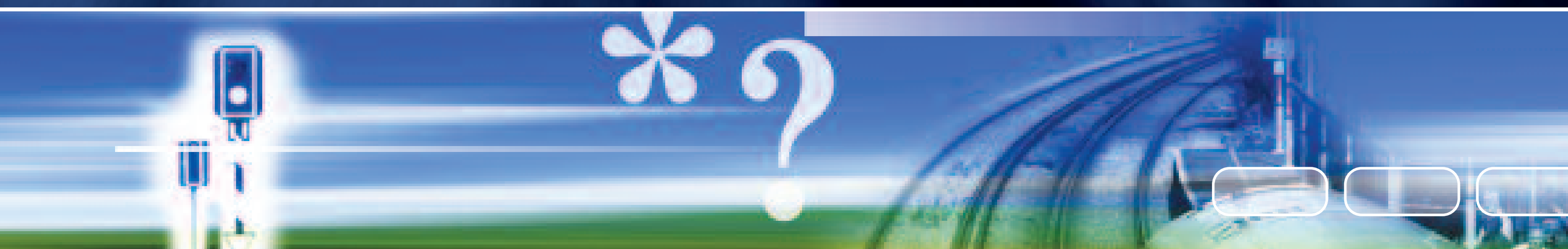
Process, Power, People

Energy Efficiency for Railway Managers



This booklet has been prepared by ATOC (Association of Train Operating Companies) on behalf of UIC (International Union of Railways) under the direction of an editorial panel comprising:

Willy Bontinck

Hub Cox

Alain Garde

Phillip Hinde (Chairman)

Gregor Hribar

Raimondo Orsini

Henning Schwarz

Iuliana Stoicescu

Enno Wiebe

Photos by: Bojan Dremelj, Phillip Hinde and UIC members.

The content has been reviewed by Paul Watkiss, an independent expert on energy and environment.

For further information contact Henning Schwarz, UIC Environmental Advisor: schwarz@uic.asso.fr

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Process, Power, People - Energy Efficiency for Railway Managers

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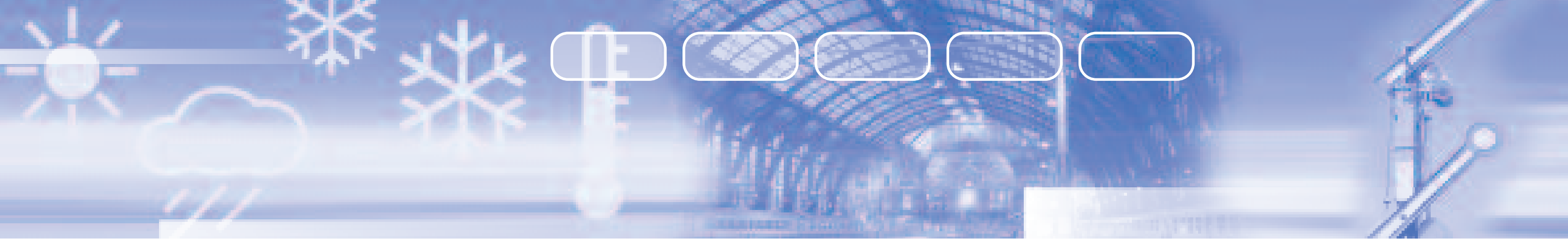


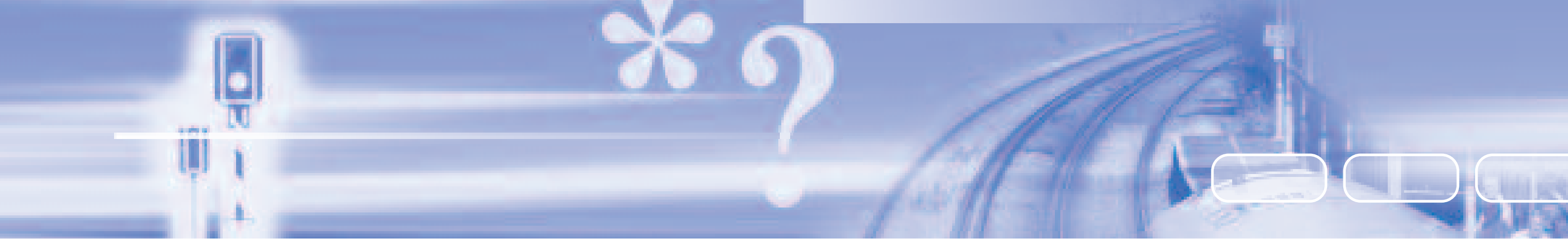
1 Introduction

Energy is set to dominate the transport agenda around the world in the coming decades for two inescapable reasons:

- Energy costs have risen dramatically in recent years and may continue, for a variety of reasons, to rise in the future
- The carbon emissions from energy use are a matter of increasing concern as the causes and consequences of global warming become clearer

Even 'renewable' energy is not cheap, nor without environmental consequences; indeed the setting of 'renewable' and 'biofuel' targets by the European Commission will add to the cost pressure. As well as being the subject of concerns about greenhouse gases, fossil fuel use is increasingly regulated in respect of pollutants such as sulphur and particulates, again adding to the cost. Globalisation of the energy market, and the inter-linking of supply networks means that everyone is affected. No one can say that these topics are not important to them and their particular business.

Both the financial pressure, and the need to manage our carbon dioxide emissions, mean that railway personnel must improve their understanding of the technology, the economics and the opportunity of energy management to reinforce the position of rail as a cost effective and environmentally friendly form of transport. This booklet sets out to raise awareness, and provide some signposts for the way ahead.



1.1 The Challenge

We may believe that the rail industry is relatively energy efficient, but we must not be complacent – our competitors will improve and we cannot continue to 'play the green card' while doing nothing practical to improve our own position.

But to be positive, we believe there is scope to get even better. This publication, the associated websites and other contacts will show railway operators where to start, to meet this challenge. The work is in three parts:

- The management process
- The technical development
- The training and motivation of staff

Hence our title Process, Power, People. We try to develop these three elements in a way that relates to railways, and with information that will be helpful to railwaymen and women at all levels – from senior managers to train drivers and station workers.

Running an energy efficient railway is not a matter of chance or luck. It requires discipline, commitment and continuous improvement. A leading sportsman once said, 'The more I practice, the luckier I get'. This booklet is designed to help railway managers develop their energy management skills and 'get lucky' for themselves and their company, by delivering a successful energy management programme.

Energy provides a challenge for both Freight and Passenger business


THE INDEPENDENT

TERRY'S TEARS

RUNNING ON EMPTY?

Alarmist media reports speculate on price and availability

1.2 Some Facts and Figures

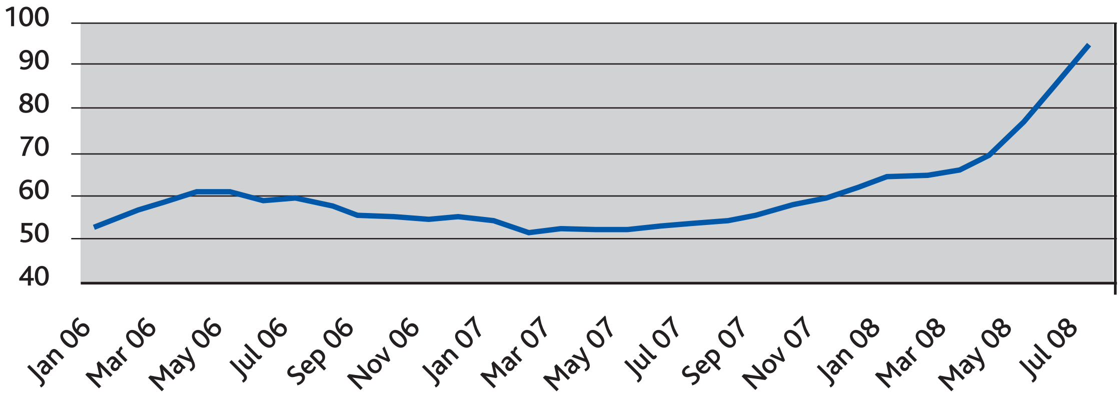
According to figures collected from the European members of UIC, in 2005 Europe's railways alone consumed 43 000 GWh of electrical energy and 2.5 million tonnes of diesel fuel.

The American Association of Railroads (AAR) report that in 2006 freight railroads in the USA emitted 51.5 Teragrams of CO_2 equivalent emissions.

Fuel and electricity prices remain at historically high levels in real terms; for example, the energy bill for main-line railways in the United Kingdom alone will exceed €500 million during 2008.

This graph from Amsterdam based securities exchange Endex illustrates how forward prices for electricity in Belgium and Holland are continuing to rise.

ENDEX electricity price, baseload for delivery in 2009 (EUR/MWh)



Effective procurement arrangements can control the costs in the short term, but on a rising tide of price, only greater energy efficiency will deliver long term success.

Over the lifetime of a passenger train, energy consumed will represent up to a quarter of the total life cycle cost, around the same amount as the capital spent on buying the train when new.

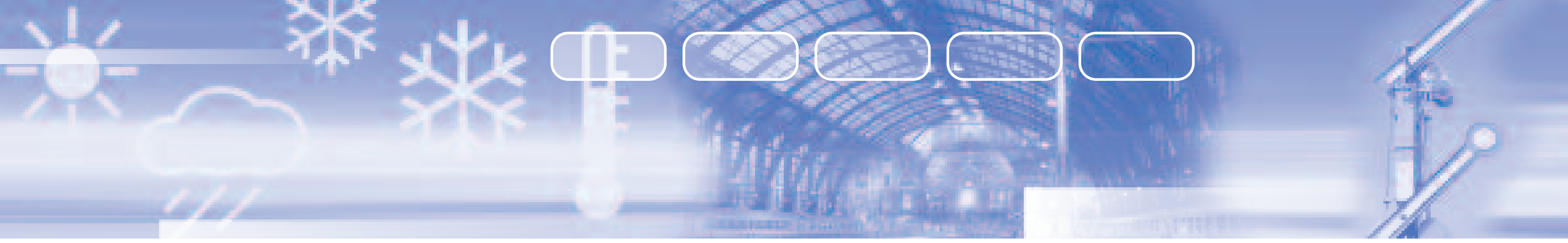
Improved traffic loadings, and more productive use of rolling stock, has reduced energy use per passenger and tonne kilometre over recent years; however improvements from technical innovation have been slower.

