



E-street Initiative

Work Package 5.1

Working tool for market players Guide for energy efficient intelligent outdoor lighting solutions

This guide is meant for personnel with responsibilities in outdoor street lighting, road keepers and advisers/ consultants.

On behalf of the E-Street project (www.e-streetlight.com)



And supported by:



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1. SHORT INTRODUCTION

Guide for energy efficient street lighting installations

This guide is meant for personnel with responsibilities in outdoor street lighting, road keepers and advisers/ consultants.

Description of a Telemangement system"

A telemangement lighting system that makes for compelling returns on investment and provides the benefits listed above can be largely achieved today with the integration of "off-the-shelf" products. The system consists of 3 main parts:

The Outdoor Luminaire Controller

First of all luminaires equipped with dimmable light sources are an important part of the system. The basic set-up is a lamp and dimmable ballast in combination with a controller for the ballast. We call this controller the Outdoor Luminaire Controller (OLC). The lamp system controller is the component that forms the link between the dynamic lighting system and the lamp. Because it is possible to have many different types of links between the lamp system controller and the ballast, standard interfaces have been selected as described before: 1-10V or DALI. This allows products from different manufacturers to be used and exchanged.

OLC specifications:

- (stepless variable) dimming
- switching (on-off)
- possibility to measure lamp operating data (nominal data as a basis for alarms)
- predictive behavior function based and status indication
- monitoring of ballast and lamp data of including:
 - lamp status (on/off/dim position)
 - burning hours
 - number of starts
 - electrical characteristics including system operating voltage
 - power consumption and electric current
 - fault and status indications
 - data, communication problems, lamp fault and ballast fault
- maintenance operation is necessary for the OLC for testing
- work autonomously as an active communication repeater in the system
- continuous communication monitoring with action (lamp to 100%) in the event of communication failure;
- implement programmed actions following an alarm for example reduce lamp voltage after a 'near end of life' alarm.

For practical reasons it would be desirable if OLC's are to be used for 'conventional' applications, i.e. as switching/dimming/communication units for existing lighting luminaires with conventional ballasts.

The Segment controller

The luminaires are connected to a power supply cabinet and communicate with the Segment Controller (SC). This basic infrastructure consists of an intelligent controller that handles various functions like scheduling/control/data logging and alarm handling per segment, as well as the WAN communications to the management system. The segment controller is the main component in the local lighting installation and should be based on open technologies so it is possible to easily modify or expand it in the future. The following specifications are based on systems currently available in the market which have the following in common:

- The segment controller must work as a network interface with repeater functionality, a web server, and have the option of accessing an ANSI 709.2 network from an IP network and/or the Internet independent of the underlying infrastructure
- The segment controller must be able to log alarms, act in response to alarms and prioritize them. If bad weather or accidents occur then a signal should be sent to set the lighting to 100% on.
- There should be an embedded calendar and scheduling functions for both absolute as well as astronomical clocks
- It should be able to operate as a web server, and have the ability to access and program functions based on SOAP/XML (Simple Object Access Protocol), and customized web pages
- Automatic collection and logging of data from connected OLC's
- Capability to automatically upload new software and data to the OLC following an update from the central system or a local update without the need to be online
- The management, processing and implementation of inputted scenarios and clock programs including the option of bypassing these functions
- Availability of digital inputs and outputs including relay control. Possible applications include;-
 - door open/closed contact;
 - pulse counter (kWh);
 - external alarm reporting outside cabinet;
 - linking of additional external triggers.
- Availability of IP (Internet Protocol) network interfacing using an ANSI 709.2 (Local Operating Network on the street side) interface to various communication carriers and protocols;
- Availability to incorporate a GPRS module and/or modem or any other ADSL modem

