WP 2: SAVING ENERGY IN METRO AND LIGHT RAIL STATIONS

Workgroup Energy Efficiency

December 2013

Table of Contents

Preface

We are delighted that RET, as the leader of the WP2 Workgroup Energy Efficiency, in May 2013 invited us to compose a report with the results and achievements of the workgroup. In a relatively short period of time, we reviewed all produced documentation, conducted interviews with the various workgroup members and published a report in July 2013. This second revised version of the report is the final outcome of the work.

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Glossary of terms

BREEAM	BRE Environmental Assessment Method, a voluntary measurement rating for green buildings that was established in the UK by the Building Research Establishment (BRE)
CFL	Compact Fluorescent Lamp, also called energy-saving light
Fluo light	Fluorescent lighting tube
kWh	kilo Watt hour, a unit to measure electricity usage
LED lamp	a lamp that uses Light-Emitting Diodes
Light bulb	an incandescent light bulb which produces light with a filament wire heated until it glows
Point heater	heating installation for railroad switches to prevent the switches from freezing (and thus not functioning) in winter times
SRRS	Sustainable Renovation Reference System
T2K	Ticket to Kyoto project (www.tickettokyoto.eu)
T2K payback time	Payback time based on TCO and T2K subsidy, consisting of: 1. initial investment (funded 50/50 by partner/T2K); 2. maintenance costs; 3. energy usage.
TCO	Total Cost of Ownership

1. Introduction

In March 2010, five European public transport companies joined forces to reduce CO_2 emissions from public transport through the Ticket to Kyoto project. The project's five European partners are:

- moBiel, Bielefeld, Germany;
- RATP, Paris, France;
- RET, Rotterdam, Netherlands;
- STIB, Brussels, Belgium; and
- TfGM, Manchester, United Kingdom

The project will finish in June 2014 and is co-financed by the INTERREG IVB North West-Europe Programme.

The project mobilises public transport companies and their stakeholders to take action against climate change and to reduce energy costs. The project consists of five Work Packages (WPs). The activities of Work Package 2 (WP2) – titled *Investing in infrastructures to reduce CO_2 emissions* – are split among three workgroups.

This report summarises the results of the workgroup *Energy saving in stations and infrastructures*.

Energy saving measures

This report gives an overview of seven possible energy saving measures that can be considered in metro and light rail stations. Each measure will be evaluated as to the level of suitability, provided with tips for the design and implementation phase and conclude with expected results and level of impact. Most of the measures will also be substantiated with a best practice example from one of the partners.

Nr.	Name	Best practice partner
M1	Replace lamps with more efficient ones	moBiel
M2	Switch lights completely off	RET
M3	Monitor lighting costs	-
M4	Energy efficient heating of railroad switches	moBiel
M5	Make underground service areas more energy efficient	RET
M6	Monitor heating costs	-
M7	Renovate old stations with guidelines and BREEAM	STIB

It is acknowledged that measures for saving energy are not limited to the seven detailed in this report, however other measures fall outside of the scope of the Ticket to Kyoto project.

The following actions are not included within the scope of this report, however represent further opportunities for improving energy efficiency:

- escalator and lift optimising;
- smart metering for electricity meters;
- doors insulation combined with smart opening and closing of entrance doors;
- roof insulation combined with installation of solar panels;
- platform insulation through the installation of screens with screen doors between platform and tracks in underground stations (often implemented with the introduction of Automatic Train Operation).

Although the above measures are not included in this report, some measures have been partly addressed in other publications of the project (see Work Package 1).

Breakdown of carbon footprint calculation

A methodology for calculating the exact carbon footprint of public transport operations is given in WP3 of the T2K project. This methodology works with the following breakdown of CO_2 emissions caused by the operations of train and metro stations:

1. electricity;
2. heating;
3. energy needed to extract and to produce heating energy;
4. cooling;
5. energy needed for cooling.

Total Cost of Ownership

When calculating the costs of an investment, it is important not to look simply at the initial capital (investment) costs but at the Total Cost of Ownership (TCO).

Regarding the TCO, this report considers three components:

- initial investment (50% funded by T2K and 50% funded by partner);
- maintenance costs;
- energy usage.