For example in UK energy per passenger kilometre on electric trains fell by 25% from 1995 to 2005, but per vehicle kilometre dropped only 6%. Fuel consumption per vehicle kilometre for diesel trains actually worsened slightly over that period though increased traffic ensured improvement per passenger kilometre. In future, however we will be expected to make absolute and not just relative cuts in our carbon footprint, while still increasing the amount of people and freight actually carried.

Rail is part of a wider transport industry that, as a whole, is responsible for a quarter of Europe's greenhouse gas emissions. Furthermore, transport has been the only sector in the European economy that is increasing its CO_2 output. Again, while we can encourage governments to move to 'greener' and lower carbon energy supplies, our biggest contribution can be to improve our energy efficiency and allow our savings to help cut the overall carbon burden in all industrial sectors world wide.

These numbers and trends, and the ways in which rail fits into the wider transport and industrial scene, illustrate the size and the extent of the energy question. It is most certainly an issue which is here to stay. We must make sure that rail becomes part of the solution, not part of the problem.

Energy management is at the heart of rail operations



How much energy do we use to move a passenger one km?

1.3 Asking Questions

Before exploring this booklet it may be worth posing some simple questions for readers to ask themselves, their bosses, their colleagues, and their staff. Here are a dozen simple points - how easily they can be answered will show how much work needs to be done to make energy management an integral part of running your railway business.

If all the answers are at your fingertips then you may not need to study this booklet!

However, if even a few of the questions leave you thinking, please read on...

1. *How much does our railway company spend on energy each year?*
2. *What percentage is that of our total financial budget?*
3. *What are our projections and plans for the energy budget in the next few years?*
4. *How will we measure progress in energy efficiency?*
5. *How much energy or diesel fuel do we use to move a passenger, or a tonne of freight, one kilometre?*
6. *How does that compare with other railway operators?*
7. *How does it vary between routes, traffic and types of rolling stock?*
8. *When did we last renegotiate our energy supply contracts?*
9. *Is energy efficiency included in the specification of new trains and new stations?*
10. *When did we last recalibrate our diesel fuel meters, and who reads the electricity meters at each station?*
11. *Do we have a company policy on our 'carbon footprint' or use of 'green' energy – is it integrated with any wider environmental programme?*
12. *Who is ultimately responsible for energy spend in our company?*

2 Process - Management Principles for Energy Efficiency

Energy is a resource like labour, capital or materials. It needs to be actively managed with the same seriousness and professionalism as we apply to managing these other aspects of our business.

Before we try to answer the technical questions about energy use on the railways, we must make sure we have a process for managing it. This process can be applied to the specialist subject of energy used by the trains themselves, and to the more ordinary tasks of heating and lighting stations, offices and depots.

The points made in this section two are based on the international standards now being developed for best practice in energy management in any industry. Our mission is to apply them to rail.

'A policy is a temporary creed liable to be changed, but while it holds good it has got to be pursued with apostolic zeal'
Mahatma Gandhi

2.1 A Policy and a Plan

For a railway company to manage its energy use it must have a clearly stated Energy Policy, and a plan to deliver that Policy. Aspects of the Policy should include:

- Avoiding wastage of energy
- Maximising the 'productivity' of the energy
- Procuring energy at an economic price
- Investing in energy efficient trains, stations and plant
- Using energy from renewable or sustainable sources
- Measuring and recording the use of energy

A successful Policy must include all significant aspects of energy use, and show:

- Commitment from top management
- Clear and credible goals
- Consistency with other company objectives

Behind the Policy must be a detailed plan listing specific actions to take the company forward. Without this the Policy will be just 'hot air' – and the company may be accused of 'greenwash' or just using energy efficiency as a public relations exercise.

The Policy must be reviewed regularly to make sure it remains relevant to the needs and objectives of the company. This review can be an opportunity to renew the commitment and enthusiasm to carry the policy into effect.

Targets must be relevant to front-line staff

2.2 Targets and Objectives

The plan must contain timescales, numerical targets and practical objectives (such as the completion of individual projects). The targets must be based on the measurements we make and the records we keep of energy use. This is discussed in detail in Section 2.5.

The first steps in setting the targets are:

- Baselining – knowing how much energy is being used today
- Understanding where and how it is being used
- Recognising the 'drivers' which determine the consumption. Is it the traffic level, the technology, the operational skill of staff, or even just the weather? Which of these factors could be better managed?
- Planning future production needs – in the case of a railway company; timetables, service patterns, rolling stock schedules

A full Energy Audit of your company may be needed to actually get to the root of what really happens and find true answers to these questions.

You must also understand what is possible and, if investment is required, affordable.
A formalised approach to energy management should include a register of opportunities for energy saving. These opportunities will include some of the technical and operational possibilities described later in this booklet. The register will become the basis for agreeing targets and setting priorities. You must also be aware of external or legal requirements that will affect your plans, including taxation, carbon trading or 'renewables' obligations.

Overall company targets must then be broken into 'bite sized chunks' and given as objectives to individual managers and their local staff teams. These must be:

- Achievable – and with realistic timescales
- Fair – don't expect one department to do all the work!
- Measurable
- Backed up by practical support; this may be capital investment, training programmes or new measurement systems

If objectives are not realistic then staff will become discouraged and the whole programme may do more harm than good.

2.3 Roles and Responsibilities

It is easy to think that energy management is 'someone else's job'. This is a particular problem on a railway where a lot of different people have an influence on the final energy bill. For example in running a single train from City A to City B the following people might be involved:

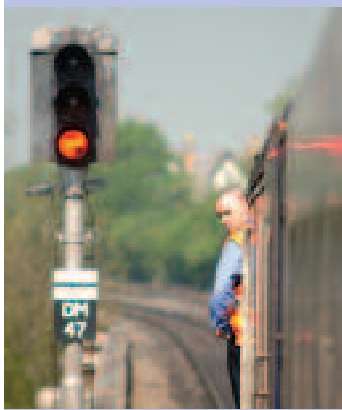
- The engineers who make sure the technical aspects are working correctly and efficiently (this includes the track and signals as well as the train itself)
- The driver at the controls
- The signaller or dispatcher who must give the train a clear run
- Station staff who ensure punctual departures
- The planning staff who write the train timetables

The Energy Policy and the supporting plan must spell out who is responsible for what, and what particular targets they each have to achieve. At the top one Director should have accountability for energy consumption – and the objectives of his colleagues and the other managers and staff must support the target that has been set.

If there are particular projects or initiatives to improve energy efficiency then there should be individual project managers with dates to meet, tasks to fulfil and results to be shared.

You may have someone in your company with the job title Energy Manager. Ideally this person will be a qualified technical adviser working to support colleagues in line management – do not expect one such individual to manage your company's entire energy bill single-handed.

And of course, all of the people given roles and responsibilities must also be given the information to help them do their job, and the feedback to measure their progress – see the section on page 13 on Measurement and Records.



Drivers and their supervisors must understand their role in energy management

Sometimes a little humour may reinforce the communication

courtesy of SNCB

2.4 Competence and Communication

Once we have identified the people with roles and responsibilities for energy, the next step is to ensure they are competent and well informed. To give a safe and reliable train service we fully expect staff to be given the necessary training, to understand risks and problems, and to have the skills to overcome them. We need to do the same for the staff who deal with energy.

Training must give the people involved an understanding of:

- The cost of energy
- The environmental problems caused by energy wastage
- How, in simple scientific terms, energy is used for different activities (see the 'Where does the Energy Go?' Section on page 20)
- How their actions can improve matters – and how to do things differently

Staff can then be briefed on the overall Energy Policy and their responsibilities in delivering the Policy. Training must be backed up by regular communication on the company policy on energy and how progress is being made against the targets and objectives. This communication should be relevant to their particular department and if possible, their particular local area or route. Devise a communication plan.

Remember in your plan to reach other stakeholders; customers, shareholders, governments, transport authorities, who may all want assurance that you are running an energy efficient railway. So involve your public relations and marketing departments, and include energy in your corporate responsibility reports.

2.5 Measurements and Records

This is the most important part of this whole booklet! Without measurement systems and good record keeping no programme can be successful. You cannot work out where you are, set targets or track progress. Measure in kilowatt-hours of electricity or litres of diesel fuel. Prices fluctuate, so measuring by Crowns, Pounds or Euros will not tell the whole story!

To run trains on time we provide clocks and watches and collect punctuality statistics to check that trains arrive on time. We must do the same for energy with our electricity meters and fuel data. Your measurement arrangements should be formally described in your Energy Policy and associated plans. Here are some important tips:

Diesel Fuel for Locomotives and Railcars:

- Collect consumption by loco or car number to check for technical problems
- Ensure all fuel points used by your fleet send data – not just the home depot
- Calibrate your fuel meters as part of your quality control system
- Automate the collection if possible – manual collection is a source of error
- Modern diesels have engine data collected through the control system – cross check between fuelling records and the on-board flow meters and computers.

