energy in diesel-electric stock
Energy storage	Braking energy recovering by super-capacitors on board equipment
	Braking energy recovering by super-capacitors in fixed installations
Eco-driving	Energy efficient driving by low-tech measures

Optimisation of comfort functions: this cluster includes all technologies concerning a new management of comfort functions oriented to avoid wasting electricity. The term "comfort functions" refers to those elements that are important for on-board people (passengers and personnel) like lighting system or system regulating the inner climate. The idea, on which these technologies are based on, is adapting the energy consumptions to the different demand situations and avoiding the heat dispersions through the use of insulating materials.

Energy recovery: the breaking energy could be recovered and re-used by the same vehicle or by trains running on the same line. The final employments of the recovered energy are essentially two: traction purpose or auxiliary functions purpose.

Energy storage: the recovered energy (e.g. the braking energy) could be stored in several ways: on-board or in fixed installations. Different devices could be employed for this purpose like super-capacitors or batteries.

Eco-driving: the measures in this cluster refer to energy efficient driving by studied driving strategies and eventually by driving advice systems. These solutions implicate a planned analysis of the characteristics of each line (altimetry and planimetry features, speed limits, distance between stops, etc) and of the recovery times in the timetable, the study of existing saving energy margins and definition of the most opportune driving strategies. Quite obviously, after this technical analysis, it is necessary to acquaint the drivers with the planned changes, to train them and often to stimulate them to do better.

The choice of solutions shown in this catalogue has been carried out looking at following criteria:

- best energy saving potentials;
- large differentiation in terms of potential problems to be faced for implementation (e.g. investment dimension, legal constraints, safety or environmental risks, implementation time, traction systems, etc.);
- experience of already awarded technologies and operational measures;

- applicability in WP4 pilot case studies;
- representativeness across Clusters.

In the following paragraphs more detailed descriptions of the selected technologies (paragraphs 7. 2 to 7.5) and operational measures (paragraph 7.6) are given.

7.2. Control of comfort functions in parked train

Cluster

Optimisation of comfort functions.

Description

Parked passenger trains are often heated all night. This consumes substantial amounts of energy. A possible solution is the development and implementation of an intelligent control tool for parked trains (e.g. pre-heating time of rolling stock as a function of external temperature, etc). Beside the installation of an automated controlled system, simple effective solutions include timers, manual control and instructions for maintenance and cleaning personnel.

Existing solutions mainly differ with respect to the following features:

- centralised control device for the entire train;
- possibility to operate lighting and heating at one third or half intensity;
- special programs for anti-freezing or preheating operation.

Advantages

Many railway companies apply control devices to reduce the energy demand during overnight standstill at a certain degree. Dynamic development of comfort functions control in parked trains is especially oriented in the field of Telematics control solutions. Some operators are reluctant to switch off heating in the night due to the danger of freezing and damage to equipment. Control of comfort functions in parked trains is applicable for electric DC, electric AC, diesel railway traction in passenger main lines, high speed, regional lines and suburban lines.

Success factors

Assessment of current operation practice for standstill in order to identify possible measures and required functionalities of an automatic control tool. Motivation and incentives of cleaning personnel to collaborate in saving measures. Advanced control systems to avoid danger of freezing etc.

Disadvantages

The on-board equipment for controlling comfort functions is highly variable between vehicles. The heterogeneity of rolling stock makes the development of a generalized automatic control with big scale effects impossible. The coaches have to be warm when the trains are cleaned. However the time the cleaning personnel arrives may vary too much to program the timer in a way to take this into consideration. Due to low salaries the motivation of cleaning personnel to collaborate in such measures may be low.

Benchmark

According to different sources in countries of Central and Northern Europe energy consumption during standstill is up to 10 % of the total energy demand for train operation. In Mediterranean countries the share will be lower. It is a reasonable estimation to assume that this energy can be reduced by ~50 % by an intelligent control system. Therefore the saving potential per vehicle is about 2÷5 %. The Swedish railway operator SJ developed an automatic control (called PLC - Programmable Logistic Control) to tackle the problem. Compared to calculations made by SJ in the context of their introduction of the PLC system the operator estimated a saving potential of 15.000 kWh per year and coach. Given the total consumption for coach heating of about 55.000 kWh per year and coach, the measure is expected to save 20 to 30 % of the energy consumed for heating. The system optimises the use of electricity so that heat and light is minimized during parking hours, but automatically switched on well before service starts again. At the end of service the coach temperature is lowered to 12°C and raised again to service temperature one hour before service starts. The system is currently tested in a pilot project involving 4 coaches.

