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LED PROJECTS AND ECONOMIC TEST CASES IN EUROPE

Work done in the context of the European Commission study "Preparing for the wide deployment of Solid State Lighting (SSL) in Europe" (SMART 2011/0069)

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Executive Summary

LED is a fast developing, promising technology, offering a wide range of potential uses. This report presents the status of existing LED pilot actions in Europe, analysing 106 LED test cases from 17 European countries. Projects from the public and commercial sectors form the focus of the report, with special attention devoted to the economics of LED projects.

Reviewed test cases include the use of LED technology in traffic lights, street lights, bicycle paths, hotels and retail stores, as well as applications in historical buildings. Replaced technologies include high pressure sodium lamps, mercury vapour lamps, incandescent lamps and fluorescent tubes.

The results of test cases demonstrate wide variation. Installations offer energy savings of 59% in average (savings range from 10% up to more than 90%), either compared to the original installation or to reference consumption. In many applications, LEDs are competitive (with payback time ranging from 2 to 10 years), yet a large number of projects are still in the trial phase. In these cases, economic aspects are relatively less relevant, and are often not even accounted for (as economic evaluation at this stage can even be a disadvantage).

From the test cases reviewed, most successful applications, in terms of savings and economic considerations, are 1) replacement of incandescent light bulbs in traffic light systems, and 2) replacement of halogen spotlights in indoor applications.

Main co-benefits of LED projects analysed include: low maintenance costs, improved lighting characteristics, good indoor and outdoor lighting quality, improved ambience and atmosphere (esp. for indoor lighting), no UV radiation, environmental benefits and improved security (road safety). On the other hand, some challenges to address include: improve the quality characteristics of LEDs and the quality of information and data provided by manufacturers/suppliers, and optimality of LED technology for existing street lighting systems (e.g., due to existing pole spacing).

In order to fully utilise the energy saving potential of LED technology, careful evaluation of existing projects and exchange of information on good practices is necessary. Exploration of bottlenecks and risks is also an important task. Quality characteristics of LEDs, and quality of data provided by manufacturers, will remain the main challenges to penetration of the technology.

1 Introduction

The first commercialised Light-Emitting Diodes (LEDs) were developed already several decades ago. However, practical test cases for HB (high brightness) white-light LEDs began to pave their way more frequently only in the last five years or so. Despite this rather short history, LEDs are starting to be used more and more in different lighting installations.

The aim of this report is to present the status of existing LED pilot actions in Europe. Specific attention is given to the economics of LED projects; however, many of the projects reported are in an experimental phase and the economics have often not yet been assessed.

Although a generalisation of the different test cases is not possible, this report highlights and assesses the main features and experiences from LED test cases and illustrates them on selected pilot projects.

LEDs nowadays offer a wide range of potential uses (varying from traffic lights to elevator lights and show-case lights to bed lamps). There are currently thousands of projects around Europe[1].

The report provides an overview of LED projects. The scope of the overview is limited to test cases in Europe. Given the number of test cases already implemented internationally, it would not be possible to effectively cover the test cases from all over the world. The list of projects which are described and analysed in this report does not provide an exhaustive enumeration, but rather a representative selection of the most relevant test cases to give as broad a picture as possible of what has been currently going on in Europe in LED installations.

The report begins with an analysis of the types of installations in which LEDs are used. The main features of the projects are highlighted. It is followed by the analysis of savings (in monetary and technical units) and discussions about the economics of the installations. The last two chapters are devoted to the main advantages and benefits, and drawbacks of the projects, as perceived by the stakeholders.

The projects come mostly from the tertiary and public sectors, but also from the industry and the services sectors. The report does not cover test cases and projects in the residential sector, with only one exception of social housing in the UK[2].

All projects, referred to in the text, are listed and further detailed in Annex 1[3]. Selected projects are highlighted in boxes in the main body of the report.

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[1] To illustrate the quantity of projects, for instance, an overview of pilot projects in the Netherlands can be found at [1].

[2] Two phases of field trials were run installing LEDs in over 30 social houses around the UK. The evaluations are currently ongoing. The reason to include these field tests in the study is that the lighting in question is on for 24 hours a day and therefore offers a large potential for savings (and replicability).

2 Methods and limitations

The survey was carried out from mid June to the end of August 2011. Lighting experts from different sectors have been asked to provide references and details on LED pilot projects across Europe. A method of snowball sampling, in which the existing acquaintances provide references and contacts to further addressees, has been partially used. Thanks to this, in the end, more than 100 experts from across Europe have been contacted. The experts reach out from lighting experts in academia, research institutes, NGOs, manufacturers, lighting installers, lighting associations, municipalities and other. The GreenLight Programme was used as a source of information too.

The response rate (even though quite high for a survey – about 30%) may have been influenced by the timing of the study during the holiday period[4].

There are likely to be hundreds, maybe thousands, of LED projects in place all over Europe. The current report presents an analysis of the 106 pilot projects selected from 17 European countries. The projects have been chosen by the experts addressed as representative and therefore, although all LED projects are not represented, a good overview of the situation in Europe is provided.

The respondents were given a common formatted Excel sheet to be filled in (Annex 2). However, in most cases, the project description did not follow the common format. The case studies, therefore, vary in form and differ in terms of level of details provided by the respondents. This is the reason why the report offers qualitative, rather than quantitative analysis (even though some quantitative data is provided).

2.1 Limitations

The sample for the analysis is not exhaustive. The aim was not to provide the full list of existing LED installations, but to give a good overview of the LED projects around Europe – typical installations and their characteristics.

Statistical conclusions should not be derived from the report. For instance, the number of projects per country does not fully correspond to the distribution of the LED projects in Europe.

Seventeen countries are represented in the sample. This does not mean there are no LED projects in the other European countries. It may mean that in those countries, data on LEDs is not systematically collected and the few projects realised so far are for testing purposes (e.g., Lithuania [2] or Slovakia[5] [3]). The proportions between LED projects

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[3] If not referenced otherwise, the data used in the study can be found in the references provided in Annex 1.

[4] A full list of experts that have provided references of pilot projects is presented in References.

[5] This is just to illustrate the situation, but obviously the case may be similar (and often is) for other countries.

from different countries do not represent the real proportions of existence of LED projects around Europe[6].
A second type of limitation pertains to the information reported. The LED projects' data have been provided by the respondents. There is no check on the correctness of the data by the authors. This being said, for the projects coming from the GreenLight Programme (14 projects[7]), the reports undergo a double check – by the National Contact Points and by the Joint Research Centre – Manager of the Programme.

At the same time, the data has often been provided by the manufacturers themselves[8], or as show-cases (good practice examples). This means, for instance, that the number of cases where drawbacks are described may be limited due to the character of the reports.

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[6] For instance, see note 1.

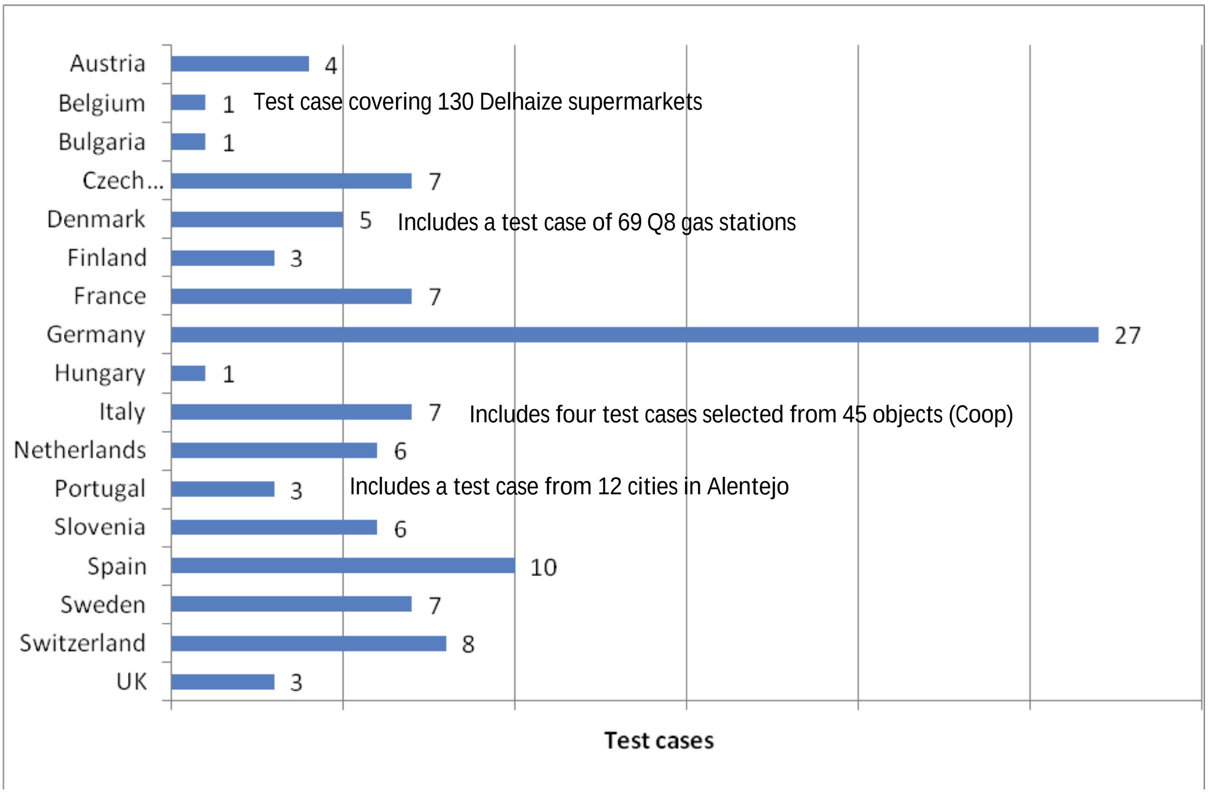
[7] City of Koenigsfeld, City of Tilburg, Municipality of Piombino, Delhaize Belgium, Gemeinde Diex, Gemeinde St. Georgen, Hamburg Streetlights, Intesa SanPaolo, Nyborg Street lights and Nyborg gas stations, Unibail-Rodamco, City of Utrecht, Stadt Villingen Schwenningen, Vossloh-Schwabe Optoelectronic GmbH & Co. KG.