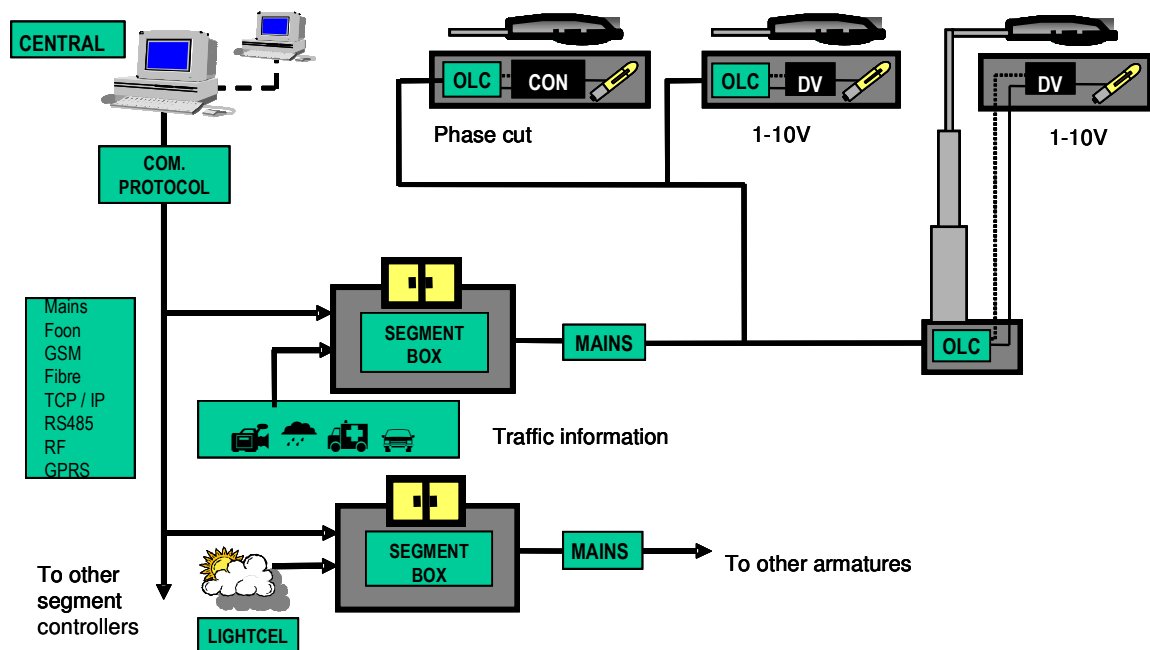
The Central Management System

The central management system (CMS) is used to control the segments and manage the data coming from the segment controllers. This third and very important part of the system is what we also call the IT interface. When there are two or three segment controllers in the network it is very easy to manage them, but very quickly it becomes impossible to do this manually when the numbers increase. Specifically if the

segment controllers reside in various different locations, with different service providers and WAN connection types it rapidly becomes difficult to manage.

The software solution in a telemanagement system should allow for the management of the system as well as for using the data in an existing IT environment. The functions this interface provides are the following:

- It manages the WAN communications and keeps track of where the segment controllers are and what the service provider is, how you can reach them and how healthy they are.
- It collects the data from your segment controllers and keeps track of when the data was collected, if all data was collected and if the right data was collected.
- It organizes and stores the data coming from the equipment. Terabytes of data are collected over a year and to find relevant data quickly then it needs to be organized and stored in a structured way.
- It synthesizes new data. The field data is usually not in the right format and not the information needed to take fact based decisions. Users are not interested in pulses but rather in the amount of kWh used. The number of burning hours is useful, but what really interest's a person is when to replace the bulbs. The recalculation part of the system needs that functionality.
- The data needs to be used in existing IT/GIS applications.



Overview of the system configuration

The system needs to function even if the central management system is failing or the WAN communication prevents it from sending control messages to the segment

controller. This is possible because the system consists of a network of decentralized intelligence in the segment controller and even in the OLC for automatic operation. Using this “distributed intelligence” means that no central controller is needed to allow the system to function efficiently and safe.

The OLC’s check the lighting, either by using information from ballasts or by using external signals. The working parts of the system can keep functioning autonomously if one of the system components or fails.

2. HUGE SAVINGS POTENTIAL

Huge saving potentials utilizing new technology

Outdated installations increase energy costs and new technology represents a large cost cutting potential in the rehabilitation of outdoor lighting installations. With new installations there is great saving potential when employing new enriching adaptive lighting techniques which are possible with today's high technology.

Old installations inflict unnecessary yearly costs. By correct investments and utilizing today's technology it is possible to reduce today's energy consumption for street and road lighting by as much as approximately 60 %. For Europe as a whole, this stands for about 36 TWh a year. In addition, you also achieve a significant saving on maintenance costs.