When calculating the payback time of an investment, all three components are considered.

Since T2K is a subsidised project the term “T2K payback time” is introduced. This means that pay back times of investments mentioned in this report are different from pay back times which are calculated without subsidy. The concept “T2K payback time” is also mentioned in the first follow up action proposed in the last chapter of this report.

Energy saving in three categories

Based on the original T2K application and the above mentioned breakdown, this report considers energy saving measures (in metro and light rail stations) in three categories:

A. Short term energy saving measures which focus on the improvement of lighting energy efficiency. These are measures M1 to M3 which are described in chapter 2.

B. Medium term energy saving measures which focus on the improvement of heating energy efficiency. These are measures M4 to M6 which are described in chapter 3.

C. Long term energy saving measures which focus on renovating existing old stations. This is measure M7 which is described in chapter 4.

The report concludes with chapter 5: conclusions and recommendations.

2. Lighting energy efficiency improvement

This chapter describes short term energy saving measures with a focus on the reduction of lighting costs. Three of these measures (M1 to M3) are given in this chapter.

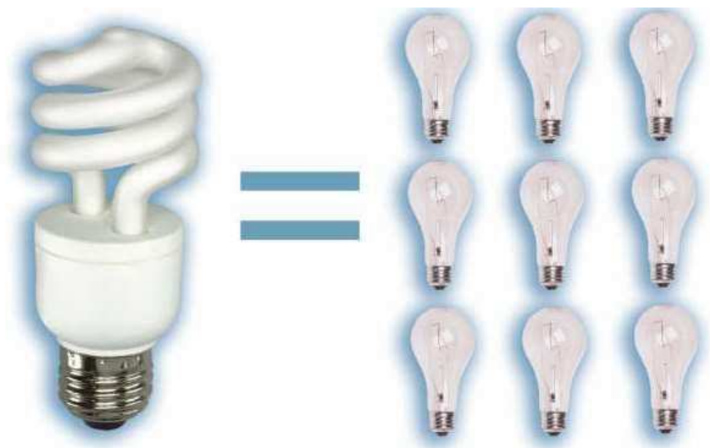
2.1. M1: Replace lamps with more energy efficient ones

Since many metro and light rail stations were built in the 20th century, lighting in many stations is conventional. That means that lighting with fluorescent lighting tubes and (incandescent) light bulbs is the norm.

Incandescent light bulbs were the main type of lighting used in Europe before 1990. They are cheap to purchase but are also the most inefficient bulb compared to all other types of lighting; most incandescent light bulbs convert less than 5% of the energy they use into visible light (with the remaining energy being converted into heat).

CFL

Since around 1990, compact fluorescent lamps (CFL) – also called energy-saving light - started to penetrate Europe's consumer markets. Since then, this technology has been improving and CFL-lamps are nowadays more energy efficient and much smaller in size than the ones first developed. Compared to incandescent light bulbs emitting the same amount of visible light, CFLs use one-fifth to one-third the electricity, and last much longer.



CFL lamp (left) lives 9 times longer than light bulb (right)

Fluo lights

Metro and light rail stations have different types of lighting and use different lamps. In general, one can say that metro lighting needs more lighting power than lighting for the consumers' market and that the heavier conventional fluorescent lighting tubes (also called fluo lights) are used more frequently than incandescent light bulbs.

Nevertheless, the same mechanism counts: the newer and more expensive the lamp, the longer it lasts and the more energy-efficient it is. It is always wise to reassess the type of lamp you use and to make a decision on replacement based on efficiency and cost. MoBiel did this and replaced numerous lamps (see best practice 1).

BEST PRACTICE 1: Replacing lamps at stations by moBiel

The German operator moBiel operates the tram system in Bielefeld, which comprises of both over ground and underground stations. In 2010, moBiel replaced the existing *T8* lamps with newer more efficient *T5* lamps (both lamp types are fluo lights and are manufactured by Osram) at station Hauptbahnhof. This reduced the energy use from 49,000 kWh to 26,000 kWh per year. The same amount of light is now given with 74 lamps (replacement every 4 years) instead of 115 lamps (replacement every 2 years).