Reference list

[1] EVENT Project, "Evaluation of Energy Efficiency Technologies for Rolling Stock and Train Operation of Railways", http://www.railway-energy.org/tfee/index

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[3] Christian Lauszat, Re-use of waste heat, Energy Efficiency Days 2009, in Tours/France

[4] Claus Doll, Fraunhofer-Institute Systems and Innovation Research, Michael Krail, University Karlsruhe, Institute for Economic Policy Research, Policy scenarios to meet Germany's GHG reduction Targhets, NIAM / APRIL meeting ULC 8-9 ian.2009

[5] UIC CODE 345R Environmental specifications for new rolling stock, 2006, 1st edition, pp.21-22

INDICATORS	POTENTIALS		
Energy savings potential	In Mediterranean countries: 3-5 % In Northern countries: 4-9 %		
Pollutants emissions saving potential:	**Electric Traction**	**Diesel Traction**	
CO_2 emission saving potential	depending on energy mix	In Mediterranean countries: 3-5 % In Northern countries: 4-9 %	
NO_x emission saving potential	depending on energy mix	In Mediterranean countries: 3-5 % In Northern countries: 4-9 %	
CO emission saving potential	depending on energy mix	In Mediterranean countries: 3-5 % In Northern countries: 4-9 %	
HC emission saving potential	depending on energy mix	In Mediterranean countries: 3-5 % In Northern countries: 4-9 %	
Particulate emission saving potential	depending on energy mix	In Mediterranean countries: 3-5 % In Northern countries: 4-9 %	
Economic potential (on LCC basis):			
Implementation Cost (IC)	Low		
Operational Cost (OC)	Lower		
Maintenance Cost (MC)	Low		
Disposal Cost (DC)	Low		
Implementation time:	**Description**		**years**
Development time	Status of development of Control of comfort functions in parked trains: in use		<1 year
Administrative time:			
○ Financial	This could be a bottleneck, depending on the given country.		<1 year
○ Technical	The needed know-how exists and is available. The installation of an automatic control tool is rather cheap as long as the rolling stock offers a convenient interface for such a system, e.g. a central control for the comfort functions. Especially in the field of Telematics control solutions, the technological development potential is still high, but it is easier to apply such solutions on new rolling stock		1 year
○ Legal	No legal process linked to the installation of on-board equipment for controlling comfort functions.		<1year
○ Management	A successful development and implementation of an automatic system for the control of comfort functions in parked trains has to be preceded by a thorough assessment of types of passenger coaches and operational practice in the treatment of parked trains. Energy meters equipment could be a powerful tool to improve the monitoring and communication of energy saving measures if they are in function or active to measure energy consumption during standstill.		<1 year
Construction time Installation time	Short to midterm (1 to 5 years), half of the time spent on construction and half for planning within the company.		<5 years
Total time	1-5 years		

7.3. On-board use of braking energy in diesel-electric stock

Cluster

Energy recovery

Description

Modern diesel-electric vehicles can be equipped with the capacity to use some of the energy recovered during braking for auxiliary and comfort functions. In modern diesel-electric 3-phase locomotives the Diesel engine drives a generator feeding the DC link. The DC link feeds the traction inverters as well as the auxiliaries and the train bus supply. During braking the traction motors feed the recovered power into the DC link. This additional power can either be converted into heat in braking resistors or used for other consumers, namely auxiliaries (compressors, ventilation etc.) or the train bus supply (supplying the comfort functions in passenger trains).The power management is usually performed as follows: the recovered braking power is fed into the DC link. The part of this power that can be used for auxiliaries or train bus supply is drawn from the DC link, the rest is dissipated in the resistors. The resistor is automatically switched on if the voltage in the DC link exceeds a certain limit value.

Reference list

[1] EVENT Project, “Evaluation of Energy Efficiency Technologies for Rolling Stock and Train Operation of Railways”, http://www.railway-energy.org/tfee/index

[2] www.railway-technical.com/locobloc.gif

[3] Lionginas LIUDVINAVICIUS, Leonas Povilas LINGAITIS “New Technical Solutions Of Using Rolling Stock Electrodynamical Braking”, TRANSPORT PROBLEMS (PROBLEMY TRANSPORTU) 2009, Volume 4 Issue 2 pp.23-35

[4] Philippe Barrade, Blaize Destraz, Alfred Rufer, Hybrid vehicle in railway applications: supercapacitive energy storage for diesel-electric locomotives, Laboratory of Industrial Electronics, STI-ISELEI, Swiss Federal Institute of Technology Lausanne, Switzerland

[5] Elena AGENJOS, Sergio VALERO, U. Miguel Hernandez, Antonio GABALDON, Mario ORTIZ Francisco G. FRANCO, Roque MOLINA Rafael J.GABALDON, “Energy Efficiency In Railways: Energy Storage And Electric Generation In Diesel Electric Locomotives “20th International Conference on Electricity Distribution Prague, 8-11 June 2009

[6] Steiner M., Scholten J., Energy Storage on Board of DC Fed Railway Vehicles, 35th IEEE PESC Conference, 21-24 June 2004, Aachen, Germany