[8] See list of projects in Annex 1 and list of experts.

3 LED projects - overview

A total of 106 LED test cases have been collected from all over Europe. The projects come from 17 European countries – a quarter from Germany, 10 from Spain and 8 from Switzerland (Figure 1).

Figure 1: Analysed LED test cases per country



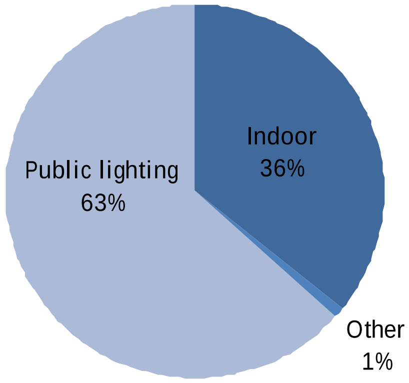
As shown in Figure 1, the number of test cases analysed does not necessarily correspond to the number of buildings or facilities. In Belgium, the Delhaize test case covers the installation of LEDs in 130 supermarkets. In Denmark, one of the test cases covers 69 Q8 gas stations, where neon lights have been replaced with LED lighting and in Northern Alentejo in Portugal, LED lights have been installed in 12 municipalities. The data for these test cases have been provided as a summary and therefore are presented as one test case. Similarly, since 2007 more than one hundred LED signs have been installed in 45 Coop shops in Italy, but the contact person selected only four test cases as representative ones, for which further data have been provided.

The LED technology is a relatively new one, at least in terms of commercial applications. Only two projects in the sample were carried out in 2003 – 2005. All the others were realised in the last five years (between 2006 and 2011). Almost 80% of the projects were carried out in the last two years, or are still ongoing.

The LEDs are typically used in public lighting installations. In the sample, almost two-thirds of the projects are public lighting projects (Figure 2), which entail street and road lighting[9], bicycle paths (three cases), but also traffic lights (five cases) and tunnel lighting (one case).

In the sample, LED lights are often used for lighting streets with less traffic, or for pedestrians and bikes only. One reason might be, as mentioned in the public lighting project in Toulouse, that current LED solutions do not offer enough performance to ensure adequate lighting of streets and roads, acceptable to the population[10]. However, the reduced power of LEDs and their colour can be an advantage for pedestrian spaces [4]. In Darmstadt, Germany, the LED lights have been tried out specifically on a road with higher luminance needs and the results were satisfactory – the LEDs complying with the standards [5].

Figure 2 Type of LED projects



Indoor LED lighting projects (36%) are much more varied. The sample includes hotels, restaurants, shops and shopping malls, markets, gas stations, museums, theatres, but industry buildings too. In the shopping malls, the areas cover indoor parking lots, offices, or corridors. One project is about aviation safety lights, which were mounted on transmitters (antennas) of mobile operators.

In the UK, a large programme on retrofit of social housing has been running. Several of the projects of complete house refurbishment included LED lighting[11]. Trials of LED lighting in communal areas of social housing in England have been launched with the evaluation currently ongoing [7].

In several projects in the sample document, LEDs are installed in historical buildings. There is the historical building of the National Theatre in Prague, Czech Republic, built in the 19th century, in which LEDs replaced incandescent light bulbs in all emergency lighting (see Box 1). Similarly, LED lighting has been used in the Musikpavilon, Luzern, Switzerland, and also the Hunterian Museum in Glasgow, UK, the oldest public museum in Scotland, in which LED lights replace halogen spotlights (more about these examples also in the section on benefits).

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[9] The difference in street and road lighting, as perceived in the projects, is in the level of traffic, where streets evoke residential areas or areas with less traffic (and consequently lower luminance needs). In this sense, street light projects largely prevail in the sample.

[10] This represents the situation at the moment of the test cases.

[11] More information can be found at [6].

4 Technology

The sample projects are quite diverse, and it is not easy to find a common denominator as to what technologies are replaced, and consequently what type of LED technology is used. The variability of LED lights, as one of their advantages, predisposes them to be a replacement for many different lighting technologies in different installations. Below, we present the types of replaced technologies found in the case studies reviewed.

In the indoor lighting projects reviewed in the study, among others, LEDs replace incandescent light bulbs (as in the case of the emergency lighting in the National Theatre, Czech Republic, Christmas lighting in Solothurn or for instance the Musikpavilon in Luzern).

More often, however, LEDs have been found to replace halogen low voltage down lights (e.g., the Ribe Kunstmuseum in Denmark, the Hunterian Museum in Glasgow, UK, the Hotel Algarve in Portugal or Delhaize Belgium, to cite a few). In the Marriott Hotel in Prague, Czech Republic, the LED lights replace the halogen lights on top of room entrances, another typical use of this technology and potential for replication.

In a trial project of social houses in the UK, LEDs have been used to replace fluorescent tubes, which are on for 24 hours a day and therefore offer sufficient potential for savings[12].
In 8 of 10 shopping malls in Spain (Unibal Rodamco, Spain) fluorescent tubes in indoor parking lots are replaced with LEDs.

In outdoor (public) lighting projects, the technology replaced is often the high pressure sodium (HPS) lamps (e.g., street lighting in Lugano, Switzerland, in Ljubljana (Slovenia), or in Regensburg, Germany, Espoo, Finland, Freiburg im Breisgau, Germany). Rather less frequent are replacements of mercury vapour lamps, which are however much less represented in some countries (e.g., the Norrbackagatan project in Sweden, Stuttgart or Darmstadt in Germany). The traffic lights projects usually entail replacement of incandescent light bulbs in the traffic lighting systems (e.g., City of Graz, Austria, Hamburg streetlights, Germany, or Northern Alentejo, Portugal).

In some cases, fluorescent tubes and compact fluorescent lamps (CFL) can be the competing technology. For instance, in Amsterdam, Tilburg and Assen (the Netherlands) over 200 pilots with 6000 luminaires are reported, mentioning CFL as the competing technology. However, it does not seem that the LEDs would directly replace the CFLs. Instead, a comparison was made saying that up to 15% savings can be achieved in the public lighting projects, compared to CFL, due to better directionality[13]. In Paderborn, Germany, the street lighting project involves the complete replacement of existing fluorescent lighting in more than 750 installations in the core urban area with LED lights. Similarly, in the road lighting project in Vienna, Austria, 58W fluorescent tubes are replaced with LEDs. In the project of lighting refurbishment in social houses in the

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[12] The complete results of the trial were not available in the time of writing the report.
[13] Comparison to HPS is made too.

UK the fluorescent tubes are replaced in communal areas and fluorescent tubes are the main technology replaced in the 10 shopping malls in Spain.

In two cases, the technology replaced is neon lighting. The Q8 gas stations in Denmark replaced the neon signs on many of their petrol station sites with LEDs[14]. Vodafone in the Czech Republic replaced neon (and halogen) aviation safety lights, installed on some 350 transmitters.

For some projects, the total number of light points in the installation decreases, as in the case of Gemeinde St. Georgen, Germany, where 124 light points, equipped with sodium and mercury-vapour lamps (with power from 75 to 165W), were substituted by 64 light-point LEDs (with a power from 26 to 50W).

Conversely, there are projects in which the number of lights installed increases. The reasons can be to maintain the level of luminance (as reported for instance in [9]), or simply because at the original state, only every third pole has a bulb, whereas the new state means luminaire on every pole (public lighting project in Sungurlare, Bulgaria).

The projects do not focus only on the lamps, but cover a complex renovation of the lighting system. Therefore, they frequently include digital control systems, motion detectors, occupancy controls, time scheduling and other management features, which can bring additional energy and cost savings, as well as comfort.