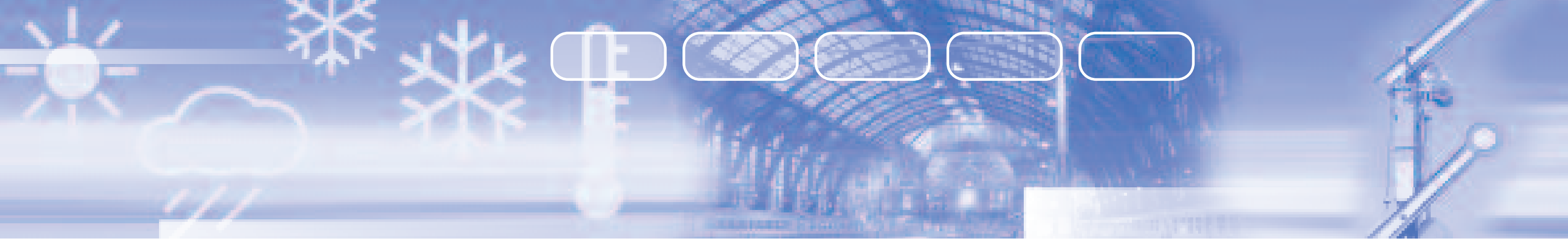
Electric Traction Energy:

- Use on-train metering whenever possible (see Appendix 1) with automated collection and data analysis
- Cross-check with lineside consumption measurements
- Modern units will have computerised traction control systems – cross check with this data

All traction data:

- Normalise by distance run, or for freight, tonne/km hauled
- Monitor energy used while not in traffic (i.e parked at terminus or depot)
- Adjust for seasonal factors
- Link the energy data to the people responsible (drivers, depot managers)
- Make data collection and data processing simple and easy for staff to do correctly

Deutsche Bahn rolling stock has pioneered on-board metering, and UIC is working to ensure a harmonised system for trains in European international traffic



Weather conditions will significantly affect power used for train heating

Non-traction data (using existing information available in the company)

- Correlate energy performance with traffic management data (e.g. - punctuality data - delay will affect drivers' train handling strategy)
- Check energy use against weather data. (The principal factor will be ambient temperature, but wind speed and direction may also affect traction consumption)

Stations and Depots:

- Ensure all locations are metered
- Use remote read-out meters wherever possible, get others read regularly
- Insist your utility provider meets their legal responsibility to give you information with your bill
- Adjust energy data for heating/cooling according to weather ('degree days')

Reporting:

- Produce regular reports
- Show results against target
- Look for variations – high variance suggests poor control
- Identify best and worst in class examples, and look for possible reasons (but avoid simply making excuses or blaming individuals!)
- Break down the data for local managers
- Track the effect of individual projects
- Submit high level reports to top management
- Provide localised feedback for individual managers and staff

General principles

By understanding where, and how, your energy is being used you will be able to target your measurement efforts on the most important energy aspects, and then track the progress of efforts to manage these items.

Wherever possible reconcile 'top down' estimates of energy use with the 'bottom-up' totals from individual trains, buildings and equipment. This may help track down areas of waste and uncontrolled loss if the numbers don't add up.

Tracking in this way for diesel fuel can also have an environmental benefit in detecting leakage, or even in revealing loss due to theft.

Automate and integrate the collection, data transmission and analysis process. 'Paper and pencil' recording methods are open to error and manual sorting of data will be costly, and may leave you overwhelmed with numbers and 'unable to see the wood for the trees'.

Make sure that the energy reporting feeds through to headline company reports, and is used in the regular review of the Energy Policy and the continuous improvement processes required by an ISO quality management process.

Documentation

Linked to the discipline of record keeping is the question of overall document control for your energy management systems.

This of course requires the formal description of your measurement systems (who, what, how often, etc.) but will also include proper documentation of maintenance procedures, power distribution networks, HVAC system layouts, thermostat settings, nominal power outputs etc, as well as the arrangements for care and calibration of your meters and recording equipment.

Signallers and Drivers both have a responsibility towards delivering the efficiency that results from effective Operational Control

2.6 Operational Control

Operational Control means managing your business so that it uses resources as efficiently as possible to produce output – in our case a train service.

Good operational control also means that the same input of resources always achieves the same amount of output. For example if a freight trip with a 1000 tonne train this week, uses 25% more fuel than the same working last week, then that may indicate poor Operational Control. Questions need to be asked, and corrective action taken, so that the fuel burn for next week's trip is back at the original level.

There are simple statistical techniques and systems such as Statistical Process Control and the Six Sigma programme to improve this aspect of management, but they all rely on the information from the measurement systems described in the previous chapter.

All the staff involved in energy use have a part to play in good operational control:

- Maintenance Staff – ensuring locomotives and traction units are in efficient working order – this includes heating and air conditioning as well as the main traction systems
- Train Drivers – we discuss eco-driving later, but an even level of fuel or electricity use is a good sign of efficiency
- Schedulers – optimising timetables for reliable and energy efficient operation
- Signallers and Dispatchers – keeping trains rolling, avoiding extra stops and starts due to route conflicts and congestion, makes a vital contribution

Good operational control will benefit all aspects of a business. Evidence shows that a punctual railway is an energy efficient railway – there is no contradiction between saving energy and timekeeping. It should also be a safer railway – fewer red lights encountered, and a steady driving technique, means there will be fewer chances for a mistake to be made.

2.7 Plan-Do-Review

Every management textbook has these three words - and with good reason!

When you write your energy policy, set your targets and detail your Plan, you have no automatic guarantee of success. The 'Do' stage must be fulfilled with enthusiasm and commitment and the results, from the measurement system checked and analysed. This is the 'Review' which sets the agenda for the next round of the programme. Ask yourself some tough questions:

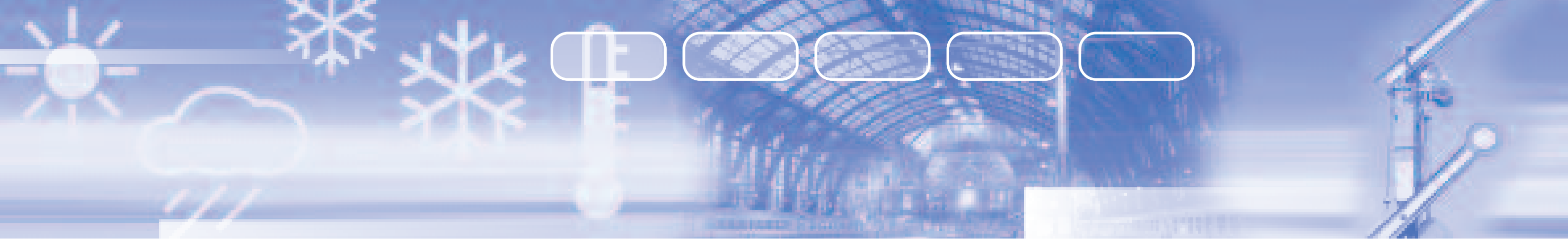
- Were the results in line with target?
- If not - why not?
- Were all the action plans in place?
- What went well - what not so well?
- How can we do better?
- Can success be maintained?

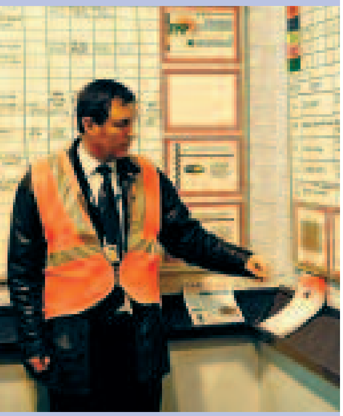
Make sure your Plan-Do-Review process looks at individual projects and initiatives, as well as the overall company picture.

If your results were below target, do not despair; learn and do better. Energy management is too important to give up!

If your results were good, do not be complacent. Follow the Japanese philosophy of kaizen - continuous improvement. Many of your energy initiatives will be 'people-based', and while technical fixes may be 'fit and forget', people will always need reminding not to slip back into bad habits!

The N700 Series Shinkansen trains are designed with improved energy performance in mind





ISO Certification brings Total Quality Management principles to energy efficiency

2.8 ISO Certification

To give your energy management programme real 'bite' why not include it in your ISO9001 Quality Management or ISO14001 Environmental Management Accreditation?

This will:

- Send a strong message to staff, management and the public that you take energy seriously
- Submit the programme to outside review and criticism – which may help you improve it further
- Enforce the keeping of good documentation – not just consumption records, but all relevant material; e.g. maintenance manuals, work procedures, train operating handbooks and training instructions
- Bring a discipline to auditing the figures, checking that the management arrangements are in place, and making the review process work
- Force you to keep Policies, Plans and Projects up to date
- Encourage regular formal review of the effectiveness of your programme

As this booklet is written a new European Standard EN16001 on Energy Management is being prepared. We have used many of the principles from that Euronorm in this publication. Further documents on Energy Audits and other supporting topics are under consideration. Meantime the International Standards Organisation is proposing a full international norm on the subject.

Continuous Improvement is an underlying theme of this Standards based approach. This should become a cornerstone of your own policy and programmes. Energy management is coming out of the shadows to become a major feature of efficient industry. Railway managers need to take part to position Rail as a leading transport mode for the 21st Century.

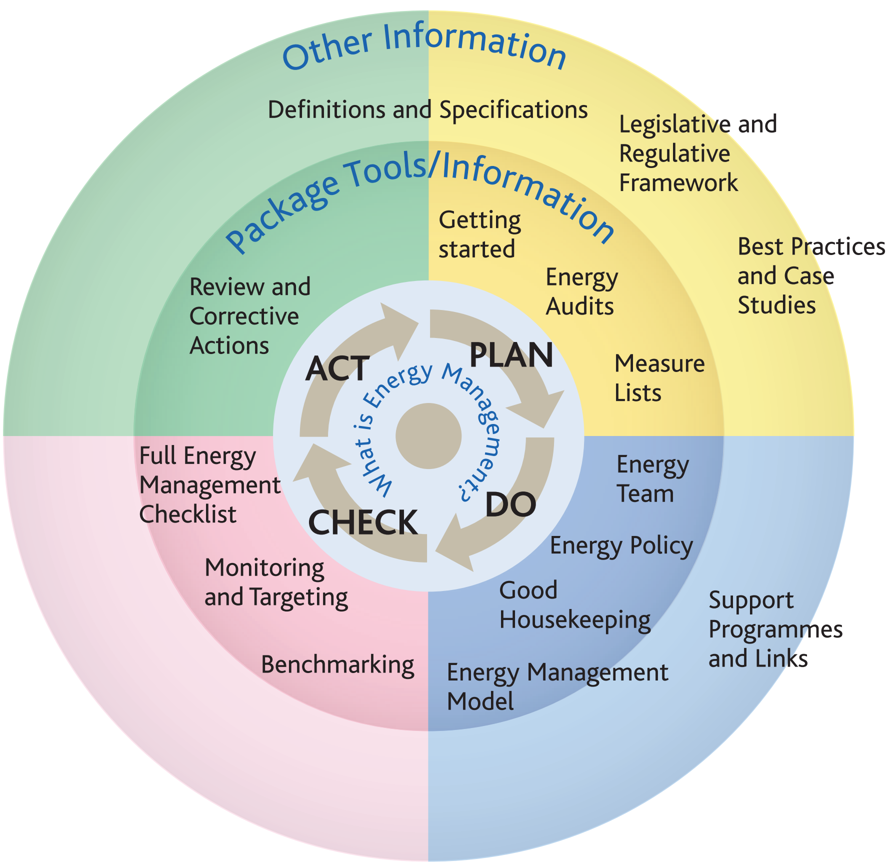
2.9 BESS

There are already tools and support programmes available to help the less experienced to start their energy management programmes with good methodology and understanding.