Reduction of energy costs and maintenance/replacement compensates very much the higher purchase price of the new lamps. A second station (Wittenkindstrasse) will be deployed with the new lamps in the Summer of 2013.

LED lights

A LED lamp (or LED light bulb) is a solid-state lamp that uses light-emitting diodes (LEDs) as the source of light. LED lighting made a commercial breakthrough around 2010 boasting longer lifespans and higher energy efficiency than conventional lights (incandescent light bulbs and fluorescent lighting tubes).

Due to the technology of LED lighting being significantly more advanced than CFL-lamps, this is reflected in the higher initial costs. However, LED lighting is the most energy efficient light on the market, possessing the lowest maintenance costs.

Since the lifespan of LED lights is very long, it is considered by many experts as the most efficient and cost-effective commercial product for a multitude of lighting purposes. For this reason, RATP is taking LED lighting very seriously (see best practice 2). LED lighting is also often considered for municipal outdoor lighting (streetlights).

BEST PRACTICE 2: Introduction of LED lighting for all stations by RATP

The Parisian operator RATP, operates an extensive transport network of metro and RER (rapid train). In 2012, RATP decided to install LED lighting on all metro and RER stations after a successful pilot in a metro station and the RATP headquarters.

Between 2013 and 2017, all 250,000 lamps (including fittings) in the 301 metro stations and 66 RER stations will be replaced with LED lighting. This will bring down energy use by 77 GWh per year which is equivalent to 6,000 tonnes of CO_2. It will also make RATP's metro system the first underground public transport network of its size which will be entirely equipped with LED lighting technology.

This planned initiative is conducted by RATP without support of T2K.

LED lighting used for street lighting

Applicability

When directly replacing fluo lights with more efficient fluo lights and/or CFL lights, there is commonly no necessity to replace the light fitting itself. The new, more efficient light can simply replace the old, inefficient fluo light. As such, it can be concluded that direct replacement of this type is highly applicable in light rail and metro due to its relative straightforwardness. This measure also improves the life cycle of the lights.

For LED lights however, applicability seems to be comparatively low at this moment. The technology is still relatively new which can make public transport operators hesitant to invest in this technology. LED lights are also expensive compared to alternatives, making installation and renewal costs high (which will be however compensated by lower electricity usage). One of the reasons of the high installation cost is that also the light fittings need to be replaced. Another aspect that needs to be considered is the influx of mass produced, but poor quality LED lights on the consumer market. For this reason, public transport operators need to research products on the market in order to select suitable LED lights.

Design phase

During the design phase, local building rules must be considered because the architect of the building might have a right to refuse the installation of lamps since this can be considered as an adjustment to the design. This can be prevented by explaining the positive benefits to the architect.

Since LED lamps have high investment costs, it is advisable to obtain LED lamps in a very big quantity through public procurement. Also the design and exact location of the lamps (including the direction of the light) is very important because this can temper an important disadvantage of LED lighting: LED lights do not emit light in all directions (as conventional lights do) which can reduce the comfort level of its users.

Implementation phase

Implementation is not difficult (especially for the replacement of more efficient fluo lights). However the organisational impact of switching to LED lights can be quite high. The variance in quality makes the selection difficult and the maintenance cycle of the lamps must be changed (but should decrease).