INDICATORS	POTENTIALS	
Energy savings potential	2-5 %	
Pollutants emissions saving potential:		
CO_2 emission saving potential	2-5 %	
NO_x emission saving potential	2-5 %	
CO emission saving potential	2-5 %	
HC emission saving potential	2-5 %	
Particulate emission saving potential	2-5 %	
Economic potential (on LCC basis):		
Implementation Cost (IC)	Medium	
Operational Cost (OC)	Lower (decrease of 15 % for energy)	
Maintenance Cost (MC)	Low	
Disposal Cost (DC)	Low	
Implementation time:	**Description**	**years**
Development time	Status of development: in use	<1 year
Administrative time:		
○ Financial	This could be a bottleneck, depending on the country.	<1 year
○ Technical	The use of recovered braking energy for on-board purposes in diesel-electric stock is a very promising energy saving measure for passenger operation. There are virtually no additional costs and barriers. Diffusion is essentially limited by the speed of stock renewal. The feature is to be integrated into specification sheets in future purchasing of diesel-electric locomotives. The potential of the feature in DMU stock has to be assessed.	1 year
○ Legal	No legal process linked to the installation of the equipment to use braking energy in a diesel-electric stock.	<1 year
○ Management	On-board use of braking energy in the new rolling stock is a choice of the management policy linked with the renewed fleet and with environmental responsibility.	1-5 year
Construction time Installation time	The construction time for a new locomotive equipped for on board use of braking energy is similar to others.	<1 year
Total time		1-5 years

7.4. Braking energy recovering by super-capacitors in on board equipment

Cluster

Energy storage

Description

By this technology it is possible to store the energy released when braking and use it during the next acceleration of the vehicle. Each time the vehicle brakes, the energy storage devices (super-capacitors) are loaded again. During the next acceleration the stored energy is released. This additional energy lowers current demands from the network, for the same traction effort.

Advantages

Charges in seconds. Double-layer capacitors compared with rechargeable batteries are extremely low internal resistance. Extremely low heating levels and improved safety. Good reversibility. High cycle efficiency (95 % or more). High output power. Little degradation over hundreds of thousands of cycles. Low impedance. Low toxicity of used materials. No danger of overcharge. Very high rates of charge and discharge. Virtually unlimited life cycle: millions of cycles, 10 to 12 year life.

Disadvantages

The amount of energy stored per weight unit (3 to 5 Wh/kg) considerably lower than an electrochemical battery (30 to 40 Wh/kg). About 1/10,000th the volumetric energy density of gasoline. The voltage varies with the energy stored. To effectively store and recover energy requires sophisticated electronic control and switching equipment. Highest dielectric absorption of all types of capacitors. Super capacitors and ultra capacitors are relatively expensive in terms of cost per watt.

Reference list

[1] M. Steiner, J. Scholten, “ Energy Storage on board of DC fed railway vehicles”, PESC 2004 Conference in Aachen, Germany

[2] M. Brenna, F. Foialdelli, E. Tironi, D. Zaninelli, “ Ultracapacitors application for Energy saving in subway transportation system”

[3] http://www.olino.org/wp-content/uploads/2009/03/bt-eco4-mitrac_energy_saver.pdf

[4] Philippe Barrade, Alfred Rufer, “The use of supercapacitors for energy storage in traction systems”, Laboratory of Industrial Electronics, STI-ISELEI Swiss Federal Institute of Technology Lausanne, Switzerland

[5] Philippe Barrade, Alfred Rufer, “High-Power Fast Energy Exchange between Storage Systems: Supercapacitors as energy buffer in transportation systems”, EVS-18: The 18th International Vehicle Symposium, 20-24 October 2009, International Congress Centre (ICC), Berlin, Germany

[6] Philippe Barrade, Alfred Rufer, "Current capability and power density of supercapacitors: considerations on energy efficiency", EPE 2003: European Conference on Power Electronics and Applications, 2-4 September, Toulouse, France

[7] Philippe Barrade, "Energy storage and application with supercapacitors", Laboratory of Industrial Electronics, STI-ISELEI Swiss Federal Institute of Technology Lausanne, Switzerland

[8] A. Schnewly, R. Gallay, "Properties and applications of supercapacitors – From the state-of-the-art to future trends", PCIM2000 Power Quality, Nürnberg, Germany

[9] http://www.railway-energy.org/tfee/index.php?ID=210.

INDICATORS	POTENTIALS	
	Electric Traction	**Diesel Traction**
Energy savings potential	20-30 %	till 35 %
Pollutants emissions saving potential:	**Electric Traction**	**Diesel Traction**
CO_2 emission saving potential	depending on energy mix	35 %
NO_x emission saving potential	depending on energy mix	>35 %
CO emission saving potential	depending on energy mix	<35 %
HC emission saving potential	depending on energy mix	<35 %
Particulate emission saving potential	depending on energy mix	<35 %
Economic potential (on LCC basis):		
Implementation Cost (IC)	Medium	
Operational Cost (OC)	Lower (decrease of 20 % for energy)	
Maintenance Cost (MC)	Low	
Disposal Cost (DC)	Low	
Implementation time:	**Description**	**years**
Development time	Mature and reliable technology	<1 year
Administrative time:		
○ Financial	This could be a bottleneck, depending on the country.	<1 year
○ Technical	Applicability for railway segments: medium Type of traction: electric – DC, AC – diesel Type of transportation: passenger - regional lines, passenger - suburban lines.	1 year
○ Legal	No legal process linked to the installation of the equipment for use braking energy with super-capacitors.	<1 year
○ Management	Use of energy recovering braking energy by super-capacitors on board equipment is a choice of the management policy linked with the purchase of new rolling stock.	> 5 years
Construction time Installation time	The construction time for new locomotive equipped with recovering storage device with super-capacitors is the same as for other types of rolling stock	<1 year
Total time		5-10 years

7.5. Braking energy recovering by super-capacitors in fixed installation

Cluster

Energy storage.