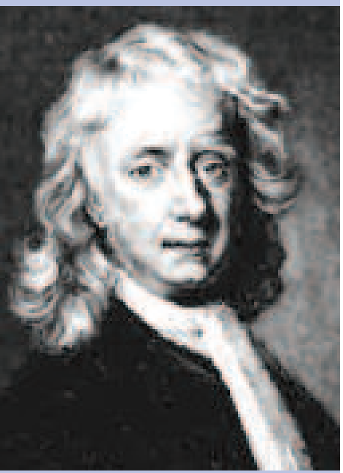
As an example, the BESS programme (Benchmarking and Energy management Schemes in Small and Medium-Sized Enterprises) has a lot of information and ideas relevant to the Rail Industry.

It has been developed as part of the Intelligent Energy Programme sponsored by the European Commission and is accessible on the web address www.bess-project.info

The picture below shows how the BESS material links into the plan-do-review cycle of good energy management.



3 Power for the Trains



Sir Isaac Newton
1643 - 1727

This is not a detailed guide to the scientific details of railway engineering. However it is vital to understand how and why the energy is used so that the best technical and operational solutions can be chosen to keep energy bills under control.

This section gives a very simple introduction to the subject and points the way to some of the energy management techniques on offer.

3.1 Where does the energy go?

The energy provided to the trains themselves is used in five main ways, plus one extra for electric traction :

1 Accelerating the train up to speed

2 Overcoming resistance to movement

3 Climbing gradients

4 Powering the control systems

5 For passenger trains, lighting, heating, cooling and ventilating the carriages

6 For electric trains, transmitting the power through the supply network

For Item 1 the basic principles are those worked out by Sir Isaac Newton in the seventeenth century! Newton's calculations tells us that the two most important factors are:

- the weight (mass) of the train and
- the speed

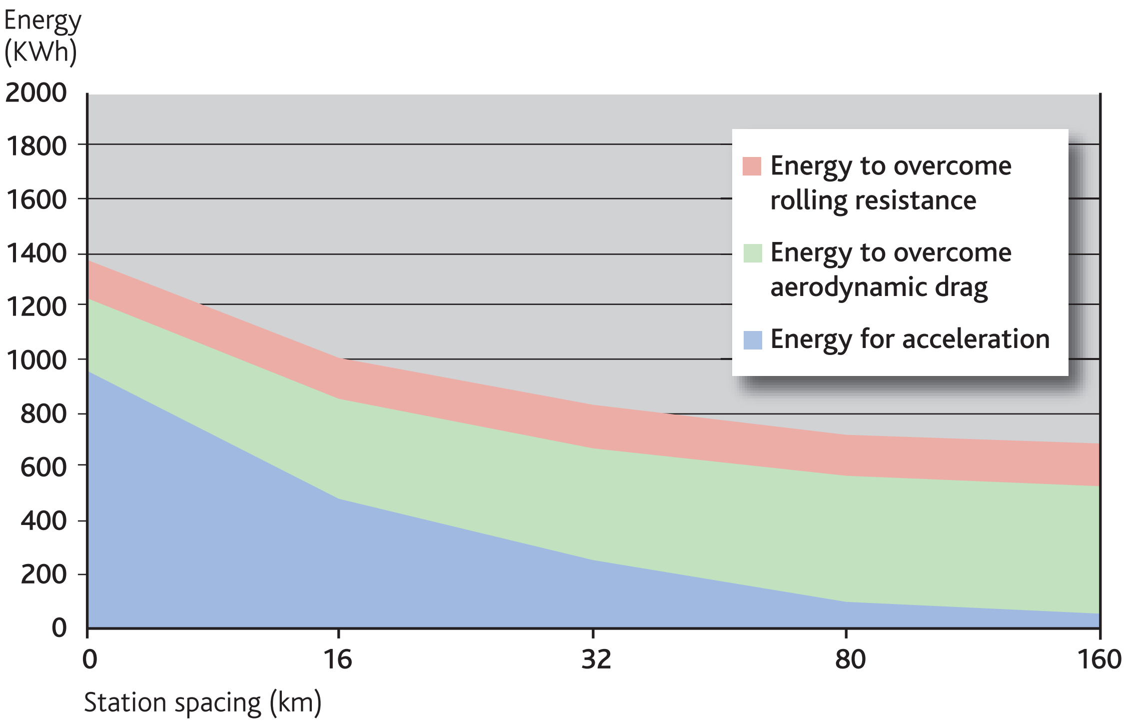
It is also vital to understand that this 'kinetic energy' increases with the speed squared. So accelerating to twice the speed will consume four times the energy; reaching three times the speed will need nine times as much.

This 'squared law' also applies to the aerodynamic resistance, the 'drag' to push the train through the air. Thanks to the use of modern roller bearings to reduce friction in the motors and wheels, this aerodynamic drag is now the main factor in Item 2, resistance to motion.

For different types of train there may therefore be different priorities.

As an example, the graph below shows how the energy needed to complete a journey of 160 kilometres on level track varies with the frequency of station stops. With less starting and stopping at stations, the total energy reduces, but the proportion taken by aerodynamic drag changes as the average speed increases.

Breakdown of Mechanical Energy



High Speed train in China

Commuter train in Poland

For a high-speed train covering long distances between stops, accelerating the train up to speed is less of a consideration than cutting the aerodynamic drag – hence the need for those futuristic front ends on TGVs, ICEs and their sisters around the world.

Therefore train mass becomes less significant for total energy consumption for non-stop high speed runs – although it needs to be controlled for other reasons such as reducing wear and tear on the track.

Recent analysis made by the Fundación de los Ferrocariles Espaňoles and published by the rail manufacturers' association UNIFE is shown below.

For commuter trains with lower top speeds, starting energy is crucial – and energy recovery from the brakes is a major opportunity. Lightweight design will also help, as described above. For heavy freight trains high mass means the priority is to avoid unnecessary stops, to keep rolling, and take only one 'hit' of kinetic energy per trip.

Understanding of these basic principles will also guide the development of good driving technique – see Section 5.2. It will also encourage good traffic management and uniformity of line speeds to avoid wasteful slowing, stopping and re-accelerating.

Good driving technique will also reduce the penalty of energy needed to climb gradients, provided the train can coast steadily on the downgrade using the 'potential energy' stored up by climbing the hill in the first place. Regenerative electric systems will also help recover energy that would otherwise be lost when braking to control the speed on long downhill runs.

Powering the control systems (Item 4) should be the least of the energy loads, but there is still a risk of waste. Number one risk is a poorly designed or maintained pneumatic system – air leaks or an inefficient compressor can be expensive – and the losses may continue even while the train is stationary.

Analysis made by the Fundación de los Ferrocariles Espaňoles

For a 10% increase in train mass the increase in energy consumed was as follows :

High Speed Train	0.5-1%
Long Distance -conventional	2-3%
Suburban Train	5-7%
Urban	6-8%

The crucial point about Item 5, power for heating, lighting and air conditioning, is that it is used in large quantities even when the train is standing still – and without any fare paying passengers on board! Typically it may be around 10% but if poorly controlled it can reach 25% of the total for commuter trains with long layovers between rush hour services. Importantly it may be a good target for 'quick hits' at the start of an energy programme. See Section 3.3 for more ideas.

In answering this question, 'where does it go?' we must not forget the final item for electric traction, the energy used in getting the energy from the power station to the train. Again the laws of science determine what will happen. Power lost in a cable carrying energy is proportional to the square of the current multiplied by the resistance of the cable. There are also transformers, rectifiers and frequency converters none of which are 100% efficient. Losses can be as low as 2% in a high voltage 50Hz AC system, but may be well into double figures on other types of network.

For energy managers the technical solutions for this topic may be expensive and long term. In the short term the system should be matched to the traffic. An overloaded electrical supply will sustain higher energy losses per train operated, and may suffer from overheating and equipment failure.

Electricity distribution must be designed to minimise losses

Load factor is an issue for both freight and passenger operators

3.2 Load Factor – getting the most from the energy

A full train is the most efficient way of moving passengers or goods – but an empty one is an environmental disaster! There are no profits in transporting 'fresh air' around the countryside and certainly no prizes for eco-awareness!

Key Points to develop in an energy management programme include:

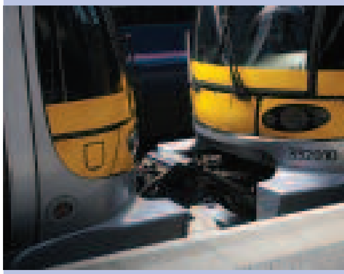
- Measuring passenger load factor – use reservation data, ticket sales, and modern systems such as load weighing and optical passenger count systems
- Normalising your energy consumption by tonne kilometres or passenger kilometres for benchmarking and trend measurement
- Management of train lengths and timetables to match demand with supply
- Ensuring quick, reliable uncoupling systems for operational flexibility
- Reduction of empty train kilometres for fuelling, maintenance and servicing moves – these can easily reach 5-10% of your fleet total if not well managed. Plan any new facilities at locations optimised for traffic patterns.
- Avoiding empty wagon movements whenever possible
- If empty train movements are unavoidable, timetabling them at reduced speed to save fuel

Calculating passenger load factor for urban operations with few seats and lots of standing space may be difficult – how to define the capacity is a matter of debate, and energy used per passenger kilometre may be the only practicable measure.

However for longer distance commuting and inter-city traffic, where it can be assumed that everyone should get a seat, it should be easier. For suburban and regional traffic without seat reservations, and subject to 'rush-hour' tidal flows, an all-day average of 35% load factor is a healthy target. In the inter-city and high speed sector leading operators report figures of 70% and more. These figures should be measured across all services 24/7 over a complete network. There is no value in just reporting the busiest trains on the busiest parts of the route!