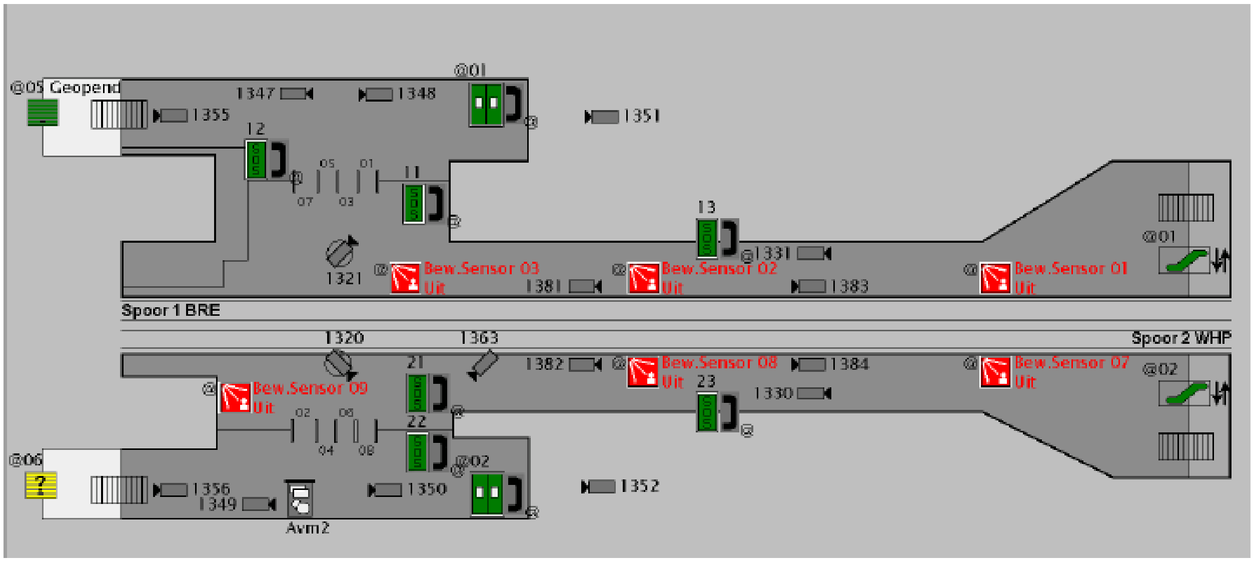
Effectiveness of this measure

A figure for the actual reduction in energy consumption that would be realised by investment in efficient lighting will be dependent on the individual circumstances of a station. For example, the scale of replacement and the type of efficient lighting procured. However, the overall effectiveness of this measure in terms of energy savings and CO_2 reductions is estimated as **high** because replacing lamps is quite easy so with relatively little investment (in time and money), larger reductions in energy usage can be achieved large scale replacements to more efficient types of lighting.

2.2. M2: Switch lights completely off

Typically it is often found that metro and light rail stations are completely illuminated for 24 hours a day, although operational hours are mostly between 18-20 hours a day. This means that stations are illuminated during night hours (4-6 hours per day), when they are not operational and public access is prohibited. During this timeframe, a station does not need lighting except for maintenance, safety and security reasons.

This measure involves the installation of motion sensors in metro and light rail stations which automatically trigger lighting when movement is detected and similarly, turns off lighting after a period when it detects no movement. Sensible design of the sensor's location can ensure that they do not unnecessarily activate the lighting when a train passes.



Motion sensors (in red) placed on RET platform in such a way that they do not respond to passing trains

As part of the Ticket to Kyoto project, RET implemented this measure in their underground metro stations (see best practice 3).

BEST PRACTICE 3: Lights out in the RET metro stations

The Dutch operator RET operates a network of metro stations which are closed during the night but were previously illuminated twenty-four hours a day. In 2009-2010 RET undertook a pilot project with motion sensors in the 'Leuvehaven' underground station. The sensors were placed in the station's hall and on the platforms. After the station closed, the station's lighting was completely switched off.

The motion sensors were only active when the station reached the 'closed' status. In case of motion detection, the station's lighting was automatically switched on; the traffic control centre received an alarm which switched on the camera system to show the images of the station on the video wall of the traffic control centre.

The pilot demonstrated that the motion sensors functioned as expected, ensuring lighting was switched off when there was no requirement thus reducing energy demand and costs.

Applicability

Motion sensors are a proven technology that are extremely effective at both activating and deactivating lighting when and where necessary, thus greatly increasing metro and rail station energy efficiency.

Design phase

Serious consideration needs to be given to the location and sensitivity of the sensors during the design phase to prevent security and safety issues (traffic control centre does not see an illuminated metro station anymore but must rely on the knowledge that – if anybody is detected by a sensor– the lights are immediately switched on automatically.