For example, in the Glasgow Hunterian Museum, Scotland, the whole system can be gradually dimmed when the area is unoccupied. The museum is divided into zones, each with sensors, so that when a visitor leaves the zone, the lights are dimmed after a few minutes.

Box 1: The National Theatre, Czech Republic

The National Theatre consists of four main buildings, out of which three are modern and one is historical, built in the late 19th century.

The renovation of the lighting system was part of the whole complex renovation, which was carried out through Energy Performance Contracting.

The LEDs were installed in all the emergency lighting, which is on 24 hours a day. Originally installed incandescent light bulbs of 15 W and 25 W were replaced with LEDs of 2 W - 4 W.

The overall payback period of the whole lighting renovation is less than two years.

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[14] Other petrol companies do the same, such as F24 in Denmark or BP in the USA [8].

5 Energy savings and quality aspects

From the 106 LED reviewed projects, 70 reported on energy savings achieved, either in absolute numbers (MWh/year), or in relative terms (%), or in both. However, for two projects, the calculation relates to the whole project, which covered other lighting technologies too, so it was not possible to separate the specific contribution of LEDs.

The relative savings in the projects reviewed average at 59% (without the two above-mentioned cases) and the total amount of energy savings reaches more than 14.4 GWh/year in the sample (from 38 projects).

The percentage of savings ranges from 10 to 90%. It is higher in indoor compared to outdoor projects: for 12 indoor lighting projects, where this data was reported, the average savings reach 69% and for the 36 public lighting projects, the average savings are 55 %[15].

In general, the relative savings are higher in cases where incandescent light bulbs are replaced (potentially up to 85 to 90% energy savings, as for instance in the case of traffic lighting system refurbishments in Northern Alentejo, Portugal). For an example of a successful project, in terms of achieved energy savings see Box 2.

In many cases, the savings reported were not achieved only by the LED technology, but also thanks to other lighting energy efficiency measures, such as occupancy and motion controls, time scheduling or luminaire optimisation.

On the other hand, there are projects in the sample, at which energy consumption (or installed power) is higher than at the original installation or higher than would be the best conventional technology.

For instance, there are trial projects currently being carried out in the city of Prague (Czech Republic) by several manufacturers. Each manufacturer selected for the project (in total there are six of them) has installed LEDs in one selected street. In three cases, the installed power of the system goes down; in three cases, the LED luminaire installed power compared to the original technology is higher[16]. The reason is most likely the trial character of this project. The main aim of the client – the city is to monitor the qualitative characteristics of LEDs and their development over time, the maintenance needs, and their perception by drivers and pedestrians.

In the retail stores Delhaize, Belgium, the power of luminaires with LEDs is almost 70% lower than the original technology (low voltage halogen lamps). However, the number of luminaires had increased significantly, being now 3.5 times higher than was the original state. Therefore, the total electricity consumption of the LED lighting system is 17% higher than it was before the replacement. Other measures in the supermarkets entailed replacement of 26mm fluorescent tubes by 16mm ones and replacement of magnetic

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[15] The sample of course is too small. However, it at least gives an indication of the levels of savings in these categories.

[16] The difference is given by different technologies, different lighting characteristics of the LEDs and shape by different manufacturers.

ballasts by electronic dimmable ballasts and change of luminaire reflectors. The number of other luminaires (with fluorescent tubes and metal halide lamps) decreased significantly (in the case of metal halide lamps, four times). Therefore, the consumption of fluorescent tube luminaires decreased by almost 50% and of metal halide luminaires, by more than 90% (while lighting quality improved). Thanks to those measures, the project as a whole comes out with a payback period of less than three years).

Similarly, in the street lighting project in Nyborg, Denmark, high performance lamps (HPL) were replaced by CFLs. All the 42 new lighting fixtures further included a blue 5.5 W LED at the top, which gave an extra consumption of 0.97 MWh/year. Nevertheless, the overall electricity consumption of the whole system decreased by 73%[17].

In Darmstadt, Germany, a trial project has been carried out to test four lighting technologies – the original mercury vapour lamps, two HPS based lamps and LED lamps. LEDs are reported to provide savings of 35%, compared to the HPS lamps. The report states, however, that the consumption is still 8% higher, compared to the best conventional technology with electronic ballasts.

The manufacturers also stress that besides energy savings, the installation also needs to be assessed from the viewpoint of quality of lighting, quality and age of the original installation and other criteria, which go hand in hand with the evaluation of savings [10]. There are projects in the sample, which reported on energy savings, but at the same time quality of lighting decreased (see the section on drawbacks), which may not be a desirable situation.

Given the quick and continuous development in LEDs, and the unstable quality of different installations (see section on drawbacks), some of the test cases specifically highlight the fact that the given installation has fulfilled the relevant norms and standards on lighting. For instance, this is the case of the street lighting trial project in Darmstadt, street lighting project in Rietberg, or in Hannover, all Germany, road lighting project in Budapest, Hungary, or shopping malls in Spain.

Box 2: Coop, Italy

Since 2007, more than 100 LED signs have been installed in 45 Coop shops. They allow cutting energy consumption by more than 80%, compared to traditional lighting, resulting in an estimated saving of more than 600 000 kWh/year and in the elimination of more than 300 tons of CO_2 emissions into the atmosphere.

The payback period of the installations, in the four selected case studies, ranges from 3.5 to 5 years.

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[17] In the parking area, 12 fixtures with two 80 W HPL were replaced by two 32 W CFLs, giving a saving of 4.8 MWh, in the residential area, 30 fixtures with 80 W HPL were replaced by 42 W CFL giving a saving of 4.78 MWh, and in the park, 18 fixtures, including 50 W HPL were replaced by 18 W CFL, giving a saving of 2.42 MWh.

The main advantages are, apart from energy and maintenance cost reduction, the enhanced quality in colour perception and comfort.

6 Economics of the LED pilot projects

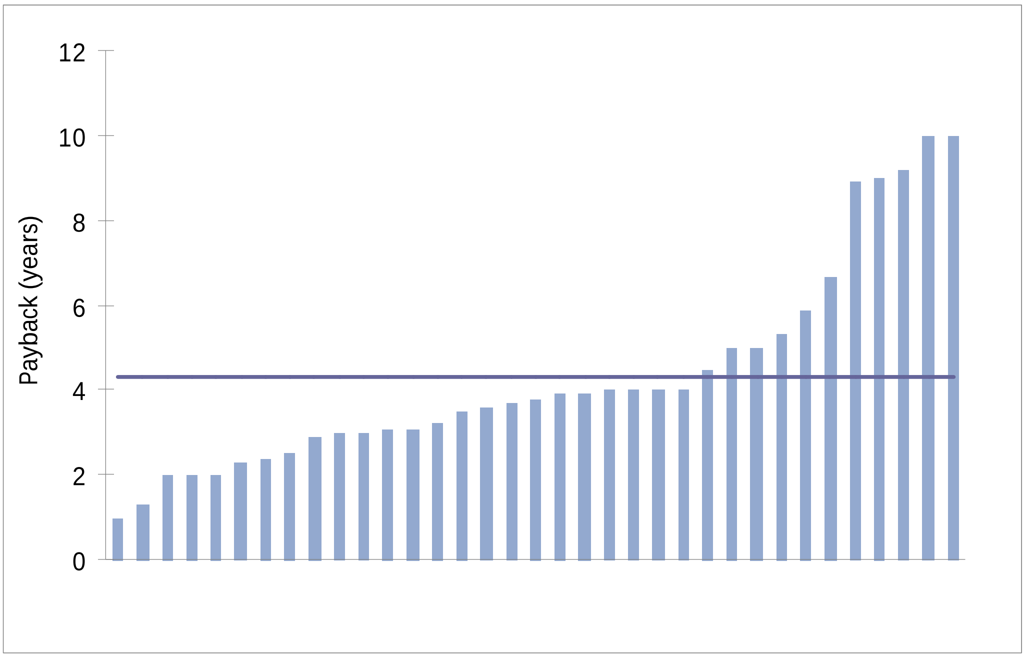
From the 106 cases studies, only 35 reported on an economic effectiveness criterion (in all cases it was the payback time[18]).

In several cases, the respondents specifically mentioned that the economics of projects have not been followed, as it is a trial/experiment project (e.g., the Municipality of Piombino in Italy, the French City of Balma, or street lighting project in Stuttgart, Germany). The representative from Philips Czech Republic pointed out that only some of the LED projects are economically effective and such evaluations always need to go hand in hand with quality aspects of the installations (e.g., for street lighting compliance with the standard EN 13201 on road lighting).

In 21 cases, the value of investment has been provided too. However, this obviously differs among the projects, which range from small-scale projects in retail, to hundreds and thousands of lighting systems installed. Therefore, the investment costs range from hundreds of euro to several million euros.

The payback period in the cases reported varies from less than a year to ca 10 years, with the average at 4.3 years (Figure 3).