Description

During the braking phases some trains which are already in service and almost all new electric trains or locomotives are able to return energy to the overhead-line if this can receive it (e.g. when other trains are in traction phase and quite near to the braking train). In the regional transport case it is difficult to have at the same time a train absorbing power near to the braking one. For this reason the new energy storage technologies, such as super-capacitors, could be considered and collocated in fixed installations near stations where many trains stop. These trains or other can reuse the energy stored in their starting phase or other use of this energy could be done. A power supply optimisation system for storage in fixed installations can be installed in substations or along the track and it will operate on purely electrical basis.

Advantages

The highest energetic benefit of energy storage systems can be achieved in parts of the network: with a low degree of cross-linking (low probability of direct use of energy by other trains); in case of DC operation (because of the lower voltage of the Overhead Contact Line cause higher losses and reduce the effectiveness of the direct use by other trains); with slopes and high speeds (high amounts of braking energy). In contrast tightly meshed parts of the network with low speeds favour a direct interchange of braking energy as well as an AC operation, because of the higher voltage of the Overhead Contact Line cause less losses and make more effective the direct use of energy by other trains.

Disadvantages

The energy flows in the system are managed in a way that braking energy is stored only if no other train can use the energy directly. In other words there should be a clear hierarchy: a) direct use by other train, b) storage. An important issue is the layout of the storage system. Assuming a 50 t light rail vehicle and a maximum speed of 80 km/h, the critical energy is 3,4 kWh. There is a complex trade-off between technological and economic needs. On the one hand the storage unit should be dimensioned in such a way that it supplies enough energy and power for a train to accelerate without additional energy supply (e.g. to enable catenary-free operation over limited distances), on the other hand storage systems have high investment costs and they imply more weight and less space available (e.g. for passengers) on board, therefore just the necessary storage capacity should be installed. The combination of both on board super capacitors and capacitors in fixed installations could be not advisable because the higher investment cost necessary in order to achieve higher efficiency of the storage could reduce the effectiveness of the singular storage systems (as they are fed by the same energy source). Problems with controlling the energy supply systems could rise.

Reference list

[1] A. Rufer, D. Hotellier, P. Barrade, “A Supercapacitor-Based Energy Storage Substation for Voltage Compensation in Weak Transportation Networks”, IEEE TRANSACTION ON POWER DELIVERERY, vol. 12, no.2, April 2004

[2] Markus Klohr, Christian Lauszat, Basic Storage components, Energy Efficiency Days, sept 24th 2009, in Tours/France;

[3] J. (Jens) Buurgaard Nielsen, H.P. (Huib) van Essen, L.C. (Eelco) den Boer, Tracks for saving energy, Energy saving options for NS Reizigers Delft, CE, July 2005 (Publication number: 05.4878.30 CE-publications are available from www.ce.nl)

[4] Philippe Barrade, Energy storage and application with supercapacitors, Laboratory of Industrial Electronics, STI-ISELEI Swiss Federal Institute of Technology Lausanne, Switzerland

INDICATORS	POTENTIALS	
Energy savings potential	**Electric Traction**	
	5-10 %	
Pollutants emissions saving potential:	**Electric Traction**	
CO_2 emission saving potential	depending on energy mix	
NO_x emission saving potential	depending on energy mix	
CO emission saving potential	depending on energy mix	
HC emission saving potential	depending on energy mix	
Particulate emission saving potential	depending on energy mix	
Economic potential (on LCC basis):		
Implementation Cost (IC)	High	
Operational Cost (OC)	Lower	
Maintenance Cost (MC)	Low	
Disposal Cost (DC)	Medium	
Implementation time:	**description**	**years**
Development time	Mature and reliable technology	<1 year
Administrative time:		
○ Financial	This could be a bottleneck, depending on the given country.	<1 year
○ Technical	Expected technological development is highly dynamic.	1 year
○ Legal	No legal process linked to the installation of the equipment for use braking energy with super-capacitors in rail infrastructure.	<1 year
○ Management	Use of energy recovering braking energy by super-capacitors in fixed installations is a choice of the management. It is dependent on the infrastructure development and on the recovering ability of already existing and future rolling stock.	<5 years
Construction time Installation time	The infrastructure construction time is important.	< 5 years
Total time		<5 years

Note: The values in the table have been calculated referring to a situation with one fixed installation having the capacity to recover contemporary the braking energy related to maximum 4 trains. Therefore the evaluation may be different depending on specific traffic near the fixed installation.

7.6. Energy efficient driving by low-tech measures

Cluster

Eco-driving.