Implementation phase

Implementation is not difficult; technically it is not complex to install motion sensors into a lighting system. Maintenance schedules of lighting will be reduced due to the nature of motion sensors minimising lighting requirements during the night. Appropriate arrangements may be necessary for security purposes if lights are activated due to unauthorised access to a station.

Effectiveness of this measure

Similar to *M1: Replace lamps with more efficient ones,* a figure for the actual reduction in energy consumption through investment in motion sensors will be dependent on the individual circumstances of a station. However, the overall effectiveness of this measure in terms of potential energy saving and CO_2 reduction is estimated as **high.**

2.3. M3: Monitor lighting costs

It is very important to monitor lighting costs and to asses if the expected savings from measures M1 and M2 will be achieved. Furthermore, an advanced system of monitoring lighting costs can analyse energy usage patterns and in this way ‘discover’ new saving measures.

To conclude this chapter, an overview of the measures is being given.

Measure	Tested/implemented by	Average energy savings (estimated)	Effectiveness of measure
M1: Replace lamps with more energy efficient ones	moBiel (for fluo lights)	21,000 kWh per station per year (for fluo lights)	high
M2: Switch lights completely off	RET	27,000 kWh per station per year	high

See *Follow-up action 4*, for how to estimate the reduction in CO_2 emissions per year (based on the average energy savings in the table above)

3. Heating energy efficiency improvement

The next three measures (M4 to M6) describe medium term energy saving measures with a focus on the reduction of heating costs. These measures can also be described as *heating control measures*.

3.1. M4: Energy efficient heating of railroad switchers

Point heaters prevent railroad switchers (typically located in or near stations) freezing in extreme cold weather, and are necessary to maintain smooth operation of a metro and light rail network without disruption. However, point heaters consume a relatively large amount of energy in order to heat all the railroad switches on the network. Most point heaters are powered by electricity, however some are powered by natural gas (compressed natural gas or CNG).

Old point heaters are switched on manually when weather forecasts predict the temperature to fall below zero degrees. . On the contrary, modern regulated point heaters automatically switch on when weather conditions (temperature and humidity) require activation. This saves energy since they will not be switched on and kept on when it is not necessary.

Snow-free railroad switcher by point heater (1st photo) and details of point heater (2nd/3rd photo)

The pictures above were taken at a (regular) heavy rail network. moBiel has piloted modern point heating on its light rail network (see best practice 4).

BEST PRACTICE 4: Introducing dynamic controls at point heaters by moBiel

The German operator moBiel operates the tram network in Bielefeld which has stations both underground and over ground (elevated). At the end of 2012, moBiel initiated a pilot study, installing dynamic controls at six electric point heaters at a tram depot in order to prevent disruption of operations.

To date, results of the pilot are encouraging with the six point heaters (twelve heating elements; two elements per heater) functioning very well, activating when temperatures fall below 0℃ (below 3℃ when snowing)

In March 2014, final results in terms of energy saved and CO_2 reduced will be available (after two winter periods) after which the eighteen electric point heaters on the network (mostly in or near stations) will also be fitted with dynamic controls.

Applicability

Applicability of this measure is very high since it is a proven technology. It is also relatively easy to purchase and to install.

Design phase

The point heaters can be bought from the shelf so it is not necessary to think about the design. It is important to purchase the best product available in terms of price and quality. It is essential to have good quality point heaters with sensors that are so advanced that heaters always switch on when temperature/humidity (and maybe wind) requires that. With less advanced sensors, disturbance of daily operations can occur (if the point heater is switched on too late and the rail-road switcher is already frozen).

Implementation phase

Implementation is not difficult since installing and maintaining railroad switches and associated point heaters are regular activities for a public transport company (usually outsourced). It is however important to include instalment of individual meters at the point heaters to monitor the effects of this measure.

Effectiveness of this measure

A figure for the actual reduction in energy consumption is not available as this will be dependent on the scale of investment in automatic point heaters by a public transport operator. However, the effectiveness of this measure in terms of energy savings and CO2 reduction is estimated as **low** since this measure does not substantially reduce the energy usage of point heaters of rail-road switchers. Improving the manual switching on/off process (by using for example an automated checklist at the traffic control centre) can also be considered.