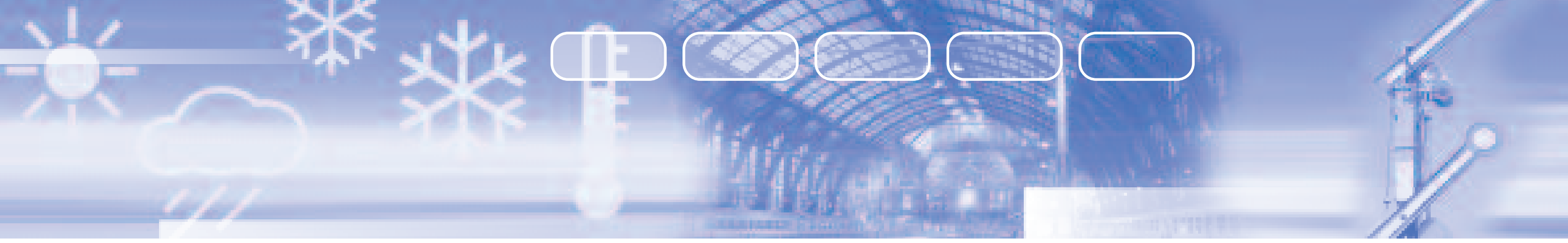
Managing train length – especially splitting and joining multiple unit trainsets – demands efficient and reliable mechanical and control wire coupling systems.

Modern, basic but efficient, fuelling and servicing facilities, as shown on the right, can save long and expensive trips for both freight and passenger units to traditional depot locations. Freight operators recommend the ‘man in a van’ approach – mobile engineering teams to carry out routine safety examination at traffic sites, to avoid costly visits to an engineering workshop for simple checks.



Managing train length demands efficient coupling systems

Fuel point in Finland



Commuter trains may be heated (or cooled) unnecessarily during layover between rush hours

3.3 Heating and Lighting of Trains

We have already said that heating and air-conditioning (HVAC) and lighting consume large quantities of power and present real opportunities for improvement in the passenger sector. Layover of trains in depots and terminus stations is the most important topic to attack with a range of technical and operational solutions.

Ideas to follow can include:

- Auto-shut down of diesel power units
- Load transfer so that on stationary trains, essential power is maintained from a single power pack – rather than leaving all in use
- Automatic Set-back to lower thermostat settings if the train is parked
- Accessible controls for cleaning staff so they can switch lights on and off for their work
- Shut-off fresh air intakes when trains parked – and close windows
- Remote activation of heating ready for start of daily service
- Using auxiliary or 'shore supplies' so that main diesel engines or electrical transformers don't have to run continuously to support servicing or staff comfort requirements

Even in traffic there is scope for improvement :

- Make sure heating and cooling thermostats are working correctly – on modern trains use the on-board computers to track performance and report problems
- Review thermostat settings – many trains in summer are overcooled – passengers actually complain they feel cold, if lightly dressed for the temperatures outside!
- Check software controls of HVAC systems are set up for stable operation – avoid cycling between heating and cooling modes (or operating both at once!)
- Review heating levels in secondary areas such as vestibules or luggage spaces
- Use CO2 measurement or load weighing technology to control fresh air intakes when passengers are few
- Fit auto-close to doors to keep heat in (or out)

3.4 Some Technical Opportunities

This is only a short introduction to the question of energy management on railways, not a textbook of railway engineering, but we want to give some signposts to the technologies that are being developed to improve energy efficiency.

Here is a 'taster' of the technical solutions that may be considered:

Quick hits

- Low energy lighting
- Improved heating and ventilation (HVAC) control
- Engine management – shut down on idling, auxiliary load sharing
- Supply Network management

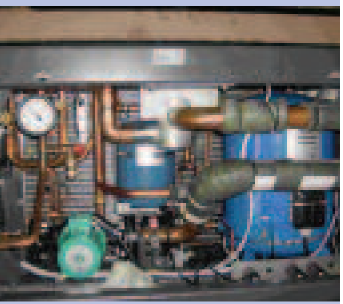
Energy Recovery

- Regenerative Braking
- Supercapacitors
- Batteries
- Lineside storage

Measurement

- Full on-board metering (see Appendix 1)
- Using on-board juridical recorders ('black boxes') to compute energy used from power settings
- 'Virtual metering' by analysing traction control computers

Virtual metering confirmed 20% saving from regenerative braking on this commuter fleet



Heat Pump Module on trial in Holland

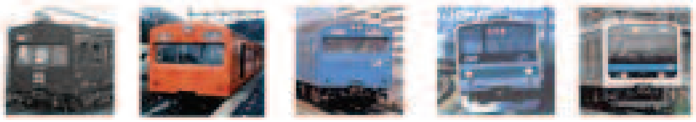
Emerging technologies

- Hybrids (various permutations)
- CO_2 control for HVAC systems
- Heat pumps for train heating - equipment can be retrofitted to an existing passenger car
- Fuel cells for auxiliary loads and diesel engine pre-heat

Major modifications – new build opportunities

- Replacing diesel power units
- Replacing electric traction controls (IGBT vs GTO)
- Improved gearboxes and drive trains
- Lightweight construction - see the example below as to how equivalent designs of Japanese commuter train car have been reduced in weight over successive generations

Japanese suburban motor coach mass



Class 73	Class 101	Class 103	Class 205	Class 209
1951	1958	1963	1985	1992
45.5t	35.3t	39.7t	32.6t	27.7t

3.5 Operational Solutions

Technical solutions are only part of the story. Evidence from around Europe suggests that the savings from energy-conscious operation can be just as great as from technical fixes to the rolling stock – and come more quickly and with less capital cost.

The three main areas of opportunity are:

Eco-driving

- Driving to the timetable, instead of trying to beat it
- Understanding how to exploit gradients for acceleration and braking
- 'Coasting', backing off power when possible
- Avoiding 'full throttle' settings that take traction units (especially diesels) outside their most efficient operating range

Active traffic management

- Clearing signals to green in good time – using auto route setting
- Keeping heavy freights and high speed services rolling
- Warning drivers in advance that they are approaching a congested area and should reduce speed

Efficient timetabling

- Checking schedules are matched to the traction units being operated
- Avoiding junction conflicts that will require trains to make extra stops
- Ensuring changes to line speed or signalling are reflected in the timetable
- Maintaining an even speed profile – work with track engineers to eliminate 'bottleneck' local speed limits

Sections 5.2 and 5.3 on Eco-Driving and the Trainer Project give more information on driver training. The challenge is to use technology to help these operational methods. In the long term ERTMS-ETCS will optimise the whole system – but that will take some years to roll-out across Europe. Meantime some solutions are ready today:

- Stand-alone driver advice systems –DSB Gekko system (Denmark)
- Advance warning of traffic conditions – NS RouteLint system (Netherlands)
- Real-time feedback from on-board meters – First Group FAR system (UK)
- Overall energy management integration – Solvera Lynx Gemalogic (Slovenia)

Give a green light to energy efficiency

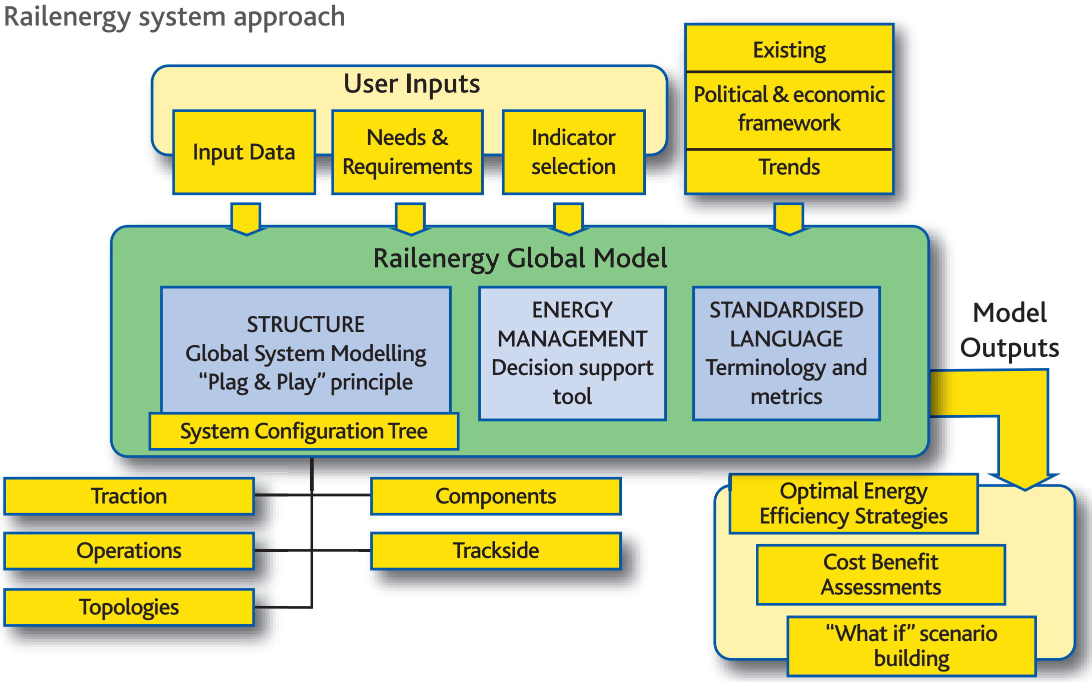
3.6 The Railenergy Project

Railenergy is a 48-month project running from 2007-2010 which is supported by the FP6 programme of technical research within the European Union. The research partners include universities, the railway supply industry and railway operating organisations. Railway Operators are in fact represented by a small number of direct partners, but more widely through the participation of the International Union of Railways - UIC. Likewise the supply industry is represented in the project not just by key individual manufacturers, but also by UNIFE, the Association of the European Rail Industry representing over nine hundred Suppliers to the rail industry in Europe. (For more details go to *www.unife.org*) Unife are also acting as project co-ordinators.

The overall objective of "Railenergy" is to cut the energy consumption in the railway system thus contributing to the reduction of life cycle costs of railway operation and CO2 emissions. The initial project target is to achieve a 6% reduction of the specific energy consumption of the rail system by 2020.

This will be done by addressing the energy efficiency of the integrated railway system and to investigate and validate solutions ranging from the introduction of innovative traction technologies, components and layouts to the development of rolling stock, operation and infrastructure management strategies.

Railenergy system approach



The inter-relationship of railway sub-systems is highly complex, especially with regard to assessment of their energy consumption. There is a need to know better which measures – technical and operational – would be most beneficial. Therefore, a fully integrated approach is the only way to identify and achieve true energy savings. The special feature of the Railenergy Project is the holistic approach. No technical or operational measure is better than its global contribution to the system efficiency. This underlines the strong cooperation needed between the main stakeholders within the sector when planning, designing, procuring and operating the railway system.