Description

In view of the barriers impeding a fast diffusion of advanced driving advice systems, non-technological short time efforts to promote energy efficient driving are especially promising. Many measures including training programmes for drivers can be implemented at good cost-benefit ratio and meet virtually no barriers. A considerable part of the reduction potential offered by energy efficient driving might be exploited by non-technological or low-tech measures (databases, systems based on GSM-R, laptop technology, etc). The following driving styles for energy efficient driving can be applied: crusing (DSB strategy) or coasting (French drivers strategy) [6], reducing maximum speed, using valleys and hills. The driving strategy depends also on the power on board of the train [7] (for coasting strategy it is advisable to have more power available).

Benchmark

DSB (Danish State Railway) decided to implement in all rolling stock by 2011 a system that handles all information required to do the mathematical calculations necessary to arrive on time and save energy, such as position, timetable and speed limitations. This means that the driver can better focus on safety related aspects[2]. A detailed report has been produced in DSB to determine the potential energy savings by introducing this system in Denmark. By conducting a series of tests and analyzing the results, the report states that DSB will save up to 15 % on the traction energy while improving punctuality.

Reference list

[1] TRAINER Project - TRAining programmes to INcrease Energy-efficiency by Railways (http://w3.disg.uniroma1.it/trainer/) (manual and video!)

[2] UK – National Express is embarking on a program of 'eco train driving'. As part of an integrated two-year programme to save energy and reduce CO_2 output, all National Express drivers are being assessed for energy efficient driving techniques. National Express believes that up to 6 % of energy can be saved in this area. (http://www.nationalexpresseastanglia.com/about_us/energy_efficient_travel)

[3] Implemented: DB (all 14 000 drivers qualified; theory, training simulator and coaching tips)

[4] Howlett PG, Milroy IP, Pudney PJ: Energy-efficient Train Control; Control Engineering Practice, Volume: 2 Issue: 2 Pages: 193-200 Published: APR 1994, ISSN: 0967-0661

[2] This view is not shared by some National Safety Authorities that think that the driver could become inattentive when following the system indication about the speed because it could be different from the speed indicated by the safety systems as the signalling systems.

[5] Lee, C.-K. (1999): A Simulation Study on the Energy Saving Strategy of Train Operation. Proceedings of the World Congress of Railway Research WCRR 99, Tokyo, 1999.

[6] D. Vastel, “SNCF Energy Savings Program”, Energy Efficiency Days, September 24th, 2009

[7] H. Rohrer, “Impatto dello stile di guida e della programmazione dell'orario sul consumo energetico”, Conference Per un uso attento dell’energia nel trasporto su ferro, Milan, 25 January 2010

INDICATORS	POTENTIALS	
Energy savings potential	**Electric Traction**	**Diesel Traction**
	5-10 %	5-10 %
Pollutants emissions saving potential:	**Electric Traction**	**Diesel Traction**
CO_2 emission saving potential	depending on energy mix	5-10 %
NO_x emission saving potential	depending on energy mix	5-10 %
CO emission saving potential	depending on energy mix	5-10 %
HC emission saving potential	depending on energy mix	5-10 %
Particulate emission saving potential	depending on energy mix	5-10 %
Economic potential (on LCC basis):		
Implementation Cost (IC)	Low	
Operational Cost (OC)	Lower	
Maintenance Cost (MC)	Low	
Disposal Cost (DC)	Low	
Implementation time:	**Description**	**years**
Development time	The needed sources exist for the implementation of the programme. Thus the time need for this is quasi zero.	<1 year
Administrative time:		
○ Financial	This could be a bottleneck (depending on: the given country; on the specific on-board technologies needed and on the availability of suitable fixed technologies).	<1 year
○ Technical	The needed know-how exists and is available	<1 year
○ Legal	No legal process linked to the adoption of such measures. Working rules and clarification of safety issues in the driver's desk with Safety Authority to be verified in advance.	<1 year
○ Management	This is the main bottleneck	<1 year
Construction time Installation time	Ideally less than 1 year, half of the time spent on construction (i.e. planning within the company), the remaining half on installation (i.e. carrying out the training itself).	<1 year
Total time		< 1 year

7.7. Interdependencies and contradictions between solutions

The matrix below represents the attitude of each solution to be implemented in conjunction with the other solutions considered in this catalogue. At this stage only qualitative judgements have been expressed and the following convention has been used:

+	It is profitable to implement the solutions together; in some cases it is possible to achieve higher potentials than the sum of the potentials of each solution.
0	The solutions are independent. Implementing the solutions together will not cause any advantages nor disadvantages: the total saving potential is the sum of the single potentials.
-	It could be not profitable to implement the solutions together: in some cases the resulting potentials would be lower than the sum of the potentials of each solution.