3.2. M5: Make underground staff service areas more energy efficient

Underground metro and light rail stations have staff service areas. These areas are only partly visible to customers, through a ticket window but also may only consist of spaces where staff has their coffee and lunch breaks. Usually staff service areas have no direct day light and no connection to the natural gas (CNG) grid. Therefore an electrical heating unit is usually present for heating purposes which operate at too high a temperature and are often left on when nobody is present. Such heating provisions are highly inefficient in terms of energy usage.

A way to improve energy efficiency and comfort of staff service areas is to install a modern intelligent climate control system (for both heating and cooling) optionally extended with LED lighting. RET has successfully piloted this modernisation in its metro network (see best practice 5).


RET conventional heating with convectors (left) and modern integrated heating/cooling (right)

BEST PRACTICE 5: Modernising heating installations in staff service areas by RET
Stadhuis station is one of the busiest stations in RET's network. This metro station has a service area with staff rooms (for taking coffee, lunch or dinner breaks) and a staffed service centre where passengers can make travel information enquires. Analysis showed that the energy bill for the service centre was high and feedback from staff showed that comfort levels were low. **In 2011, RET decided to modernise the heating, cooling and lighting installations of the service area. The new installation has been built in such a way that all the components are integrally constructed, meaning lighting, heating, cooling and ventilation are intelligently controlled using motion detection. The lighting specification used was LED with a life expectancy of ten years.** **The heating system comprises of infrared heating panels on the ceiling, quickly warm up a room to a comfortable temperature through radiant heat. The cooling system cannot operate simultaneously with the heating system which prevents unnecessary waste of energy. The new installations have been in use since February 2012, so far reducing electricity costs by 76%.**

Applicability

This measure is highly applicable when improving the energy efficiency of staff service areas since independent electrical heating units are highly inefficient and all elements (heating, cooling, lighting and sensors) are now standard products on the consumer market. The challenge is creating an integrated intelligent system of all the elements which will require specific expertise from the suppliers.

Design phase

During the design phase, one has to consider how to integrate all the different elements in an efficient way. Modernising installations in underground staff service areas in this way seems relatively new

Implementation phase

Implementation is relatively easy. The new installations can be installed in one or two weeks. During this time, the service area cannot be used but this is easy to solve (by referring passengers and staff to another location or by installing a temporary cabin in the metro station with a service desk and staff area).

Effectiveness of this measure

Although exact figures on the reduction in energy consumption depends on the specific situation, the effectiveness of this measure in terms of overall energy saving and CO_2 reduction is estimated as **high**. Purchase and installation is relatively easy to do while the new heating, cooling and lighting elements are in general much more energy efficient than the old ones. Therefore, savings can easily reach up to an estimated 50-70% compared to conventional electric heating units.

3.3. M6: Monitor heating costs

It is very important to monitor heating costs and to asses if the expected savings from measures M4 and M5 will be achieved. Furthermore, an advanced system of monitoring heating costs can analyse energy usage patterns and in this way 'discover' new saving measures. More information on this topic can be found in the publication 'Quick Wins' produced as part of work package 1 of the Ticket to Kyoto programme.

To conclude this chapter, an overview of the measures is being given.

Measure	Tested/implemented by	Average energy savings (esti-mated)	Effective-ness of measure
M4: Energy efficient heating of railroad switchers	moBiel	1,000 kWh per *point heater* per year	low
M5: Make underground staff service areas more energy efficient	RET	29,000 kWh per *staff area* per year	high

See *Follow-up action 4* for how to estimate the reduction in CO_2 emissions per year (based on the average energy savings in the table above).

4. Renovation of stations

This chapter describes long term energy saving measures with a focus on the renovation of existing metro and light rail stations which has been built more than 25 years ago. These measures can also be described as *eco-renovation measures with a focus on increasing energy efficiency*. This chapter consists of one measure (M7).