Figure 3: Payback of 35 LED projects



Note: Dark blue line represents the average payback time of the projects.

In two cases (Delhaize, Belgium and the National Theatre, Czech Republic), the calculation relates to the whole installation, which also includes other types of lighting (such as CFLs or HPS, etc.). In the Delhaize project, LEDs have been installed as part of a

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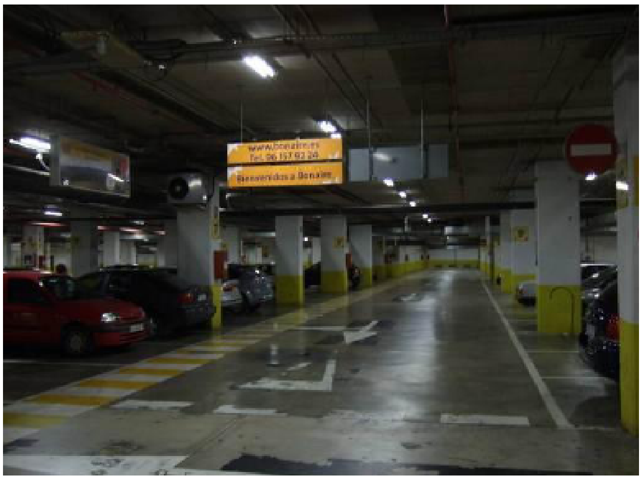
[18] Payback time is the length of time required to recover the cost of an investment (see e.g. www.investopedia.com).

complex lighting renovation project. Lighting applications, with higher saving potential, provide a cushion for the less effective ones, and therefore the overall payback is 2.9 years. In the case of the Czech National Theatre, the overall payback time of the project, which entailed installation of CFLs, efficient halogen lamps and LEDs (see Box 1), was two years.

Even though the sample for economics of the installations is rather small, there is a clear difference in the sample between the payback times for public lighting projects and indoor lighting projects. For street lighting (and traffic lighting systems), the average payback period (of 14 projects) is 6 years, whereas for indoor lighting projects the average payback period (including offices and retail stores, in total 21 projects) is 3.3 years (see Box 3 for a case study from Spain).

Box 3

Unibal Rodamco Shopping malls, Spain



In 10 shopping malls across Spain, LED lights have been installed mainly in the underground parking areas, access and technical stairs and corridors, indirect mall lighting, offices, restrooms and exterior parking areas.

The technology replaced is mainly fluorescent tubes, but also metal halide lamps and halogen down lights.

The total savings of the 10 malls amount to more than 5 200 GWh/year and maintenance costs decrease by more than 48 000 EUR/year in total. The payback varies from 2.3 to 5.3 years.

The lighting quality has improved or been maintained. In a few cases, where the lighting quality decreased, it still respects the minimum requirements.

Some projects in the sample have been realised through an Energy Performance Contract (EPC)[19] or similar type of energy service contract. If an EPC is applicable for the project, it automatically implies cost-effectiveness of the project. In the project in the Czech National Theatre, LEDs were part of a larger, complex and very successful EPC project (see Box 1). Energy Performance Contracting was also used in the case of the public lighting project in Sungurlare, Bulgaria. In Graz, Austria, incandescent bulbs in traffic lights were replaced by LEDs in a “Thermo-Profit Contract” of the Graz Energy Agency (see Box 4).

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[19] Energy Performance Contracting (EPC) is a proven and cost-efficient instrument for tapping existing energy saving potentials in the buildings sector. The main distinguishing feature of a project carried out through EPC is financing of the investments via (contractually) guaranteed cost savings, achieved through improved energy efficiency. [12]

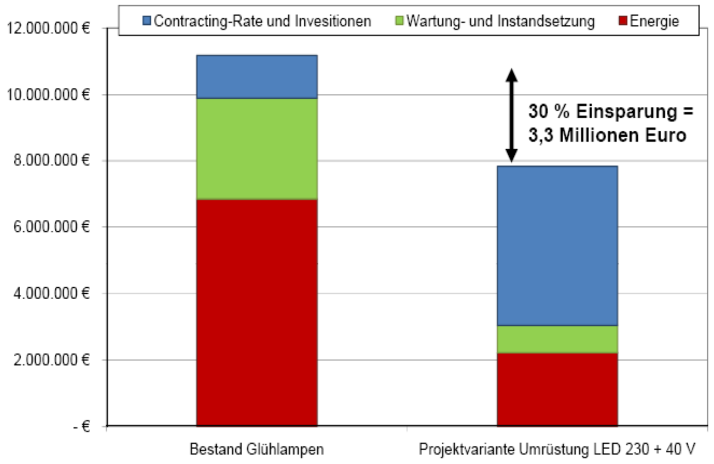
Box 4
Traffic lights in Graz, Austria

The City of Graz runs 227 traffic light systems. In total, some 7 700 traffic light signals for road traffic, public transport or pedestrians, are equipped with light bulbs. The energy costs for the operation to the traffic light systems increased to more than 300 000 € per year in 2009. The city of Graz decided to change overall traffic lights into LED lights. The project was carried out from July 2009 to February 2010, using the Thermoprofit-Contracting-Model of the Graz Energy Agency. The refinancing of the investment (2.3 Million €) is organised with a nine year fixed contracting rate.

The economics of the project are:

- Total savings of 339 000 €/year (75%)
- Energy cost reduction of 185 000 € (68%)
- Reduction of maintenance costs 92 000 € (80%) - LED lights have lower failure rate
- Annual replacement of 62 000 € not applicable, because life-cycle of LED lights is 10 years
- Reduction of electricity 1 200 MWh/year
- CO_2 reduction of 460 t per year
- Road safety increased by bright shining signals (better visibility) and lower failure rate.

The graph below shows the contracting model and total savings.



Source: [13]

Note: LEFT slope = Original light bulbs, RIGHT slope – LED lamps

blue = contract rate and investment, green = service and maintenance, red = energy. The difference between the slopes illustrates the 30% savings, i.e., 3.3 million. €

The economics of the projects have not been reported in almost 70% of the projects. The managers of the street lighting project in Stockholm went as far as to point out that “even if the installation cost had been higher for the LED installation, it was the best solution, considering the attractiveness of the city.“

In the French city of Balma, a trial project on street lighting was implemented. According to the project reporter, the economics of the installation have not been advantageous.

However, the results would have been different with different pole systems and spacing, while the LEDs have been installed in the existing system.

Similar conclusions are provided by two studies carried out by the National Lighting Product Information Programme in 2010 [9], [14]. In the studies, life cycle costs of various street lights for collector roads and local roads (High Pressure Sodium, Induction and LED lamps) have been calculated. Essentially, the illumination levels had to strictly follow the national standard for Roadway Lighting. Costs per mile were determined for each lighting source.

The studies found that the LED street lights tested (for local roads) required 41% less to 15% more power per mile than the base case[20]. The life-cycle costs of the whole installation were dominated by the costs of the poles though. To put it simply, the pole spacing for LEDs needs to be more frequent in order to comply with the standards. Given that the average life-cycle costs per mile for the LEDs were 1.9 times higher than the base case (100 W HPS).

However, one of the conclusions of the study is that the standard may not be “meeting the needs of street light system owners” [14], as 75% of the street light system owners do not light their local roads to PE-8 recommendations (which were used in the study, as there is no other national standard).

Life-cycle costs have been calculated for a street lighting trial project in Espoo, Finland, installed in 2010. LEDs replace high-pressure sodium lamps, bringing yearly savings of 125 kWh per lamp. The current value of the life-cycle costs has been estimated at 73 €/road metre[21]. The conclusions, however, are that the best results (and the biggest savings in energy costs) would have been achieved by optimising the pole placing, but this would have, in turn, created additional costs [15].

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[20] Similar results have been found for collector roads too. [9]

[21] The costs include dismantling of old luminaires, installation, use, maintenance and end-of-life. The purchase price may have been higher than average due to the size of installation - only 4 pieces of luminaires.

7 Advantages and co-benefits

One of the most often mentioned benefits is the reduction of costs of operation and maintenance. About one-third of those respondents who described the benefits of the installation (ca 66 case studies) explicitly mentioned that the comparative advantage of LEDs, over other technologies, would be the reduced operation and maintenance costs, which is mainly due to longer life-time of the LEDs. The need to substitute the burnt-out or damaged lamps is much less frequent. In Solothurn, Switzerland, LED Christmas lighting has been installed. Before that, the city had to change one-third of Christmas lights every year, which no longer happens with the LEDs.

In Hamburg, Germany, in total, 500 lighting signal systems will be changed, LEDs replacing incandescent light bulbs (so far ca 380 light signal systems have been replaced). While the incandescent light bulbs needed to be changed every year, the LEDs are to be changed only once every eight to ten years. About 80% of the cost savings realised so far are maintenance cost savings (580 000 € per year from a total of 716 000 € per year).