Within the project Railenergy partners are specifically committed to deliver:

- Baseline performance figures, and reference scenarios against which the benefits of other initiatives can be evaluated
- A system-based concept for modelling energy consumption in railway operations
- A standardised methodology to determine energy consumption by sub-systems and components at the development and procurement stage
- A tool to integrate energy consumption into Life Cycle Cost analysis
- A formalised approach to railway energy efficiency management, and a decision support tool to help make choices on energy management policy
- Strategic energy efficiency targets for rolling stock engineering, infrastructure and traffic management
- An Energy Infrastructure Management Module to provide an Infrastructure Manager with a diagnostic of their complete installation (main energy flows, and their distribution, power peaks and mean, links with energy contract subscription, real time and statistics...)
- New energy efficiency-oriented railway technologies for trackside and on-board sub-systems and equipment, validated in compliance with the new integrated approach
- Best practices for Railway Operators and Infrastructure Managers Strategies for incentives, pricing, and policy making

These deliverables will clearly help operators and infrastructure managers to take the generic steps recommended in the earlier parts of this booklet – to use standardised measurement methods, to set realistic targets, and to evaluate the possibilities of new technical solutions.

A longer term outcome is likely to be the evolution of formal standards (e.g.UIC, EN or ISO norms) for measuring and describing the energy efficiency of components, of complete locomotives and trainsets, and ultimately of whole networks.

To keep up-to-date with the progress of the project visit *www.railenergy.org*

Railenergy Project is involving train builders and UIC members throughout Europe

New trains must be designed with energy in mind

3.7 Procuring New Trains – the Prosper Project

New trains represent a risk and an opportunity.

- A risk, because they last a long time. A wrong decision today can mean energy efficiency suffers for the next forty years!
- An opportunity, because it is much cheaper and easier to include energy efficient technology in a new train, than to fit it to an old one

Train operators must make it clear to suppliers in the tendering process that energy efficiency is a priority. In other transport sectors everyone understands that the next plane or bus has to burn less fuel than the last one supplied. Including energy efficiency in your new train specification will bring this culture to the rail industry.

The UIC Prosper Project produced Leaflet 345 Environmental Specifications for New Rolling Stock, which gives strong guidance on including all environmental topics in a new train specification. The leaflet can be ordered from UIC by visiting *www.uic.asso.fr*. The Railenergy project will develop standard duty cycles for new trains – this will help benchmark energy performance of new rolling stock and equipment and Leaflet 345 will be updated accordingly.

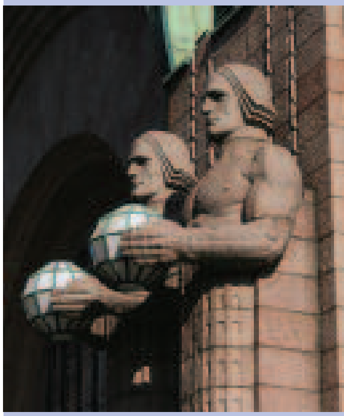
Any new electric train should also be specified with state-of-the-art metering systems (see Appendix 1) for both billing and management information purposes. For diesel trains comprehensive fuel monitoring systems are available, and for all types of train there are great opportunities to exploit the inherent 'intelligence' in the traction systems of modern software-controlled rolling stock.

4 Power for the Stations

Power for stations and depots must not be forgotten. For commuter railways with many stations, some of them perhaps underground with lifts, escalators and drainage systems as well as the more usual lighting and heating loads, it can reach up to 20% of a railway company's energy bill.

Managing this 'domestic energy' demand may be easier than the traction load. There are sometimes 'quick wins' just from a 'switch off' campaign with staff. Stations and workshops are like other industrial buildings – so it is possible to use 'best practice' from other organisations. And there is much advice and support available from governments, from the European Commission and from building services experts to get this type of energy use under control.

Organisations such as SenterNovem in Holland and The Carbon Trust in UK have been set up by governments especially to advise on these matters.



The 'stone men' outside Helsinki Station

4.1 Passenger Facilities and Depots

As we have said before, railway premises are actually quite similar to the buildings used by other industries, and the expertise can be shared from those other sectors. Nevertheless, here is a list of top tips that are especially relevant to railway yards and buildings.

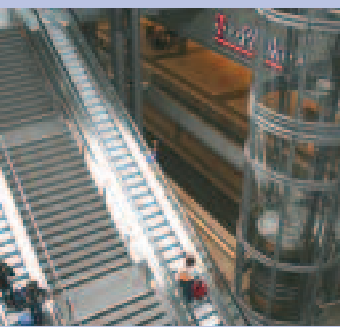
Lighting

- Use low energy lighting – replace incandescent lamps and update fluorescent light fittings, latest types are more efficient than those of a few years ago. LED lighting is developing fast and may soon overtake fluorescent technology in terms of light output efficiency
- Fit timeclocks and photo-cells to ensure outdoor lighting is never on in daylight
- Fit movement detectors to staff rooms
- Switch-off/reduce lighting to station platforms which are not in use
- Maintenance Depots – reduce lighting when the trains are out working and there is no activity inside the depot
- Inspection pits – lights only need to be on when a train is over the pit

Heating and cooling

- Check thermostat settings
- Maintain boilers and air conditioners; replace old, less efficient installations
- Reduce fresh air intake when buildings not in full use
- Improve building and pipework insulation

Lighting in Paris



Lifts and escalators in Berlin

Machinery and Equipment

- Switch escalators off, or fit variable speed control, to save energy when stations are less busy
- Depot services – switch off when not in use – check compressed air and steam systems for leaks

Manage Supplies and Tenancies

- Fit smart meters at main locations – a few large interchange and terminus stations may be the largest part of the energy use – and act on the information
- Manage and meter your tenants, shops, coffee bars etc.
- Make local managers responsible for reading their own gas and electricity meters and controlling their own station consumption
- Check your tariff with your electricity supplier – you may be paying extra for system capacity that you do not need

The principles we have discussed for traction energy, of understanding where the energy is being used, and concentrating efforts first on the areas of high energy usage, apply just as much to 'domestic' consumption as to the trains themselves.

4.2 Other Infrastructure use

There are several other uses of energy on railways that must be managed and controlled.

A significant but unavoidable requirement is the signalling system. Even here it is important to understand the key factors. Where supplies are integrated with traction supplies, ensure that signalling loads are separately accounted for – and if possible sub-metered. LED signal lamp technology is proving successful to guarantee a longer lamp life and may save energy. Modern interlocking equipment, and the systems to ventilate the equipment rooms, will offer opportunities for energy efficiency.

In colder countries there are several other potentially costly uses:

- Heating of switches (points)
- De-icing of conductor rails and catenary wires
- De-icing of platforms

Energy management solutions include:

- Use of heat pumps
- Ground water/geothermal heat sources
- Ensuring accuracy of thermostats
- Limiting switching-on to risk periods (e.g. high humidity, for icing)

As well as this 'operational support' use of energy by the infrastructure departments, there are other significant uses of energy – and generation of carbon emissions – by maintenance and back-up activities.

Some of the advice on managing diesel traction can be applied to track maintenance machinery:

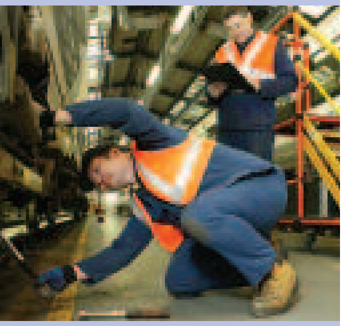
- Reduce idling times
- Use auxiliary sources, including fuel cell technology, for stand-by power and crew amenities
- Replace obsolete and inefficient machinery

Lastly all organisations must remember two areas that are often overlooked:

- Office premises away from the operational railway
- Road vehicle fleets

A comprehensive Energy Policy and management programme will cover all these energy aspects.

5 People - Motivation and Education



Professionalism of staff should include energy awareness

Around the world there are several millions of people working in the rail industry. In Europe alone there are nearly 1.7 million railwaymen and women (and that is before numbers from Russia, which of course partly includes Asia, are added to the total). This is a powerful army to have fighting for energy efficiency. Without the support of these personnel, at all levels from chief executives to shunters, from rolling stock engineers to signalling technicians, an energy campaign will not deliver a successful result.

5.1 Hearts and Minds

A successful energy programme needs both the understanding, and the sympathy of staff. Just preaching at people will not be enough; boring them with scientific facts will also be unsuccessful. Effective energy training will guarantee a long-term benefit and ensure energy efficiency is not just a 'nine-day wonder'.

A good training programme will:

- Explain why energy is important – financially and environmentally
- Explain how energy is used
- Explain how it can be controlled – and how staff action helps
- Give staff the support to put the training into practice
- Provide feedback on progress already made

This last point means that training on its own is not enough. It will only have value if the other systems described in Section 2 are put into practice; the planning, target setting, the measuring, the record keeping and the feedback processes.