4.1. M7: Renovate old stations with guidelines and BREEAM

Much of the metro and light rail infrastructure across Europe was built in the period 1960-1990 when environmental standards were weaker than today and when energy saving was not high on the political and business agenda. Since then, we have experienced exponential growth in new technology and product development, alongside a heightened awareness of the need for sustainable design and construction of our buildings. Renovating old, inefficient metro and light rail stations offers the opportunity to harness this new dynamic and achieve large energy and CO_2 reductions as well as increase their overall sustainability. In general a metro or light rail station needs to be renovated when it is older than 25 years. This means that all stations built before 1990 (and which have never been renovated so far) can be considered as interesting stations for renovation.

It is important to note that reducing energy consumption and environmental impacts alone are never the sole reasons to renovate a station. There are other requirements such as increasing capacity, modernising the area or attracting more passengers. Renovating a station can be very expensive and needs to be initiated (or at least supported) by the legal owner of the station.

Including energy saving and sustainability issues in renovation plans for stations is a relatively new phenomenon in public transport. Since every city has uniquely designed metro and/or light rail systems, it is important to be able to apply a consistent and applicable approach to enhancing the energy efficiency and overall sustainability of a transport operators stations. It is advisable to develop a set of guidelines, in order to achieve this and guide the renovation process. Guidelines of this sort can be described as *sustainable renovation guidelines*. STIB in Brussels, have developed extensive sustainable guidelines for the renovation of their metro and light rail stations (see best practice 6).

BEST PRACTICE 6: The design of a Sustainable Renovation Reference System by STIB

The Belgium operator STIB operates bus, metro and the light rail network in Brussels. They developed a Sustainable Renovation Reference System (SRRS) for the 69 metro and light rail stations in the city. This SRRS divides these stations in six comparable design types (e.g. one level overground station or underground station with platforms on two different levels). The SRRS aims to evaluate the environmental quality of a station's renovation project. This system consists of two tools: a document describing the potential renovation measures and a self-evaluation tool.

In order to maintain flexibility, the SRRS works on three levels:

(1) Minimum level. On this level, the SRRS works as a tool for self-management. It serves as internal guidance and support to make decisions at various stages of a renovation project.

(2) Medium level. On this level the SRRS works as an internal self-management tool to potentially obtain a certification of environmental performance. An external auditor verifies the results afterwards.

(3) Maximum level. On this level the SRRS works also as an internal self-management tool but an auditor is present during all phases. The certification to obtain on this level is the BREEAM certification.

BREEAM

BREEAM (Building Research Establishment's Environmental Assessment Method) is the world's leading and most widely used sustainable building certification scheme. The assessment method has been developed in the UK where there are over 115,000 buildings certified and over 700,000 homes and buildings currently registered for assessment. BREEAM can be used to assess any building type anywhere in the world.

BREEAM sets the standard for best practice in sustainable design and construction and has become the de facto measure used to describe a building's environmental performance. The BREEAM scheme involves assessment at design stage and post construction where credits are awarded in nine categories plus an innovation category. The individual credits for each category are then added together to produce an overall score that determines the rating of the building. The scale of the rating is: Pass, Good, Very Good, Excellent and Outstanding.

To use the certification methodology, BREEAM scheme documents are available for free download from the BREEAM website. These documents function as technical guidance documents and for the UK, different BREAAM scheme documents (for different sectors) can be found on the website. For outside the UK, three categories are given: one specifically for the Gulf region, one for Europe Commercial (offices, retail and industrial) and more generic document called BREEAM International Bespoke.

The BREEAM International Bespoke scheme can be used to design a tailor made assessment method (a 'bespoke') for your buildings.

A BREEAM standard covers nine categories of sustainability plus one for innovation:

1. management;
2. health & wellbeing;
3. energy;
4. transport;
5. water;
6. materials;
7. waste;
8. land use and ecology;
9. pollution;
10. innovation.

Application of the BREEAM methodology for assessments of metro and light rail stations is unique. STIB in Brussels has particular experience in applying the BREEAM assessment (see best practice 7).