In the City of Graz, Austria, the traffic lighting system has been renovated, with the replacement of 190 traffic lights with LEDs. From the total 339 000 € of cost savings, about 55% can be attributed to energy savings and the rest being reduced maintenance costs. Nevertheless, unlike these two examples, the maintenance costs are rarely explicitly quantified in monetary terms.

Apart from energy savings, the test case reports often highlight “soft” co-benefits, which add to the potential of energy savings. These co-benefits include, among others:

- road safety for traffic lights,
- no UV radiation,
- indoor and outdoor lighting quality, indoor ambience and atmosphere,
- the variability in design of LED applications, and
- environmental benefits.

These co-benefits (supplementary to energy savings) are rarely quantified, possibly hardly quantifiable, yet apparently perceived as very important by the customers. Often, these are highlighted as the major benefits, outdoing the “direct” benefit of energy savings, which moreover, as mentioned above, may not be sufficient to cover the higher investment costs of the projects.

In traffic lighting systems, an important co-benefit has been mentioned several times: road safety, which increases thanks to higher reliability of the LEDs in traffic lights. Similarly, the project of traffic lights replacement in the City of Norderstedt, Germany, reports that, in comparison to incandescent bulbs, the “sun phantom effect” is avoided [16]. A slightly different case, but related to safety issues, is the street lighting project in Freiburg im Breisgau, Germany, which stresses that the new installation increased the sense of security, among other benefits.

Box 5

Municipality of Diex, Austria

The project is one of the earliest LED test cases in the sample, the solar lighting system was installed and put into operation in 2007 – combining PV panels and LED lamps. The initial costs were 19 000 € and the annual savings reach 300 € per year.

Many field trips are arranged to Diex, thanks to its street lighting system. In the course of the headline goal:
“energy independent village with the aid of solar energy” Diex hopes that it can establish a positive development to a soft and sustainable tourism – clean air, landscape and energy.

Another important group of benefits, which has been mentioned in the case studies, could be summed up as “indoor and outdoor lighting qualities, improved ambience and atmosphere”. The street lighting project in Toulouse, France, highlights the benefits of stable chromatic effect, whereas more uniformity in lighting is appreciated in the street lighting project in Lugano, Switzerland. In some projects, the overall improvement of lighting quality is reported (such as in case of Prague's Marriott Hotel, the City of Tilburg in the Netherlands or the Municipality St. Georgen in Germany). Pleasant, neutral light is the benefit perceived of street lighting projects in Haví•ov and Pardubice in the Czech Republic. Significantly improved colour reproduction has been cited as one of the main advantages of the street lighting project in Freiburg im Breisgau, Germany, as well as Espoo, Finland. For the indoor projects, cafeterias and bars can benefit from the improved atmosphere provided by LEDs (Safenwil, Switzerland).

Other co-benefits, mentioned in several cases, are that the LED lamps do not produce UV radiation on objects and have a low direct heat output. This has been appreciated for instance in the Hunterian Museum in Glasgow (UK), reporting to be able to illuminate sensitive parts of their collection in an aesthetically much more pleasant manner, while certain ancient objects could be illuminated for the first time. Similarly, in Bern's Parliamentary Library, Switzerland, LEDs provide lighting of book-shelves and reading tables. For the books, the heat protection is very important.

The following benefits have been reported from a chain of supermarkets (Coop in Oberwil, Switzerland). Thanks to the LED down lights the products remain fresh for a longer time and overall the presentation of the food (and of other products) is perceived to be better. The LEDs also provide more attractive colour rendering to customers.

LEDs are also seen to open up a broad opportunity for design. In the above-mentioned Parliamentary Library in Bern, Switzerland, thanks to LEDs the lighting could be unobtrusively incorporated into the interior design.

Parliament Library, Bern, Switzerland [17]

In Stockholm, Sweden, several street lighting projects have been realised. Specifically, the project in Katarinavägen, shows “a different approach on how to light urban spaces” [18]. The colour temperature of the LEDs fits well with the surrounding stone-walls, as illustrated in the picture below.

Katarinavägen, Stockholm, Sweden [18]

Last, but not least, LED lights also bring environmental co-benefits. One public lighting project emphasised that new LED installation does not attract insects (Freiburg im Breisgau, Germany), whereas the other points out that the new installation is protective to the local bat population and other fauna in the surroundings (Wuppertal, Germany). A street lighting project in Hannover, Germany, highlights that the LED installation causes only a low level of light pollution in the upper-half space (<3%, "Dark Sky"). Significantly, contribution to climate change goals are mentioned as co-benefits, too (for instance in Göttingen, Germany, the street lighting project is a part of a CO_2 reduction plan). However, this indeed is the case for all efficient lighting, not specifically for LEDs.

8 Drawbacks and challenges

In 23 (out of 106) project reports, some drawbacks are mentioned related to LED installations.

In some cases, what has been reported as a benefit at one installation has been reported as a perceived drawback in another one.

- Uniformity of light: For instance, in the City of Séquestre, France, a trial project was launched in 2007, testing LED street lighting at a roundabout. The report concludes that while drivers and pedestrians generally welcomed the colour of the light and little glare, the uniformity of light was not perceived very well; in contrast to other projects of street lighting, which highlight the uniformity of lighting as one of the strong points - Paderborn and Kieselbronn, Germany or Lugano, Switzerland. Similarly, the report on installation of LEDs at ski slopes in Kittilä, Finland, highlighted the functioning at low temperatures, unlike in the Swedish project in Kalix, where roadway tests were carried out and reported degradation of the light sources at low temperatures [18].

- LED technology is not yet delivering high luminance: In Stockholm (Akalla-provsträcka, Konradsbergsparken and Katarinavägen) various problems related to lighting (luminance) quality have been spotted by the company that installed the lighting systems [18]. For instance in the Akalla-provsträcka project (Stockholm, Sweden), only four of ten tested LED-fixtures gave the requested amount of light and only one passed all criteria. In another project, from the City of Stockholm, Konradsbergsparken, the LED fixtures give too little light and light is perceived as gloomy and cold, making the space “uninviting” [18]. The same problem was perceived also in the Norrbackagatan project, Stockholm, where moreover too much unwanted backlight seems to be pointing towards the apartments. On the other hand, no light to surroundings is perceived as one of the drawbacks in Konradsbergsparken.

  In Toulouse, France, low levels of lighting attained with LEDs were the reason why the city has installed LEDs only in pedestrian zones so far (mentioning though that for pedestrians, the reduced luminance is actually more convenient).

- Poor quality LEDs: Another challenge (and one of the major ones) is the quality of the LEDs, which as M. Lipa from CEVO puts it, sometimes does not meet the technical criteria that the customers require [3]. In the Katarinavägen project,Stockholm, after two years the whole installation had to be changed, due to manufacturing error in the LED-boards. During this process, the whole installation was dark for a period of six months. This is totally unacceptable for this type of installation, as public lighting needs to be reliable and easy to maintain, with spare-parts readily available.

- Missing data from the manufacturers: In the Swedish Akalla-provsträcka project (for more information, see Box 6), the installers complained about “big gaps in information received from manufacturers" and "missing or incorrect data for fixtures" [18]. These concerns are heard also from other sources [20], and similar notions come for instance from Lithuania, where according to the National Contact Point of the GreenLight Programme, the lack of LED projects, so far, can be, among others, attributed to the low quality of LEDs coming from some manufacturers and the high costs of LEDs. Therefore, only a few trial projects have been implemented so far in Lithuania [2][22].

- New suppliers have reduced knowledge of LED products: The evaluators of the LED project in Tilburg, the Netherlands, specifically highlight that "new suppliers with no public lighting experience are a risk and so is too much pressure from politicians to implement LEDs. A LED pilot has to be evaluated seriously in order to build up knowledge" [19].
- High initial investment cost: In a number of projects, the high initial investment costs are perceived as a limiting factor (specifically reported for instance by Coop, Italy, Ribe Kunstmuseum, Denmark and Galerie Forsblom, Finland). However, the high initial costs are often offset by lower energy and maintenance costs, as reported in the section on economics.

Box 6
Akalla-provsträcka, Stockholm, Sweden

In summer 2009, a test installation with 10 types of LED-fixtures was installed on existing 4m poles, 20m spacing. In total, 3 times 16 fixtures were installed on about a 1 km demonstration installation.

Compared to High Pressure Sodium lamps, the LEDs consume 38% less energy. The economics were not assessed in this case.

Compared to another competing technology, the ceramic metal halide, LEDs emitted less light in surroundings and were perceived as glary and uncomfortable. More importantly, only 4 of the 10 tested LED-fixtures gave the requested amount of light and only 1 passed all the criteria. Big gaps in information received from manufacturers were identified, with missing or incorrect data for fixtures.

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[22] Quality of the LED lights, in general, is a chapter on its own. Poor quality of some LEDs is perceived as a major concern. Low quality LEDs on the market give bad publicity to the whole LED lighting and may discourage some system designers and the final users from using LEDs in future. One bad experience tends to discourage users for many years – a similar situation happened with CFLs some years ago [21].