Recently there has been a tendency towards a shift in the responsibility for costs related to installation and operation of street lighting installations. In Norway this came as a law reform in 1991, the law stated that it is no longer allowed to make cross subsidies of street lighting within the electricity companies. This means that the road keeper have to cover all the costs related to installation and operation of the street light.

There are several factors that emphasize the importance of a holistic focus when considering investments in these kinds of installations.

Normally public authorities have two different budgets for running and maintaining the installations as well as investing and construction. This does not make it easy for overall consideration of the installations total economical aspects. This is also applicable to adaptive lighting where re-investments, in some cases, can have a "payback time" as short as 5 years or less.

When sending out a tender, there is today a public demand that all purchasing and contracts should be in accordance to existing laws of public purchase. It is also important that the tender gives a thorough description of what functional demands should be addressed in a lighting installation, **so that afterwards you can choose the best total solution in terms of both investment costs, running costs and maintenance costs (ref. LCC).**

As much as 50-70 % of the original energy consumption can be saved by reinvesting in new technologies where old in-efficient luminaires have been replaced, changed lighting arrangements and the introduction of stepless dimming in relation to adaptive lighting and as much as **70 % in energy reduction has been achieved.** By replacing the luminaires only, between 40-50 % energy reductions is achieved.

In addition, by implementing two way communication (luminaires with built-in intelligence), you achieve an accurate prediction of the lamps condition and thereby reduce the need for manual control, and may plan maintenance in a cost effective way.

To keep a better track of your installation and secondarily to optimize the priorities for the maintenance of the road, the road keeper should have an electronic record of his installations, based on a digitalized mapping system where each component is registered as individual traceable objects with a geographical reference.

3. ORGANIZING OUTDOOR LIGHTING

Management of road and street lighting

Road and street lighting place heavy demands on the public road budget. Recent studies in Norway indicates that the daily costs represent about 20-40 % of the total budget, half of this figure covers the energy costs and the other half goes to running and maintenance.

It's important that the road keeper has control and awareness of the costs. It's being observed that some road keepers try to reduce their costs by transferring the responsibility to private road keepers and community associations. A complicating factor with such a solution, is that many of these installations are constructed and integrated with the main supply grid. It can therefore be the case that one installation contains several customers. For instance in Norway, the Public Road Authority, ("Statens Vegvesen") is the road keeper in all of the municipalities.

Road lighting guidelines

By writing such guidelines for the diversion of responsibility gives better control for your costs.

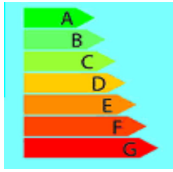
When introducing guidelines you should also consider making the establishment of road lighting an obligated part of the allowance for constructing roads in the municipality.

The guideline can describe the correct work method for securing quality and these should follow the municipalities' general regulations of road construction. This paper will then represent a minimum demand for (private) initiated installations to be connected to the public grid.

The guideline should consider the following subjects:

- * Description of public measures. Where the municipality has made a political or administrative decision for the initiator to include road lighting as an obligated and included cost for the road construction, the cost for new establishment will be transferred to the initiator.
- * The quality standards for luminaires and technical equipment must be described (see notes)
- *The municipality should define the desired level of lighting on the road in accordance with international and national regulations with recommendations and set limits for the use of energy related to defined luminaires.
- *Considerations of light pollution issues should be described
- *Describe which parameters should dictate when to switch on/off the luminaires and under which conditions the installation should operate at dimmed levels.
- *Where in the existing grid system it should be derive power. For installations with two way communication, describe the requirements for the communication equipment and define the protocols for communication to the administrative system.
- *Specifications of correct integration points for energy measurements. (How will the energy consumption of the installation be measured?).

With the rapid development of luminaries and lighting control gear it is of great importance to keep the guidelines "up to date".



Accomplishing public demands

To comply with the regulations concerning the removal of hazardous PCB from lighting installations, it is especially important to emphasize to the responsible authorities the energy saving potential that can be achieved by upgrading the technology of their installations.

New installations have to comply with today's regulations for lighting levels, electrical installation regulations and environmental demands. The proposed EU "ECO-directive" also sets demands for the "lifecycle analysis", lead and mercury free installations and a ban against ineffective electromechanically control gear. **Let your new lighting installation be a class A installation!**

By implementing these changes you prepare for future European recommendations and regulations concerning the environment and the energy reduction.