	Control of comfort functions in parked trains	On-board use of braking energy in diesel-electric stock	Braking energy recovering by super-capacitors on board equipment	Braking energy recovering by super-capacitors in fixed installations	Energy efficient driving by low-tech measures
Control of comfort functions in parked trains		**0**	**0**	**0**	**0**
On-board use of braking energy in diesel-electric stock			**–**	**0**	**–**
Braking energy recovering by super-capacitors on board equipment				**–**	**–**[3]
Braking energy recovering by super-capacitors in fixed installations					**–**[3]
Energy efficient driving by low-tech measures					

[3] This assessment depends on operation and characteristics of the trains. This aspects should influence the strategy adopted for the driving style in relation also to the power of the train. If a braking energy recovering storage system exists and the train has the needed power available, a Coasting strategy [6],[7] could be adopted to save energy and this assessment could be changed in a +, but if we adopt all the other strategies (see *Description* in paragraph 7.6) we reduce the number of braking phases and speed and consequently the energy stored on board (i.e. what it is saved up by energy efficient driving reduces the effectiveness of the braking energy recovering if the capacity of the storage systems it is not overfilled in any case (e.g. due to a low storage capacity).

8. Conclusions and future development

8.1. General remarks

The energy consumption of a train (as described in paragraph 3.2) strongly depends on the energy consumption of the many equipments of the traction system, auxiliaries and comfort function equipments, that, in their turn, depend in terms of EE on their instantaneous operational parameters and their maintenance conditions. Moreover the energy consumption of a train depends on characteristics of the train, characteristics and conditions of the line, environmental conditions, comfort parameters, the foreseen operational conditions of the train (timetable, empty running, parking period and mode, …) and the different driving styles that could cause high variation between different drivers (more than 49 %, see Fig. 5-1 and Fig. 5-2).

In order to approach the measurement of energy consumption in a systematic way, two main cases can be identified: in the awarding procedure for services or rolling stock the network utilized is:

- technically unlinked with other networks and the awarded services are the unique on this network.
- linked to other networks or used by many trains with different characteristics or operated by different TOCs.

In the first case the measurement systems could be managed by fixed energy meters installed in the electrical power supply substations.

In this last kind of service the data acquired could be profitably stored and used for the specification, in the energy balance sheet of the transport company, of the two indicators KPI2 and KPI4 as suggested by the Energy Manager of the ATM urban public transport company of Milan some years ago [14].

These two indicators provide a very helpful baseline about the energy consumption and make it possible to evaluate the actual energy saving potentials of different technologies / operational measures adopted during the real operation.

Usually the energy consumption measurement of the train is not foreseen in the diagnostic systems of the vehicles that mainly aim to identify the failures of the train components.

The installation of energy meters in railway vehicles provides consumption data that could be used for the identification and assessment of energy saving of technologies and operational measures adopted.

Some experiences on energy measurement and recording documentation are already ongoing. RFF (French IM) imposed traction units equipment with energy meters starting on the 1st of January 2010. Direction Committee of SNCB/NMBS (Belgian TOC) agreed on May 5th 2009 to install on board Energy Metering Systems on all new Traction Units.

Infrabel (Belgian IM) shall use the consumption recorded starting from January 2011.

TSI and CENELEC rules will impose the requirements for the energy meters and their accuracy (about 2 % for those available in the market) levels (see Fig. 5-3 and Fig. 5-4).

Energy meters can be used for:

- billing purposes (reference time of 5 minutes) in order to calculate the real energy consumption of each TOC and let them pay what they really consume;
- saving purposes, which implies functioning in real time (reference time of about 30 s) and possibility to exchange information with ground equipments able to send information to the driver in order to optimise the driving parameters by comparing the actual data of consumption with reference values for the position along the line.

The nomination of a correspondent responsible for Energy Savings (e.g. in Italy the Energy Manager) in each transport company is recommended by the French incumbent SNCF for each of its Business Units [22].

Moreover SNCF's rolling stock department recommends not creating sub-parks equipped with energy meters within traction unit series to keep an easier maintenance of traction units. These aspects could be relevant in particular for diesel engines where a bad maintenance by TOC could cause more pollutant emissions, energy consumption and costs for the general overhaul.

The strong influences of environmental factors, regional aspects (e.g. different cost of energy and power generation processes) let an approach be preferable which is based on target values to be granted by applicants to the bids.

The EU Railenergy Project is working to agree and propose specific sets of requirements (example for energy storage systems in Fig. 3-2) and global and single domain target values (example in Fig. 3-3).

These target values might be used within a weighting process to be applied to the energy saving potentials defined in the Pilot Catalogue of technologies and operational measures (see paragraph 7).

In all these cases a monitoring system to evaluate the keeping of the contract related to an awarding procedure for services, or for vehicles, should foresee:

- the specification of a limit value for the KPI2 and KPI4 as a requirement to be fulfilled by the proposed rolling stock (as for RAM indicator) in a direct contract procedure (possibly with bonus/penalty clauses in case the effective value of the indicator will be less or more than this limit value);
- to ask the manufacturers or the TOCs for calculating and providing their best offered values for KPI2 and KPI4 (again as foreseen for the RAM indicator).

In any case the PTAs have to specify all the characteristics and conditions defined in paragraph 3.2 with reference to the state of the art.