9 Conclusion

LED lights are a fast developing technology, with a high potential for development in future years. The growing number of projects all over Europe proves this trend. LED installations are highly variable and diverse and so are their effects.

From the 106 LED case studies reviewed in this report, there are several conclusive points that can be made.

- LEDs can replace a great variety of lighting technologies, from high pressure sodium and mercury vapour lamps in public lighting, through incandescent lamps in traffic lights or indoor applications to fluorescent tubes or halogen (spot) lights indoors. Sometimes, LEDs can replace CFLs too.
- Given the variability of installations, the resulting energy savings range from 10% to as much as 90%. In some cases though, the energy consumption is higher than with the original technology.
- In many applications, LEDs are competitive (offering payback time from 2 to 10 years).
- In a large number of projects (trials and test cases), the economics are not relevant, not measured or would not be advantageous. Yet, all applications show a clear potential for competitiveness in the (near) future.
- It seems that the results of the projects are highly dependent on the specific features and conditions of each installation. Given the great variability of LED installations, what may have worked in one application may not be the most suitable and optimal for another one.
- There are several common success factors for replication in the current state-of-art, such as replacement of incandescent light bulbs in traffic light systems or specific installations in retail stores and shops, replacing e.g., halogen spotlights.
- Main co-benefits of the LED projects analysed are:
    - Lower maintenance costs,
    - Improved atmosphere and lighting characteristics, no UV radiation and flexibility in design,
    - Improved security (road safety),
    - Contribution to climate change goals and environmental protection.
- Some drawbacks were also perceived by the respondents:
    - LED quality characteristics (uniformity of light, glare, etc),
    - Information and data provided by the manufacturers/suppliers,
    - LEDs may not be the optimal solution for the existing street lighting systems (e.g., given the pole spacing).

The number of LED installations is growing fast. Most of the projects reviewed in this study are reporting substantial benefits, be it on energy (and money) savings or having impact on the environment. Nevertheless, some challenges remain. Wajer et al [19] sum it up by calling for implementation of “coordinated neutral pilots before changing over to LED solutions for public lighting on a wide scale”.

Careful evaluation of the existing projects and exchange of information on the good practice examples, as well as on bottlenecks and risks, may be ways to enhance expansion of LEDs. In the meantime, the quality characteristics of LEDs, and proper data provided by the manufacturers, are among the main challenges.

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Annexes

Annex 1 - List of projects

No	Country	Name	Provided by	Sector	Energy and/or Cost Savings	Replaced/reference technology	Further information /Source
1	Austria	Gemeinde Diex	GreenLight Programme	Public lighting	300 EUR/year	n/a	www.eu-greenlight.org
2	Austria	Vienna	Ledworx	Road lighting	48 %	Fluorescent tube 2x 58 W	www.ledworx.com, http://www.advantageaustria.org/ca/events/Ledworx_LED_Streetlighting.pdf
3	Austria	Vienna	Ledworx	Car park light	70%	n/a	www.ledworx.com, http://www.advantageaustria.org/ca/events/Ledworx_LED_Streetlighting.pdf
4	Austria	Graz	Graz Energy Agency	Traffic lights	1200 MWh/year 74 % 330 000 EUR/year	Incandescent 75 W and 49 W	http://www.grazer-ea.at/cms/projekte/umruestung-von-lichtsignalanlagen-auf-led/content.html
5	Belgium	Delhaize supermarkets	GreenLight Programme	Retail	60 %	Halogen low voltage	www.eu-greenlight.org
6	Bulgaria	Sungurlare	Black Sea Regional Energy Centre	Public lighting	n/a (payback 3 years)	n/a	Email communication with author
7	Czech Republic	Aviation Safety Lights on Vodafone Transmitters	Buysmart	Aviation safety lights	n/a	Halogen and neon lights	www.buy-smart.info
8	Czech Republic	Haví•ov	Philips, Mr. Hynek Bartik	Street lighting	n/a	Sodium vapour lamps	www.philips.cz
9	Czech Republic	Kladno	GreenLight Programme	Street lighting	5000 EUR/year	n/a	www.eu-greenlight.org
10	Czech Republic	Marriott hotel Prague	GreenLight Programme	Hotel	90 %	Incandescent	www.eu-greenlight.org
11	Czech Republic	National Theatre	ENESA, a.s.	Emergency lighting - theatre	50% or 460 MWh/year whole lighting project	Incandescent light bulbs 15 W and 25 W	www.enesa,cz
12	Czech Republic	Pardubice	Philips, Mr. Hynek Bartik	Street lighting	n/a	Sodium vapour lamps	www.philips.cz

No	Country	Name	Provided by	Sector	Energy and/or Cost Savings	Replaced/reference technology	Further information /Source
13	Czech Republic	Prague	O Sv• tle Magazine	Street lighting	n/a	n/a	http://www.osvetle.cz/index.php/kestazeni/category/5-aplikace.html?download=5%3Aled-brozura-mhmp
14	Denmark	Nyborg harbour street light	GreenLight Programme	Street Lighting	Consumption increased by 0.97 MWh/year	Added on top of installation	www.eu-greenlight.org
15	Denmark	Q8 69 gas stations	GreenLight Programme	Gas station	1 724 MWh/year 69 %	Neon lights	www.eu-greenlight.org
16	Denmark	Grønfeldt clothes shop	EnergyPiano, Casper Kofod	Retail	3700 EUR/year	Halogen spot lights	www.energy-piano.dk, Casper Kofod
17	Denmark	Business park	EnergyPiano, Casper Kofod	Offices	2 652 kWh/year 250 EUR/year	GU10 30W Downlighters	www.energy-piano.dk, Casper Kofod
18	Denmark	Ribe Kunstmuseum Denmark	ERCO Lighting AB, Johan Elm	Art Museum	80 – 90 %	QT12 90W halogen lamps	www.erco.com, Johan Elm
19	Finland	Espoo	Aalto University, Ms. Leena Tähkämö	Street lighting	125 kWh/year per lamp	High pressure sodium	Email communication with author
20	Finland	Kittilä - Levi ski resort	Université Paul Sabatier - Toulouse III, prof. G. Zissis	Ski slope lighting	n/a (4.5 years payback)	n/a	ttp://www.osram-os.com/osram_os/EN/News_Center/Spotlights/Success_Stories/first-LED-street-lighting-in-finland.html
21	Finland	Galerie Forsblom Finland	ERCO Lighting AB, Johan Elm	Art Gallery	80 – 90 %	n/a	www.erco.com, Johan Elm
22	France	City of Balma	Université Paul Sabatier - Toulouse III, prof. G. Zissis	Street lighting	n/a	new	Email communication with author
23	France	City of Séquestre	Université Paul Sabatier - Toulouse III, prof. G. Zissis	Road lighting	n/a	n/a	Email communication with author
24	France	Le Havre – Viaduc de la Brèque	Université Paul Sabatier - Toulouse III, prof. G. Zissis	Road lighting	n/a	n/a	http://www.agglo-lehavre.fr/delia-CMS/projets/all-1/article_id-566/article_principal_id-/folder_id-/topic_id-118/le-viaduc-de-la-breque-en-lumiere.html

No	Country	Name	Provided by	Sector	Energy and/or Cost Savings	Replaced/reference technology	Further information /Source
25	France	Grenoble	Université Paul Sabatier - Toulouse III, prof. G. Zissis	Street lighting	n/a	n/a	http://www.enerzine.com/3/4220+Windela-alternative-a-l-eclairage-public-de-Grenoble+.html
26	France	ZAC Clichy Batignolles	Université Paul Sabatier - Toulouse III, prof. G. Zissis	Street lighting	50 % (including occupancy and motion controls)	n/a	de LOGIVIERE, X., L'éclairage public à LEDs Enjeu économique et environnemental, 2010/2011Mémoire, Université de Lille
27	France	Rouen	Université Paul Sabatier - Toulouse III, prof. G. Zissis	Street lighting	70.5 MWh/year 60%	n/a	http://www.citeos.com/files/citeos/fiches_ref/ep/ep_leds_mairieRouen2010.pdf
28	France	Toulouse	Mairie Toulouse, Joël Lavergne	Street lighting	30 – 40 %	n/a	Email communication with author
29	Germany	Bremen	Berliner Energy Agency, Ms. Sabine Piller	Street lighting	44 %	n/a	http://www.on-light.de/home/news/article/auch-kiel-in-der-cree-led-city-initiative.html
30	Germany	City of Erfurt	Berliner Energy Agency, Ms. Sabine Piller	Street lighting	n/a	n/a	http://www.optischetechnologien.de/forschung/leitmarktinitiative/wettbewerb-kommunen-in-neuem-licht/teaser/629/
31	Germany	City of Freiburg im Breisgau	Berliner Energy Agency, Ms. Sabine Piller	Street lighting	n/a	Sodium vapour lamps	http://www.optischetechnologien.de/forschung/leitmarktinitiative/wettbewerb-kommunen-in-neuem-licht/teaser/629/
32	Germany	City of Königsfeld	GreenLight Programme	Street lighting	55.2 MWh/year 56 % 19 000 EUR/year	n/a	www.eu-greenlight.org, http://www.optischetechnologien.de/forschung/leitmarktinitiative/wettbewerb-kommunen-in-neuem-licht/teaser/629/
33	Germany	City of Norden	Berliner Energy Agency, Ms. Sabine Piller	Street lighting	n/a	n/a	http://www.optischetechnologien.de/forschung/leitmarktinitiative/wettbewerb-kommunen-in-neuem-licht/teaser/629/