Financial considerations

The calculation of return on Investment is important to identify today's energy cost, including the cost of both electrical power consumption and of energy used. Furthermore a lifecycle calculation will have to consider the future changes in cost.. The calculations will use the "present value method" with discounted cash flow or by the use of continuous cash flow analysis. For the calculation of financial costs or of financial payback, the **public rate of calculation** should be utilized.

By utilizing new types of luminaires and control gear you can prolong lifetime values so that the annual maintenance costs is reduced.

In total one could say that by reinvesting in new technology and planning according to today's lighting level demands, the road keeper will achieve a payback on invested capital within a time period of 4-6 years depending on the initial situation,; energy price level, and the level of maintenance costs involved. (Whatever the situation this is a short payback time compared with other safety improvement measures.)

How to get started?

For existing installations it is of high importance to be aware and have control of the existing installation. For new installations and refurbished installations one has to make optimal lighting choices taking into consideration the roads complexity, traffic volume, way of construction and the volume of pedestrians and cyclists.

Remember: The evaluation of alternative solutions sets the groundwork for good results!

If there isn't an already working guideline for the installation to comply with, the installation has to be built according to the relevant national and international regulations. Check whether today's infrastructure (columns, electrical grid etc.) is still applicable? Is there a clear understanding between the road keeper, electrical supplier and any other parties (phone company, estate owner etc)?

In this concern there are several publications worth considering (see notes). Eventually the installation has to be evaluated and designed with regard to the technical specifications, both lighting values and electrical requirements by using computerized programs.

Being aware the current technical developments you also should consider how your new installation should be monitored, controlled/regulated, and maybe integrated with digital maps. It's of great importance to make an overall strategy plan on the organization of the everyday running and maintenance operations.

By calculating the costs for different solutions it's important to know today's cost for by instance each luminaires. If a higher financial investment is made today so that stepless dimming is implemented, then this will lower energy costs and provide a potentially longer interval between each luminaires replacement. Furthermore, one will be able to plan and use personnel resources more efficiently by utilizing handheld computer solutions such as so-called "fleet control".

One will also have to put some thought into how to exploit the modern technology to reduce the costs for everyday running and maintenance of the existing not upgraded installations.

There is therefore a need to use a calculation model (LCC) that calculates the alternative solutions affects on equipment-, installation-, energy-, running- and replacement costs, as well as the general maintaining costs. The respective elements have to be calculated with its corresponding lifetime expectancy and cycles.

4. UPGRADING INSTALLATIONS

Upgrading of outdated installations

Throughout Europe you find miles of outdated installations. Today this represents an enormous energy saving potential, and at the same time in many situations, do not solve the lighting task in a satisfactory way. New technology represents new possibilities.

Remember: Retrofitting of old installations can utilize up to 50-70 % energy reductions, in addition there are the reduced running costs!

Introducing new technology does not necessarily demand a reconstruction of the electrical supply. For instance existing technology can utilize the existing power distribution grid for communication, in addition to radio and digital mobile communication (GPRS/GMS).

When new luminaires are retrofitted it is found that lower power consumption is used to achieve the original lighting levels on the road. New luminaires contain both better optical systems and lighting sources that contribute to more light for less electrical energy, and also contribute to less light pollution (obtrusive light) by directing more of the light onto the road and not the surroundings. An installation designed using the old standards, also has a higher averagely lighting level compared to today's needs. These improvements in technology allow us to consume less electrical energy and at the same time to achieve adequate road lighting.

As the implementation consumes reduced energy then the existing electrical infrastructure is more than capable of supplying the retrofitted luminaires. Since the retrofitting does not involve the electrical grid, the implementation of a control system that demands a separate communication cable will result in a bad return of investment.

On the other hand there are alternatives for the feeding of communication. Both radio communication and the so called "PowerLine communication", are alternatives that do not require any physical connections in addition to what already exists.

The main principal is to install a component in the feeder cabinet that communicates, two-ways, with each and every one of the luminaires either by radio waves or by communications signals on the existing power grid.. The component located in the feeder cabinet can be programmed to control and log every luminaries on an individual basis (in some situations only the component in the feeder cabinet can contribute to a significant better control and feedback from the installation, without the upgrading of the luminaries). With this technology one have the opportunity for individual energy logging and updated information on running/maintenance that will contribute to an easier planning of the daily maintenance. A considerable reduction of the municipalities costs for running and maintaining the road lighting installations will be the result of such an investment.