In order to clearly measure the energy consumption for the specified line or for the selected reference track in a commonly accepted and agreed (legally secure) way, a combined test could be performed during the commissioning phase (acceptance by the customer of the prototype) under the following controlled (during the test) conditions:

- respect of the driving style suggested by the manufacturer or the TOC and of the specified timetable;
- no other trains disturbing the test (respect of timetable without any delay);

- agreed (possibly in compliance with TSI and CENELEC standards) energy meters to measure the energy consumption with different payload (train fully equipped for service operation but without passengers on board, maximum payload, estimated payload); an agreed overhead contact line voltage (e.g. minimum and/or nominal value); where relevant an agreed energy receptivity by the overhead contact line (e.g. completely receptive and/or not receptive overhead contact line, to consider the extreme conditions);
- evaluation of KPI2 and KPI4 (on the basis of the simulated payload condition) and comparison with the offered values;
- monitoring of the real operational performance of the rolling stock data provided by the energy meters in case the contract is with the TOC (not applicable in case of an awarding procedure for the procurement of rolling stock by a PTA) and verification of the possible bonus/penalty clauses specified in the contract taking into account the operational measures provided by the TOC for energy savings (e.g. the effectiveness of the used energy meters data, the real use of the technologies and their operating efficiency).

Combined tests for a new class or series of vehicles is anyhow foreseen for other purposes (e.g. the authorisation process by the National Safety Authority in case of a network linked to the national network or from the Ministry of Transport or other local authorities in case of railway infrastructure which is not under national control). The results of previous tests, related to previous contracts, could be evaluated by PTAs if made available by previous customers because they have the property of these results, as provided for by EN 17025.

In the Railenergy project standard service profiles are being determined and some of them could be interesting for ECORailS in view of a possible integration in the awarding procedures. The energy consumption calculated referring to this service profile will not be compared in a real environment, thus these service profiles are not linked to a real test track.

In order to assess the saving potential for energy and pollutants of specific solutions, the manufacturers should provide on-off switching devices to allow the measurements with and without the new solutions and to ensure the availability of the train, although in a degraded operational mode, if the technology occasionally fails.

It seems difficult to monitor the real operational performance of single solutions, nevertheless it could be possible to ask for the repetition of specific type, or combined, test at certain time intervals.

The repetition of specific type, or combined, test at certain time intervals (e.g. the general maintenance overhaul of engines, other maintenance intervals, …) could be useful in order to verify the compliance to determined standards of specific technologies or of specific issues, e.g. noise emissions and pollutants. Up to now only homologation tests were provided, in contrast with some experience in the road sector where specific tests at certain intervals of time have to be performed to circulate within restricted area (e.g. the centre of the cities).

The mentioned examples of best-practice of energy efficiency and environmental requirements in awarding (cfr. Paragraph 4.4) show that there are positive approaches towards integrating environment-related criteria in tenders of regional rail services or the procurement of new rolling stock.

Anyway such good practices are still rather exceptions than standard procedures; indeed the necessity and usefulness of environmental measures are generally accepted, nevertheless economic criteria are still almost absolutely dominant for decisions concerning the procurement of rolling stock and the awarding regional rail services. Thus the potential, even on the economic side, of the environmental measures could have positive effects on the environment and the public opinion, but it should be clarified to PTAs and TOCs.

The TOCs perspective (see ARRIVA's experience and observations, paragraph 4.4) is very interesting for the ECORailS project because TOCs are both user of the Guidelines (when they have to acquire rolling stock) and the other contractual part respect to the PTAs (when they offer services).

From a TOC point of view the best way to include EE/EF criteria in tenders is:

- Not being too prescriptive
- Having realistic expectations
- Use lessons learnt from road sector
- Environmental requirements level to be decided at local level according to willingness to pay of passengers and focusing on new vehicles instead of requiring mandatory changes to existing vehicles.

ECORailS project has highlighted up to now that the most suitable way to be not too prescriptive is asking requirements about target values of direct and indirect indicators (cfr. Chapter 5). Furthermore this approach seems to PTAs (cfr. Paragraph 5.1) the more legal secure way for asking requirements respect to ask requirements about specific technologies or operational measures.

The considered assessment of the EE/EF potential of selected technologies and operational measures is the ECORailS way to answer to the second bullet point (cfr. Chapter 7). From the ECORailS point of view also the last two aspects together with the evaluations on the basis of the LCC are of high importance and refers to ECORailS ongoing activities.