Staff will need reassurance that energy management is not just a new form of management control or enforcing discipline. There are in fact many positive features for staff in an effective energy programme:

- The company becomes more efficient without taking anything from pay packets or cutting employment opportunities
- There is fresh opportunity for them to demonstrate their professional skills – the positive reaction of traincrew in many networks to eco-driving programmes shows how staff will respond
- The business will grow by exploiting rail's environmental and economic position against competing transport modes
- Trade Unions and Workers Councils can share in the development and implementation of the programme

5.2 Eco-Driving

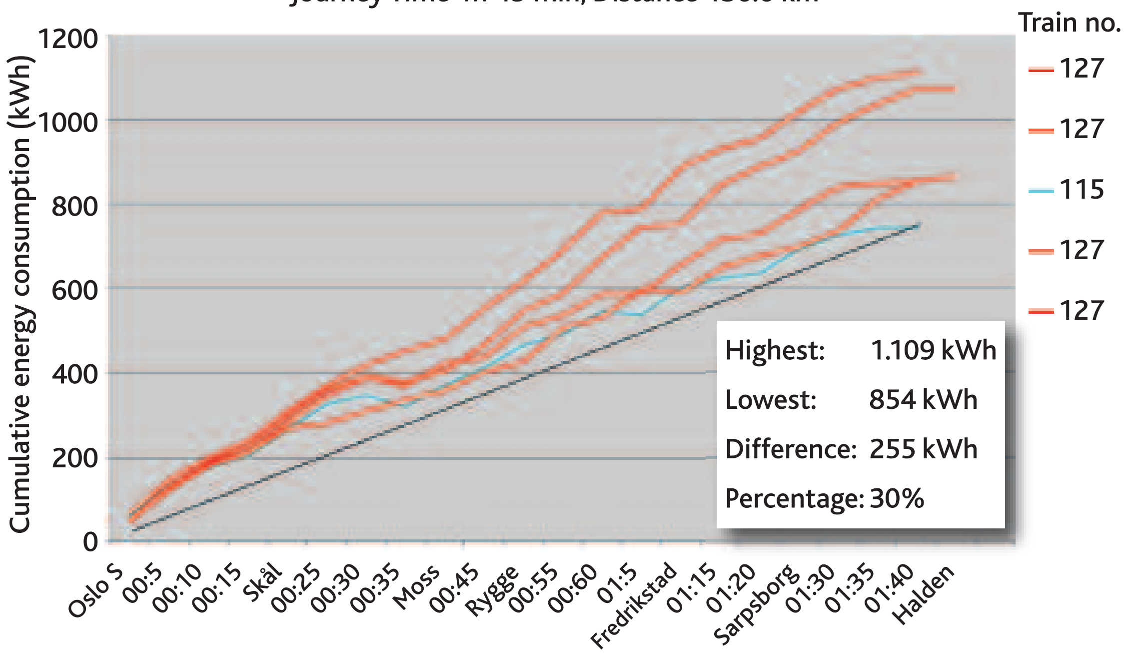
Experts are agreed that energy efficient driving is one of the biggest single opportunities for energy saving in rail. The exact size of the prize in any particular railway company may vary due to differences in traffic pattern, signalling systems or type of rolling stock; however it is invariably as great as that from any purely technical initiative.

Studies from a variety of networks around Europe show significant variations in usage of fuel or electricity when an identical train is run over the same route section. The attached graph from Norway is very typical of the results of such studies.

For five trains over the same route – four of them being the same unit (Train 127) on different days – the cumulative electricity consumption was plotted over a distance of 136.6 kilometres. This showed, not only differences in the grand total, but also in the usage pattern through the route. If all of the trips could be made at the same energy consumption rate as the 'best' trip, then significant energy savings would be made.

The training should show people how they can affect energy use

Train Service 73-04 Oslo to Halden May 2006
Journey Time 1h 45 min, Distance 136.6 km



Simulators are an important tool in eco-driving programmes

There are some important conclusions from the various studies done around the world on this subject.

- 10% saving is a realistic target for benefits averaged across all traffic types
- Freight traffic, and high powered diesel traction will benefit particularly from eco-driving. Savings up to 20% are reported
- Eco-driving does not contradict good timekeeping – in fact it can help by keeping trains in their planned pathways
- On busier route sections, overall traffic management is as important as the driving technique of individual train drivers (so involve signallers and train planners in the programme)
- Eco-driving will assist safety by encouraging a more thoughtful driving style

For maximum effect eco-driving must be integrated with other aspects of an energy management programme. In particular the following are absolutely essential:

- Measurement systems
- Communication and feedback to staff
- Effective train planning

And of course, eco-driving training must be linked with the other elements of train driver education – it is not a separate issue. The 'Trainer' programme described in the next section is promoting best practice in this area.

Remember that eco-driving is a 'human-factors' issue and is based around actual driving skills. Unlike some technical improvements it is not a 'one-time fix'. It requires continuous management effort to maintain staff interest and discipline.

A last point to stress on this topic, is that teamwork is an important part of a successful energy programme. Understanding other people's jobs and points of view must be an important part of the training. Drivers and signallers, for example, need to have an improved understanding of how they can work together to keep traffic moving – helping energy and punctuality.

5.3 The Trainer Project

Trainer is a Europe wide programme for promoting energy efficiency among railway staff through training and education. A main element, though not the only one, is training the drivers of both freight and passenger trains in eco-driving technique. The project began in November 2006 and will run until October 2009.

Five European networks are directly involved including Slovenia and Italy, but the project aims to take best-practice in eco-driver and energy-awareness training to a wider audience across Europe in association with UIC – International Union of Railways.

Outputs will include 'model' training packages, a simple driver simulation tool that can be used on an ordinary PC, 'Virtual Trainer', and an Inventory of Good Practice.

The Inventory is complete and can be downloaded from the trainer website at *www.iee-trainer.eu*

Trainer - Five European networks are directly involved including Slovenia and Italy

6 Energy and Carbon

The United Nations, the European Commission and national governments are now united in their response to the IPCC (International Panel on Climate Change) advice that carbon dioxide emissions must be curbed to stop global warming becoming an ever more serious environmental threat.

In Europe, the European Commission has set ambitious targets for reducing greenhouse gas output by 2020 and the G8 group of nations is contemplating a target of halving emissions by 2050. Overall, energy use accounts for 80% of all such emissions, and even railways and nations that source their energy from low-carbon generation have a part to play – in a global market, energy saved by one customer frees up 'green' supplies for others to use.

This booklet concentrates on energy management since energy use is what individual railway teams control; local managers and staff may not have influence on the source of their energy. But everyone must understand that by using energy efficiently on their railway they are helping the fight against carbon emissions overall.

6.1 Measuring the Footprint

Having a clear understanding of the 'carbon footprint' of your railway operations will become increasingly important as regulation of carbon emissions becomes stronger, whether through mandatory targets, fuel taxation or carbon trading. Public scrutiny and media pressure may also increase.

Common definitions for CO_2 output from traction energy use are elaborated by UIC in their Leaflet UIC330 Railway Specific Environmental Indicators (see Appendix 2). Calculating a full carbon footprint to include CO_2 created in the whole supply chain of a particular industry can be much more complex, and there are various international protocols that have been developed. Fortunately for rail, because the assets have a relatively long life the carbon footprint of construction may be smaller, averaged per unit of production than in some other industries. However it is not trivial and this must be recognised when making claims on behalf of the industry. The carbon footprint of stations and depots must, where appropriate, be acknowledged as well as that of the trains themselves. We have seen that the energy use in these places is not unimportant – therefore the CO_2 effect must not be overlooked.

Because facts about carbon footprint are used in marketing campaigns, inter-modal comparisons and politically in making 'the case for rail', it is important that statements about carbon footprint are:

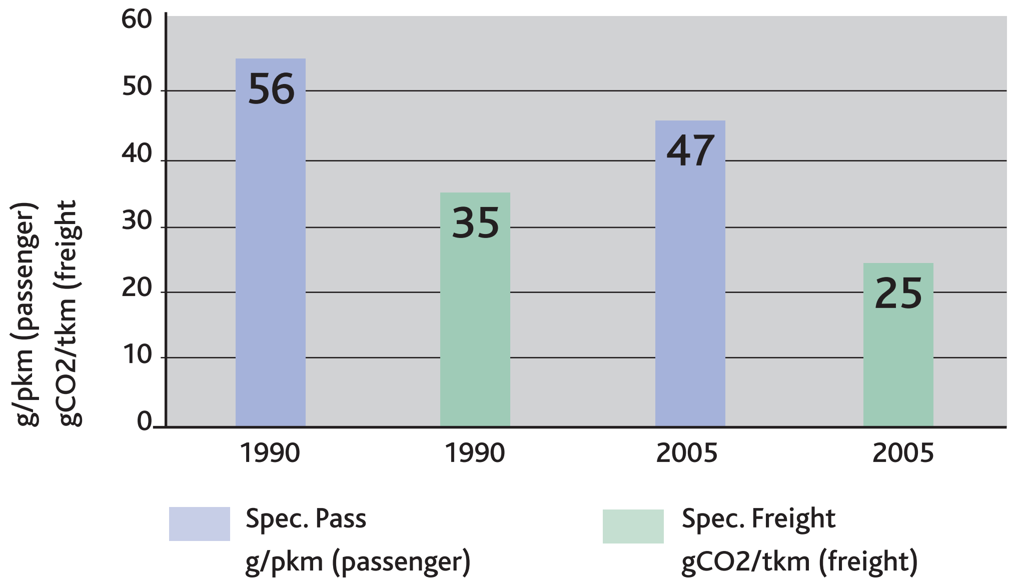
- Honest – claims about the source of energy must be true and accurate
- Comprehensive – simply listing best performing trains is not enough
- Transparent – assumptions behind the calculations must be clearly stated
- Verifiable – it must be possible for numbers to be independently checked

In particular, claims to be using 'green' or renewable energy must be backed up by proof that the supply chain is traceable. Because of the sensitivity, false, careless or misleading claims may be open to costly legal challenge from competitors or environmental and consumer organisations. By following the strong management processes recommended in this booklet, and by obtaining certification of your Energy Management to ISO or EN standards you will be in a strong position to produce truthful analysis of your carbon footprint, and to defend it against competitors.

For electric train operators, what is achievable will depend heavily on the carbon mix of your energy provider. This may be governed by national energy policies outside of the immediate control of railway managers. Networks with a high nuclear or hydropower content in their electrical supply will 'score' better in CO2 terms. Note, there may be considerable scope for railways to develop on-site renewables using solar or wind power, especially when buildings or infrastructure are renovated or replaced.

CER, The Community of European Railway and Infrastructure Companies, has publicly committed to an overall average reduction of 30% in CO2 emissions per passenger and tonne kilometre over the period of 1990-2020. Thanks to improving load factors, technical innovation and changes in generating mix, the railways involved are on track to deliver this commitment. However, positive and practical energy management programmes are needed to ensure that the improvement is sustained. The graph below shows progress so far. (Source: UIC energy/C02 database)

Average European specific railway CO2 performance 1990 - 2005



European rail sector to cut CO2 emissions by 30%

8 May 2008

The CER Commitment

Energy efficiency is a world-wide challenge for the industry

6.2 International Targets and Long Term Agreements

Railway administrations can contribute to the fight on carbon emissions and energy waste by signing up to national, international and industry-wide programmes on energy management and carbon reduction.

Initially these agreements are voluntary – but railway managers must be prepared for them to become mandatory – and to be backed up by financial incentives and penalties through carbon trading schemes and other controls. Adopting the practices outlined in this booklet now will put railway managers in a stronger position to respond to possible formal regulation in the future.

Particular examples include the accords entered into between the principal railroads in Canada and their national government, which covers all aspects of emissions from their diesel fleets, the Long Term Agreement between NS - Dutch Railways and their government and the CER Commitment described in the last chapter.