No	Country	Name	Provided by	Sector	Energy and/or Cost Savings	Replaced/reference technology	Further information /Source
34	Germany	City of Norderstedt	GreenLight Programme	Traffic lights	67 % 67 000 EUR/year	Incandescent	www.eu-greenlight.org, http://www.euco2.eu/resources/Norderstedt-Presentation.pdf
35	Germany	City of Paderborn	Berliner Energy Agency, Ms. Sabine Piller	Street lighting	n/a	Fluorescent tubes	http://www.optischetechnologien.de/forschung/leitmarktinitiative/wettbewerb-kommunen-in-neuem-licht/teaser/629/
36	Germany	City of Trier	Berliner Energy Agency, Ms. Sabine Piller	School centre	n/a	n/a	http://www.optischetechnologien.de/forschung/leitmarktinitiative/wettbewerb-kommunen-in-neuem-licht/teaser/629/
37	Germany	City of Wuppertal	Berliner Energy Agency, Ms. Sabine Piller	Bicycle path	n/a	n/a	http://www.optischetechnologien.de/forschung/leitmarktinitiative/wettbewerb-kommunen-in-neuem-licht/teaser/629/
38	Germany	Darmstadt	Technical University Darmstadt, Prof. Tran Quoc Khanh	Street lighting	35 % 1400 EUR/year	Mercury vapour lamps	Email communication with author
39	Germany	Darmastadt - Landgraf-Georg-Straße	Technical University Darmstadt, Prof. Tran Quoc Khanh	Street lighting	n/a	High pressure sodium	Email communication with author
40	Germany	Gemeinde St Georgen	GreenLight Programme	City hall	12.9 MWh/year 67 %	n/a	www.eu-greenlight.org
41	Germany	Gemeinde St Georgen	GreenLight Programme	Street lighting	24.9 MWh/year 70 %	Sodium and mercury-vapour lamps	www.eu-greenlight.org
42	Germany	Görlitz region	Berliner Energy Agency, Ms. Sabine Piller	Indoor and outdoor lighting	n/a	n/a	http://www.optischetechnologien.de/forschung/leitmarktinitiative/wettbewerb-kommunen-in-neuem-licht/teaser/629/

No	Country	Name	Provided by	Sector	Energy and/or Cost Savings	Replaced/reference technology	Further information /Source
43	Germany	Göttingen	Berliner Energy Agency, Ms. Sabine Piller	Street lighting	6.6 MWh/year 80 %	Mercury vapour lamps	http://www.lighting.philips.de/projects/goettingen_nonnenstieg.wpd
44	Germany	Hamburg Streetlights	GreenLight Programme	Traffic lights	4 468 MWh/year 88 % 940 000 EUR/year	Incandescent	www.eu-greenlight.org
45	Germany	Hannover	Berliner Energy Agency, Ms. Sabine Piller	Street lighting	35 %	High pressure sodium and metal halide	http://www.enercity.de/include/Downloads/PK/LED_2-Inbetriebnahme-Kurzversion.pdf
46	Germany	Kiel	Berliner Energy Agency, Ms. Sabine Piller	Street lighting	13 %	Fluorescent tubes	http://www.on-light.de/home/news/article/auch-kiel-in-der-cree-led-city-initiative.html
47	Germany	Kieselbronn	Berliner Energy Agency, Ms. Sabine Piller	Street lighting	66 %	Mercury vapour lamps	http://www.lighting.philips.de/projects/kieselbronn.wpd
48	Germany	Lenbachhaus in München	Berliner Energy Agency, Ms. Sabine Piller	Museum	n/a	n/a	http://www.optischetechnologien.de/forschung/leitmarktinitiative/wettbewerb-kommunen-in-neuem-licht/teaser/629/
49	Germany	Mönchweiler	GreenLight Programme	Street lighting	35 %	n/a	http://www.hess.eu/en/Specials/Umsetzung_der_LED-Projekte__BMBF-Wettbewerb_/
50	Germany	Public service Villingen-Schwenningen	GreenLight Programme	Street lighting	3.6 MWh/year 70 %	Mercury vapour lamps	www.eu-greenlight.org
51	Germany	Regensburg (Ratisbonne)	Université Paul Sabatier - Toulouse III, prof. G. Zissis	Street lighting	50 %	High pressure sodium	de LOGIVIERE, X., L'éclairage public à LEDs Enjeu économique et environnemental, 2010/2011Mémoire, Université de Lille

No	**Country**	**Name**	**Provided by**	**Sector**	**Energy and/or Cost Savings**	**Replaced/reference technology**	**Further information /Source**
52	Germany	Rietberg	Berliner Energy Agency, Ms. Sabine Piller	Public lighting	n/a	n/a	http://www.optischetechnologien.de/forschung/leitmarktinitiative/wettbewerb-kommunen-in-neuem-licht/teaser/629/
53	Germany	Stuttgart	Berliner Energy Agency, Ms. Sabine Piller	Street lighting	n/a	Mercury vapour lamps	http://www.stuttgart.de/img/mdb/item/358752/50566.pdf
54	Germany	Verkehrs Lenkung Berlin	GreenLight Programme	Traffic lights	500 MWh/year 10%	High voltage traffic lamps	www.eu-greenlight.org
55	Germany	Vossloh-Schwabe Optoelectronic GmbH & Co. KG	GreenLight Programme	Industry building	35 MWh/year 27 % 3 900 EUR/year	n/a	www.eu-greenlight.org
56	Hungary	Budapest	Ledworx	Road lighting	35 %	n/a	www.ledworx.com, http://www.advantageaustria.org/ca/events/Ledworx_LED_Streetlighting.pdf
57	Italy	Comune di Piombino	GreenLight Programme	Street lighting	20 – 30 %	n/a	www.eu-greenlight.org
58	Italy	Apecchio	Université Paul Sabatier - Toulouse III, prof. G. Zissis	Street lighting	65 %	n/a	de LOGIVIERE, X., L'éclairage public à LEDs Enjeu économique et environnemental, 2010/2011Mémoire, Université de Lille
59	Italy	Intesa Sanpaolo	GreenLight Programme	Bank	54 % 750 EUR/year	n/a	www.eu-greenlight.org
60	Italy	Coop - UnicoopFirenze - Pontedera - parking area	FIRE, Daniele Forni	Retail	42 MWh/year	n/a	Email communication with author
61	Italy	Coop - Coop Estense - Copparo - mall	FIRE, Daniele Forni	Retail	55 MWh/year	n/a	Email communication with author
62	Italy	Coop - Cooperativa Consumatori Nordest - Montecchio Emilia - sales area,	FIRE, Daniele Forni	Retail	26.6 MWh/year	n/a	Email communication with author
63	Italy	Coop - Unicoop Tirreno - Civita castellana - sales area	FIRE, Daniele Forni	Retail	22.2 MWh/year	n/a	Email communication with author

No	Country	Name	Provided by	Sector	Energy and/or Cost Savings	Replaced/reference technology	Further information /Source
64	Netherlands	City of Tilburg: “LED’s GO project”	GreenLight Programme	Street lighting	86.2 MWh/year 26.3 % 92 000 EUR/year	Fluorescent	www.eu-greenlight.org
65	Netherlands	City of Tilburg - Heikantlaan, City Ring, Lighting on demand	GreenLight Programme	Street lighting	303 MWh/year 44 %	Low pressure sodium	www.eu-greenlight.org
66	Netherlands	Amsterdam	Université Paul Sabatier - Toulouse III, prof. G. Zissis	Road lighting	180 MWh/year 40 %	n/a	de LOGIVIERE, X., L’éclairage public à LEDs Enjeu économique et environnemental, 2010/2011Mémoire, Université de Lille
67	Netherlands	Utrecht	GreenLight Programme	Street lighting	13.1 MWh/year 82 % 3 042 EUR/year	High pressure sodium	www.eu-greenlight.org
68	Netherlands	Amsterdam, Tilburg, Assen	Laborelec, Rob Van Heur	Public lighting	15 %	CFL	www.agentschapnl.nl
69	Netherlands	25 municipalities in Netherlands (35 pilots)	Laborelec, Rob Van Heur	Public lighting	n/a	n/a	www.agentschapnl.nl/programmas-regelingen/praktijkvoorbeelden-openbare-verlichting
70	Portugal	North Alentejo	ManageEnergy Case Study	Traffic lights	241.5 MWh/year 85 % 79 000 EUR/year	Incandescent	www.managenergy.net/lib/documents/131/original_cs_15_ARENATejo_Portugal.pdf
71	Portugal	Hotel Algarve	ADENE, Diogo Beirão	Hotel	70 %	Halogen	Email communication with author
72	Portugal	Shopping Area	ADENE, Diogo Beirão	Shopping area	n/a (payback 2 years	Halogen	Email communication with author
73	Slovenia	Liptovska street, Slovenske Konjice, Slovenia	GRAH Automotive, Jasna Krajnc	Public lighting	96.4 MWh/year 86 %	n/a	www.grahlighting.eu
74	Slovenia	Cvetkova street, Murska Sobota, Slovenia	GRAH Automotive, Jasna Krajnc	Public lighting	8.7 MWh/year 75 %	n/a	www.grahlighting.eu
75	Slovenia	Street Toneta Melive, Slovenske Konjice, Slovenia	GRAH Automotive, Jasna Krajnc	Public lighting	25.6 MWh/year 88 %	n/a	www.grahlighting.eu