BEST PRACTICE 7: Application of BREEAM Bespoke for the Brouckère station in Brussels STIB
The Belgium operator STIB operates bus, metro and the light rail network in Brussels. Nearly all 69 metro and light rail stations in their network are older than 25 years. For the Brouckère station, STIB applied the BREEAM Bespoke scheme to renovation plans for the station. All categories of BREEAM were assessed for this station. In the Transport category, the score was - logically - good but other categories were adapted by the BREEAM assessor to tailor the assessment to metro and light rail stations. The renovation project of the Brouckère station is still in planning phase but during the whole process, the BREEAM procedure will be followed completely. The Brussels Region authority owns the station; therefore they have the responsibility for the renovation activities.

Applicability

Applicability of guidelines is relatively low, because existing BREEAM schemes are generally not applicable for public transport infrastructure such as metro and light rail stations. As such, BREEAM Bespoke has to be tailored for use with stations, which is time consuming and at an additional cost. Careful consideration should be made whether undertaking BREEAM assessment will be of benefit and what level of ambition an operator has. When a simple renovation is required, a BREAAM analysis is not advisable due to the high amount of work (of the very detailed assessment process required by BREAAM).

Design phase

During the design phase it is important to follow one format: either tailor made guidelines (for example based on SRRS) or the BREEAM Bespoke certification scheme.

Implementation phase

Implementation is relatively difficult due to the complexity of a renovation. Since renovating a station is very expensive, a professional project organisation should be in place to plan and execute the modernisation.

Effectiveness of this measure

Although there is not an exact figure on the percentage decrease of energy consumption as this will depend on the circumstances of a particular station, the estimated effectiveness of this measure in terms of energy savings and CO_2 reduction are potentially **high** since renovating a station more than 25 years old will have many opportunities for transforming the station into a more energy efficient building through the use of modern insulation techniques (for doors, roof and platform) for instance.

5. Conclusions and follow-up actions

This final chapter gives the main conclusions of the report. It also gives some recommended follow up actions for the workgroup.

5.1. Conclusions

The following conclusions can be made:

1. Lighting control measures are relevant for the short term. Replacing lamps with more energy efficient fluo lamps has a high impact.

2. Heating control measures are relevant for the medium term. Making underground staff service areas more energy efficient has a high impact.

3. Long term measures mainly consist of renovation of metro and light rail stations which are older than (roughly) 25 years. Dedicated guidelines can be used. Renovation has a high impact.

4. All measures have substantial effects on energy reduction. Payback periods are estimated at 2-3 years for lighting measures and 10-20 years for renovation measures.

5. The regulatory framework for public transport can hinder the implementation of long term measures. Engagement with relevant parties who have ownership of stations and other assets is advisable before designing any of the above measures.

6. Existing working patterns (plus ingrained habits) in the maintenance cycle can also hinder the implementation of lighting and heating control measures. It is advisable that stakeholders within public transport companies have an open attitude towards new measures.

5.2. Follow-up actions

Based on the summary of the insights so far, the recommended follow-up actions of the Energy Efficiency workgroup for the remaining twelve months before finalisation of the T2K project are listed below:

1. Collect specific data on the five public transport systems to calculate payback periods of the seven measures. Calculate the general payback period (without subsidy) and the "T2K payback time" (payback time with T2K subsidy).

2. Design different practical transition paths based on payback periods and CO_2 reduction targets. This is an action that can be done in cooperation with the work group (WP3) developing strategic CO_2 reduction plans. A path can for example exist of replacement of existing fluo lights by more efficient ones (first step), instalment of LED lights some years later (second step) and finally complete renovation of the metro station some ten years later (third step).

3. Collect specific data on the local regulatory framework in the five cities to be able to assess every investment proposal in the decision process. One can think about ownership of stations, approving procedures by architects (regarding adjustments of metro stations) and the functioning of the local energy market (regarding electricity provision and pricing to the public transport operator). This action can be done in cooperation with the work group Optimizing policies and regulations for CO_2 reduction measures (part of WP4).

4. Estimate the reductions of CO_2 emissions per year on the basis of the average energy savings (in kWh per year) as given in the two tables of paragraphs 2.3 and 3.3. For this estimation, a European average of CO_2 emission per kWh can be used. Also more specific CO_2 emission data per country can be used, for example the data mentioned in table 3 of the full version of the T2K report *Contextual drivers for CO_2 reductions in public transport*.