5. ADAPTIVE LIGHTING

Adaptive road lighting

Road lighting is present to increase the safety of traffic and to enhance the sense of security for individuals. Previous regulations and guidelines were designed to use the technology that was available at the time.

The basis for all road lighting engineering has been to maintain safety by being able to observe objects on and beside the road. Important factors are the roads geometrical design, complexity, traffic volume and speed.

One also has to consider wet surfaces, the presence of pedestrian crossings, parked vehicles, schools etc. All installations were designed in the past based on the worst case scenario which is still valid.

The photoelectric detector was considered as a revolutionary development at the time, and is present in most road lighting installations today. As new technology can adapt the light levels steplessly, new possibilities arise. Modern technology for supervision of the traffic will optimize the lighting, it will also still need to cater for the worst case scenario but should also be able to automatically adapt fully to the current needs. For example if the traffic flow low during the night or if the traffic speed is low during rush hours, or in snowy conditions the reflection from the road surface is so high that the need for lux levels is considerably lower than during wet or dry conditions and so on.

The obvious advantage of using adaptive lighting, with built in intelligence, is reduced energy consumption and reporting from the lamp of the current status. This gives better control of the installation and ensures that the equipment actually delivers what is required to the customer which leads to an improvement of the quality of the delivered product, “road lighting”. This can be used to deliver higher quality form the installer organisation. It also makes possible to achieve better fleet management.

Better control also gives increased predictability and secondarily it lowers maintenance and running costs, by being able to achieve better planning and better implementation of error corrections in the installations. Adaptive lighting introduces demands for better energy measurements in the installations allowing the automatic regulation of both electrical parameters, burning hours and light levels. This will call for a demand for measured installations where metering is not installed today. How this is to be included must be a part of the agenda when an installation is being carried out. If the same system implements the measurement function and the control function then the communication expenses will be reduced, it will minimise the number of components needed in the system so reducing costs and simplifying the operation and maintenance.

6. PURCHASE - AN IMPORTANT FUNCTION

Purchase- an important function

Good planning will ensure the foundation for a good lighting installation. Your decisions will have consequences for more than 20 years into the future, so this obligates a thorough planning phase. This can mean the need for independent and high quality competence in this phase.

For new installations and refurbished installations it is important to ensure that the tender has an accurate and precise technical description that at the same time doesn't favour any "brand specific" technology. At the same time it's important to end up with an installation that in the future can function well, without being dependent of any single supplier or contractor. A good example is to use standard lamp sockets (by instance E27 or E40) and ballasts that can ignite different types of lamps (by instance both metal halide and high pressure sodium lamps).

When the project initiator is provided with a good description of the technical functionality this goal is obtainable. When carrying out large investments and/or implementing a "framework agreement" it is also important to give the administrative system some thought. This system can embrace the control of the installation, gathering of information on energy consumption, log the burning hours of each lamp, link burnt out lamps to a superior mapping system and many other useful functions concerned with documentation and the daily running of a streetlight installation.

Often it's also the road keeper's job to deliver lighting for parks, pathways, floodlight tracking tracks and so on. It's important to consider individual demands for these lighting tasks also.

In Norway public purchasing is obligated to include a Life Cycle Calculation (LCC) when deciding a purchase. The tender therefore has to specify clearly how these calculations are to be carried out. This will include information on the total efficiency of the system, power loss in the ignition system, efficiency of the lamp, expected decrease of maintenance costs due to extended life times etc.

7. LIGHTING CALCULATIONS

Basic lighting aspects

Lighting calculations can initially seem quite simple to perform using today's computer based calculation programs. But it takes an experienced lighting planner to make correct assumptions and premises, and also to interpret the results. Normally several adjustments have to be made before you receive an optimal result.

It's important to perform genuine calculations for your installation.

During rehabilitation it's important to consider lamp heights and possible "extended mounting brackets". By switching from old mercury lamps to high pressure sodium lamps it is often possible to decrease one "step" of the installation and still provide for today's demands for lighting. In these situations lighting calculations should be carried out with an independent counsellor. With a new installation lighting calculations are to be documented so that all demands are being fulfilled.

When building new installations you are free to optimize your installation dependent on lamp height and relative placement of the columns.

Which demands are to be met when carrying out lighting calculations?