The last TOCs warning about the technical ability of retrofit (cfr. D6 paragraph 5.3) and legal problems as barriers for safety[4] issues (cfr. D6 paragraph 5.6), that could rise if mandatory

[4] At the present time there is only an abstract definition of the term "safety".
As example of traditional definition, the railways are obliged to operate safely and to construct the railway infrastructure, vehicles and accessories safely and to maintain them in an operationally reliable condition. Railway installations and vehicles must be designed in such a way that they satisfy the requirements concerning safety and order. The requirements are regarded as having been met if the railway installations and vehicles comply with the specifications contained in this regulation and, insofar as it does not contain any express specifications, the accepted rules of engineering practice (all technical rules based on knowledge and experience which must be complied with in order to prevent risks and which are known in the expert groups and are recognised as being correct by the majority).
This approach proved to inhibit competition and progress, for example with regard to the use of new technologies. Although it would have been possible with new solutions and technologies to extend the approach to include new regulations, due to the rate of technological progress and the average agreement period in expert committees this approach could not stay the course in the long term.
The aim of the EU Safety Directive 2004/49/EC is to compare and optimise the safety of the various European railways. Amongst other things, it requires the gradual introduction of common safety targets on an overall system level and procedures to demonstrate safety (common safety methods), in order to maintain the high level of safety achieved as more and more railways become privatised. This can be achieved with a risk oriented approach.
The main definitions on which this concept is also based in the CENELEC standards are:

- Safety: freedom from unacceptable levels of risks, changes would be asked for existing vehicles, are already evaluated in previous WP2 activities for each solution.

8.2. Integration of D7 contents into Guidelines

One of the aims of D7 is to provide further relevant inputs for the ECORailS Guidelines in order to integrate the technological feedback from the User Platform and the PTAs of the ECORailS consortium.

In the first project period WP6 worked on a first hypothesis of Guidelines structure and issued a first draft version of them, divided into:

I) General considerations;

II) Legal and Economic framework;

III) Criteria and methodology for application (main part);

IV) Results of the case studies and other background information.

Some D7 contents, suitably re-ordered according to Guidelines structure, may be considered ready to be integrated into the new version of the Guidelines.

In particular the General considerations (Part I – chapter 4) provide useful content from D7:

- paragraph 3.2 concerning the description of the state of the art and of present and foreseen trends concerning the measurement methodology for the energy consumption assessment;
- paragraph 3.3 related to the barriers for PTAs to ask requirements;
- paragraphs 4.2 and 4.3 about the application to different types of operation;
- paragraph 4.4 for best practice examples from a TOC participating in the 2nd User Platform in Berlin and the integration of some useful information about the weights for energy efficient criteria in the tender by the regional rail network of Lombardy, Italy;
- chapter 8 for conclusions and future developments

At the same time the core part of the Guidelines (Part III – chapters 3, 4, 5 and 6) will find useful contents from D7:

- in the definition of the application field technical context (paragraphs 4.1 and 4.2), concerning the identification of features and dimensions of operated fleets and services for the Guidelines application to different types of operation;
- chapter 0 referring to direct indicators and methodological approach for technologies and operational measures qualification, needs and preferences of PTAs, baseline

- Risk: the combination of the frequency, or probability, and the consequence of a specified hazardous event,
- Harm: physical injury or damage to the health of persons,
- Tolerable risk: the maximum level of risk of a product that is acceptable to the Railways Authority,
- Hazard: a physical situation with a potential for harm.

These definitions regarding safety differ fundamentally from the traditional definition described above since the absence of an excessively high risk must be demonstrated (in contrast to the formulation and compliance with detailed technical regulations).
Reference: J. Braband, B.Brehmke, S. Griebel, H. Peters, K. Suwe, "The CENELEC-Standards regarding Functional Safety, Edition Signal+Draht.

indicators, their detailed and exact description, applicability of indicators, energy consumption measurement systems, the monitoring system to evaluate the keeping of the contract, giving advices and comments for monitoring the performance;

- chapter 6 describing the specific indicators in order to qualify pros and cons, potentials and limits in terms of methodology and technology, detailed and exact definition, how to include in awarding procedures, advice and comments for monitoring the performance;
- chapter 7 with features and equipments of the vehicles to be used selected by ULS and agreed by the other partners, their qualification on the basis of EE/EF potentials, LCC basis, interdependencies and contradictions between solutions.

Further contribution to Guidelines will be provided by WP2 at a later stage (Sub Task 1.2 and 1.3, Task 2) within the contents of Deliverable 8.

8.3. Further project activities and next deliverables

Many preliminary results achieved in Task 1.2 of WP2 and summarised in D7 will represent key premises for the further development of ECORailS.

In particular, with specific reference to WP2 activities only, on the basis of the detailed review of technologies and operational measures, including the database fed by qualitative and quantitative information, a first Pilot Catalogue represents the test of the methodology used to evaluate:

- advantages and disadvantages;
- life cycle costs;
- benefits;
- Interdependencies and contradictions between solutions.

Their matching with the identified needs of Public Transport Authorities (PTA) and Train Operating Companies (TOC), will enable the WP2 to achieve the compilation of a more extended Catalogue of efficient and environment-friendly rail technologies differentiated by operational contexts (e.g. on regional basis).

It will also be a premise for the identification of potential technological paths in different future scenarios, based on:

- environmental impact calculations;
- selection of suitable indicators to be introduced in the procurement requirements (the present deliverable suggests a first methodological approach to the methodology for measuring direct and indirect indicators).

The full catalogue of technologies and operational measures and the identified potential technological paths in different future scenarios will be the main output to be included in D8 to represent the technological overview which shall be included into the final version of the guidelines in order to discuss the project results also in the mid- and long-term perspective.