As the United Nations encourages development of the successor to the Kyoto agreement we must expect these targets and commitments to involve railways worldwide.

7 The Way Forward

In concluding we must reflect on the size of the problem and the size of the opportunity.

We must also remind ourselves of the steps outlined in this booklet.

Firstly the size of the problem:

Energy cost usually varies between 5 and 20% of a railway operator's total operating expenditure, depending on the nature of the organisation structure and the type of traffic. However, as a proportion of those items which can be easily controlled, it may be much higher. It is also an item for which prices are rising faster than for other operating costs.

It is therefore an area where action will be rewarded by a direct result on the financial health of the railway company – it makes the difference between hitting financial targets or not.

As regards opportunity:

As with anything else, the opportunity for improvement depends on the starting point. Some train operators will have already been managing efficiency. For those attacking the topic for the first time the savings may be greater.

There is also the question of what is possible in the short to medium term, by 'good housekeeping' and marginal improvement, as opposed to what is possible in the longer term. Studies in the UK, and the Swiss (SBB) Energy Management Programme suggest that 10% saving may be a good target for the initial efforts.

In the longer term we may be much more ambitious. Many have the vision of a completely carbon neutral railway. Changing our primary energy sources will obviously be at the heart of this, but introducing new technology and new control systems to our networks, and designing all new trains for maximum energy productivity will be the contribution and responsibility of individual railwaymen and women.

This brings us neatly back to the theme of this brochure, Process, Power, People.

To achieve the savings – short and long term will require:

- Process – a professional railway management approach to the challenge of radically improving our stewardship of energy resources
- Power – understanding the science behind our energy use and applying the latest technical solutions in the search for efficiency
- People – motivating all of our managers and staff to understand the problem, to support our energy policies and to use their personal expertise as operators , planners and engineers to actually make energy efficiency happen

Appendices

1 On-Board Metering for Electric Traction

On-train metering of electric traction is rapidly being adopted for two main reasons.

1 It allows direct billing of train operators on a 'per locomotive' basis so that they are only billed for the electricity they actually consume. This ensures that operators are encouraged to save energy, because they see the benefits reflected in their financial 'bottom line'. Charging for electricity on a per kilometre or 'lump sum' basis does not create this incentive.
2 Operators have the opportunity to study the way they are using energy in much greater detail. The effectiveness of eco-driving programmes, and the success of technical changes can be exactly studied.

Typically, meter readings are broken into 5-minute, or even 1-minute segments and location stamped with co-ordinates from a GPS satellite navigation or other position recording system. There is the opportunity to integrate outputs from the meters with advice systems for drivers, to encourage eco-driving.

To ensure a common approach to metering, a number of initiatives are under way. These will help manufacturers to supply metering equipment to a common and cost-effective standard, and ensure that differences in metering arrangements do not become a barrier to operation of electric trains in international traffic. The principal activities are:

The UIC Billing Project

This project, due for finalisation in 2009, specifies data protocols and rules, and creates a common framework for transfer of energy consumption data for billing purposes, particularly for trains in international traffic operating on more than one infrastructure network.

Technical Specifications for Interoperability (TSIs)

The European Rail Agency will include basic requirements for on-board meters in the TSIs for conventional and high-speed traction units, ensuring common standards for metering equipment, and its certification to a recognised standard and level of accuracy across Europe. Drafts will be finalised in 2009 for formal publication in 2010.

Development of European Norm EN50463

This norm is being updated to cover all aspects of metering systems, to elaborate the basic requirements in TSIs. It will fully cover the metering installation itself, plus related points such as localisation and secure systems for remote data transfer from a train to a central data collection point. Again, a draft version will be circulated as a prEN in 2009, prior to formal publication in 2010.

These remarks are written from a European perspective, as regards standards, legal requirements etc. but the arguments in favour of on-board metering are universal.

2 Key Performance Indicators (KPIs)

Section 2.5 of this booklet describes the importance of measurements and record keeping. To make comparisons for benchmarking purposes it is important that common definitions are adopted for the more useful and immediate measurements.

These can be applied for an entire fleet, or a network but do not remove the need to take individual measurements at a local or individual train level.

UIC has prepared the following indicators. These cover both energy use and resultant carbon emissions. For more information and full details as to how they should be calculated, see UIC Leaflet 330 Railway Specific Environmental Indicators.

Final energy consumption

This is defined as energy down the pantograph, or litres of fuel into the tank per passenger kilometre or per tonne kilometre of freight.

Primary energy consumption

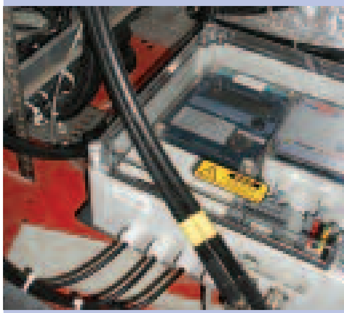
This is defined as the raw energy consumed per passenger or tonne kilometre, including that which is lost in the energy production and distribution process. To compute this figure requires a knowledge of the energy source and distribution arrangements. For electricity in particular, this figure will vary from network to network.

Share of renewable energy

This may be a strategic goal for a railway company that wishes to affirm its 'green credentials'. It cannot usually be influenced by local railway staff! Again it requires a knowledge of energy sources. Carbon offsets and carbon credits should not be claimed as a form of renewable energy for the purpose of calculating this KPI. It is likely that as the renewable energy question becomes internationally more important, more precise definitions of what is 'renewable' will be produced by international bodies. This is particularly important in determining the extent to which bio-fuel for example can be classed as 'renewable'.

Specific CO2 emission

This is defined as grams of CO2 produced per tonne or passenger kilometre. For electric traction it will vary according to the national energy mix being supplied to particular networks. For benchmarking purposes it is inappropriate to claim carbon offsets, or that the operator has purchased 'green' or nuclear energy from the market, unless it can be proven that the contract has leveraged the creation of additional carbon-free generating capacity – or the renewable energy is generated 'in-house'.

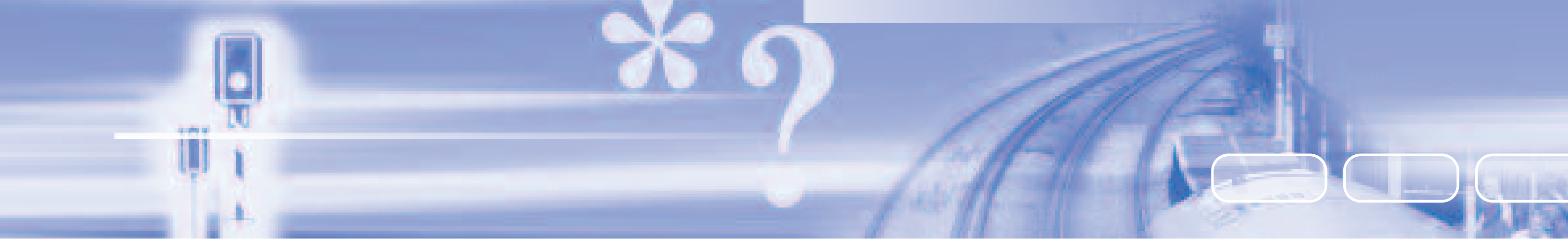


Meters allow accurate calculation of KPIs

Note that these are high level indicators that give a good comparison with other transport modes. They will of course be improved by productive load factors as discussed in Section 3.2. Engineers and traffic managers may choose to set themselves subsidiary targets of energy/CO_2 per seat kilometre, or per gross tonne hauled since these will not be influenced by economic variations in passenger numbers or freight volumes loaded.

Initial results from the Railenergy project recommend that certain further KPIs are adopted as a way of controlling overall efficiency. These will be developed in due course. Meanwhile railways should consider interim arrangements to study the following particular factors:

- Infrastructure – efficiency of the electrical distribution network as managed by an Infrastructure Manager. This is an important consideration in respect of the metric, Final Energy Consumption, when comparing Direct Current (DC) and Alternating Current (AC) systems. The primary energy KPI may appear to favour DC traction since the train itself does not have to cover the losses in transformers or from the higher currents flowing in the catenaries or conductor rails
- Energy consumed by parked trains – the energy consumed while the train is not in public service
- Energy recovery – the percentage of braking energy recovered for reuse and which creates a net saving in total energy consumed. (This may be achieved by returning electricity to the catenary for use by other trains, by returning electricity to the catenary for return to the national supply network, by storing power in on-board devices including capacitors, batteries and other devices, or by reusing energy within the train itself on heating and auxiliary systems)



3 Links and Contacts

This list is just an indication of the contacts available. Many leading train operators, including the organisations contributing to this document, have relevant information on their home websites. Note also the links given in the main document to the Trainer and Railenergy projects.

Association of American Railroads www.aar.org
AAR is the representative organisation for the major railroads in Canada, USA and Mexico and deals with technical, political and, increasingly, environmental issues.

CER – Community of European Railways www.cer.be
CER is the political voice of the rail transport industry in Europe – its vision to make rail transport the locomotive of a sustainable European economy. Publications and activities cover environmental, energy and carbon issues.

European Environment Agency www.eea.europa.eu
The agency's remit is to provide sound, independent advice on the environment to policy makers and the general public. Its activities include monitoring of greenhouse gas emissions in Europe.

Intelligent Energy Programme ec.europa.eu/energy/intelligent
This programme is maintained by the Directorate for Energy and Transport of the European Commission.

International Energy Agency www.iea.org
The IEA/AIE is an intergovernmental agency established by international treaty. The website gives access to data on prices, production and consumption worldwide.

NTM – Nätverket för Transporter och Miljön www.ntm.a.se
NTM – Network for Transport and Environment is a Swedish based association monitoring transport and environmental issues particularly in the Nordic region. The website and many publications are available in English.

UIC – International Union of Railways www.uic.asso.fr
The UIC is the worldwide organisation of co-operation for railway companies with active members from every continent, promoting technical development, harmonisation of standards and exchange of information. The website hosts a general environment page *www.uic.asso.fr/environnement* and UIC also maintains the site *www.railway-energy.org* with data and research reports on energy issues.

UNIFE www.unife.org
UNIFE is the Association of the European Rail Industry representing the interests of the rail supply industry in Europe and to markets beyond. The website includes links and reports on energy aspects of rail technology.

Advice and Resources for energy management are available worldwide

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