No	Country	Name	Provided by	Sector	Energy and/or Cost Savings	Replaced/reference technology	Further information /Source
76	Slovenia	Ljubljana	Javna razsvetljava d.d., Marko Bizjak	Public lighting	10.2 MWh/year	HST (High Pressure Sodium)	www.jrl.si
77	Slovenia	Ljubljana	Javna razsvetljava d.d., Marko Bizjak	Public lighting	4.37 MWh/year	CFL	www.jrl.si
78	Slovenia	Ljubljana	Javna razsvetljava d.d., Marko Bizjak	Public lighting	4.24 MWh/year	HST (High Pressure Sodium)	www.jrl.si
79	Spain	Unibail-Rodamco, Albacenter (Albacete)	GreenLight Programme	Shopping mall	93 MWh/year 1 200 EUR/year	Fluorescent tubes	www.eu-greenlight.org
80	Spain	Unibail-Rodamco, Los Arscos (Sevilla)	GreenLight Programme	Shopping mall	587 MWh/year 3 700 EUR/year	Fluorescent tubes	www.eu-greenlight.org
81	Spain	Unibail-Rodamco, Barnasud (Gava - Barcelona)	GreenLight Programme	Shopping mall	643 MWh/year 3 300 EUR/year	Fluorescent tubes Halogen lights	www.eu-greenlight.org
82	Spain	Unibail-Rodamco, Bonaire (Valencia)	GreenLight Programme	Shopping mall	693 MWh/year 7 600 EUR/year	Fluorescent tubes Metal halide	www.eu-greenlight.org
83	Spain	Unibail-Rodamco, Equinoccio (Majadahonda - Madrid)	GreenLight Programme	Shopping mall	191 MWh/year 3 700 EUR/year	n/a	www.eu-greenlight.org
84	Spain	Unibail-Rodamco,Les Glories (Barcelona)	GreenLight Programme	Shopping mall	941 MWh/year 8 700 EUR/year	Fluorescent tubes	www.eu-greenlight.org
85	Spain	Unibail-Rodamco, Habaneras (Torrevieja - Alicante)	GreenLight Programme	Shopping mall	470 MWh/year 2 100 EUR/year	n/a	www.eu-greenlight.org
86	Spain	Unibail-Rodamco, Maquinista (Barcelona)	GreenLight Programme	Shopping mall	739 MWh/year 7 800 EUR/year	Fluorescent tubes	www.eu-greenlight.org
87	Spain	Unibail-Rodamco, Parquesur (Leganes - Madrid)	GreenLight Programme	Shopping mall	745 MWh/year 8 600 EUR/year	Fluorescent tubes Halogen lights	www.eu-greenlight.org
88	Spain	Unibail Rodamco, Vallsur (Valladolid)	GreenLight Programme	Shopping mall	227 MWh/year 1 500 EUR/year	Fluorescent tubes Halogen down lights	www.eu-greenlight.org

No	Country	Name	Provided by	Sector	Energy and/or Cost Savings	Replaced/reference technology	Further information /Source
89	Sweden	Stockholm, Akalla-provsträcka	Stockholm city, Traffic office, Henrik Gidlund	Pedestrian and bicycle road	63 %	Mercury Vapour Lamp	Email communication with author
90	Sweden	Stockholm, Konradsbergsparken	Stockholm city, Traffic office, Henrik Gidlund	Pedestrian and bicycle road	50 70 %	Mercury Vapour Lamp	Email communication with author
91	Sweden	Stockholm, Katarinavägen	Stockholm city, Traffic office, Henrik Gidlund	Pedestrian and bicycle road	3.72 MWh/year	n/a	Email communication with author
92	Sweden	Norrbackagatan		Residential street	60 %	Mercury Vapour Lamp	Email communication with author
93	Sweden	Railway Yard	Swedish Transport Administration, Petter Hafdell	Railway yard	100 W/piece	High pressure sodium	Email communication with author
94	Sweden	Roadway - tests in Kalix	Swedish Transport Administration, Petter Hafdel	Road lighting	n/a	n/a	Email communication with author
95	Sweden	Lighting of road tunnels with new technology	Swedish Transport Administration, Petter Hafdel	Tunnel	n/a	High pressure sodium	Email communication with author
96	Switzerland	Lugano	Topten.ch, Eva Geilinger	Street lighting	55 %	High pressure sodium	http://www.toplicht.ch/index.php?page=dokumentation
97	Switzerland	Winterthur Jewellery shop	Topten.ch, Eva Geilinger	Retail	90 %	Halogen spotlights	http://www.toplicht.ch/index.php?page=dokumentation
98	Switzerland	Luzern Musikpavilon	Topten.ch, Eva Geilinger	Cultural facility	90 %	Incandescent and HIT (Tubular metal halide)	http://www.toplicht.ch/index.php?page=dokumentation
99	Switzerland	Oberwil Coop	Topten.ch, Eva Geilinger	Retail	n/a	n/a	http://www.toplicht.ch/index.php?page=dokumentation
100	Switzerland	Bern Parliament Library	Topten.ch, Eva Geilinger	Library	n/a	n/a	http://www.toplicht.ch/index.php?page=dokumentation

No	Country	Name	Provided by	Sector	Energy and/or Cost Savings	Replaced/reference technology	Further information /Source
101	Switzerland	Safenwil	Topten.ch, Eva Geilinger	Cafeteria	n/a	n/a	http://www.toplicht.ch/index.php?page=dokumentation
102	Switzerland	Sempach	Topten.ch, Eva Geilinger	Bird observatory	35 %	n/a	http://www.toplicht.ch/index.php?page=dokumentation
103	Switzerland	Solothurn Xmas lighting	Topten.ch, Eva Geilinger	Outdoor decoration lighting	90 %	Incandescent	http://www.toplicht.ch/index.php?page=dokumentation
104	UK	Leeds	Université Paul Sabatier - Toulouse III, prof. G. Zissis	Street lighting	n/a	n/a	de LOGIVIERE, X., L'éclairage public à LEDs Enjeu économique et environnemental, 2010/2011Mémoire, Université de Lille
105	UK	Hunterian Museum Glasgow	Université Paul Sabatier - Toulouse III, prof. G. Zissis	Museum	n/a	Halogen spotlights	www.lsgc.com/dmdocuments/Hunterian%20Museum.pdf
106	UK	Social houses	Energy Saving Trust, Alex Stuart	Social houses	n/a	Fluorescent tubes	Email communication with author

Annex 2 - Case study template

		Please fill in columns here
	CASE STUDY	1
	Title and place	
1.	**Year of installation**	
2.	**Sector**	
3.	**Technology used**	
4.	**Description of the installation**	
5.	**Achieved/Planned savings (kWh, EUR, ..)**	
6.	**Economics of the installation (payback time, NPV and/or other economic criterion)**	
7.	**Life-cycle costs (compared to competing technologies), if available**	
8.	**Benefits/comparative advantages**	
9.	**Drawbacks/bottlenecks**	
10	**Notes**	

Annex 3 - List of abbreviations

CFL	Compact Fluorescent Lamp
EPC	Energy Performance Contract
HB	High-Brightness (LEDs)
HIT	Tubular metal halide
HPL	High Performance Lamp
HPS	High Pressure Sodium
HST	Single-ended tubular high pressure sodium lamp
LED	Light Emitting Diode
UK	United Kingdom

European Commission
EUR 25352 – Joint Research Centre – Institute for Energy and Transport

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Abstract

Light Emitting Diodes (LEDs) are a fast developing, promising technology, offering a wide range of potential uses. The report presents the status of existing LED pilot actions in Europe, analysing 106 LED test cases from 17 European countries. Projects from the public and commercial sectors form the focus of the report, with special attention devoted to the economics of LED projects.

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