- Independent of the supplier
- Adjustments to the present road geometry and surface
- That it uses the same lamps in the in the planned installation as those used in the calculation.

When ownership is transferred/accepted, measurements should be carried out on the installation to verify that the actual lighting level relates to the deliverable lighting calculations!

8. TECHNICAL ASPECTS

a. Two way communication

There are several technologies available for communicating with street lighting installations. The three dominant technologies are:

- **Radio/telephone**
- **Fiber**
- **Powerline**

All these technologies are today utilizing digital signalling. Prior radio/telephone systems operated on an analogic basis, in some cases still in use in old systems.

Radio/telephone

Telephone /radio communication is undergoing rapid development and changes. Prior airborne GSM solutions now currently are provided with GPRS, 3G or EDGE. For fixed wire/twisted pair solutions ADSL is more commonly used than the previous ISDN. The different capacity, flexibility and tariffs will define your choice.

Fiber

Fiber-cable is developing in competition with existing telephone and video-cable installations. In many cities fiber is available at reasonable pricing for long distance transfer of data. Fiber is in use for street lighting installations between the switch cabinet and central database.

Powerline

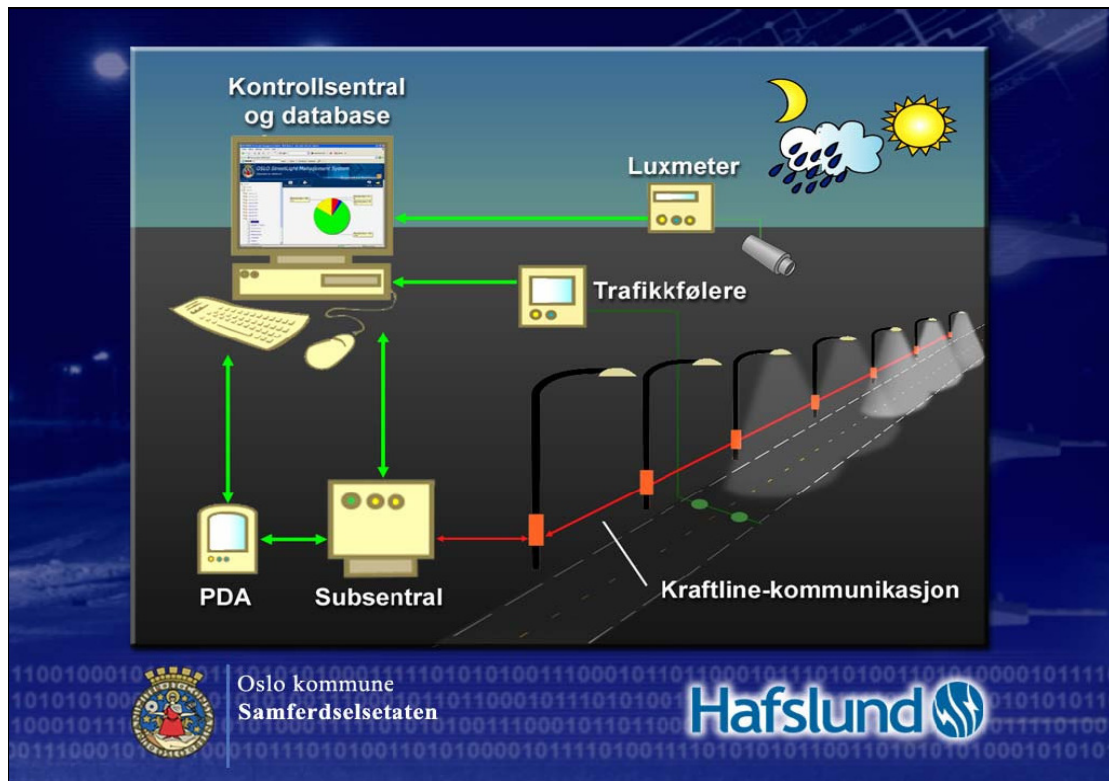
Powerline is a relatively new technology. It utilizes the existing power-cabel for high frequency signalling. Powerline is now available for the private home market in applications for i.e local broadband internet connections. In street lighting installations it is commonly used between switch cabinet and the luninieres.

1.4 Data collection from street light

Functional controlled street lighting

Hafslund Nett AS currently have some 6.500 functional controlled road lighting fixtures from two different suppliers. Both of the suppliers use LNS-database (a database solution from Echelon) for exchange and storage of data. In connection to the introduction of a common administration system, the existing street lighting databases will be used as a data source. In the next phase, the existing system will be omitted, and the administration system will be related directly to each fixture, but still via a concentrator (subcentral).

Today's structure is based on two-way communication of data through the installations power supply , so called "power line communication" The data to and from the different fixtures are transferred to a concentrator located in the fixture's electrical supply (switch cabinet). The concentrators then communicate, individually for the two systems, via telephone (GPRS with MDA Mobil Data Access) with the central database.

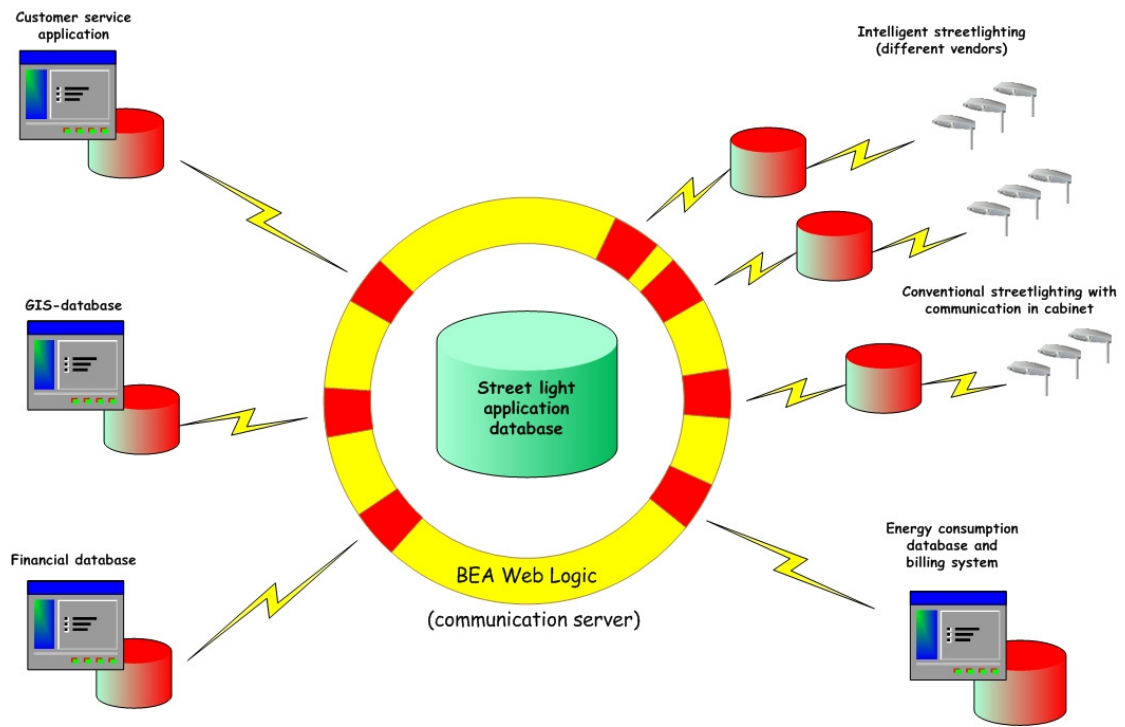


b. System integration

1.3 Principal description

Below is a principal system sketch with an adjoining system where communication channels/integrations are to be established. The communication channels are in the sketch and shown in red in a “common” intermediate layer solution.

The communication channels will be a part of the administration system in an implemented solution, but for this delivery it will be included as a part of both the administration system and the client service application. It means that the integration between the client service application and the Administration database, together with the integration between the client service application and GIS is to be delivered as a part of the delivery “Client service application”. The integration between the Administration database and the functional controlled street light, together with the integration between the Administration database and GIS is to be delivered as part of the delivery “Administration system”.



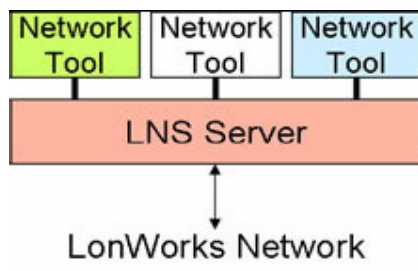
c. Exchange of data and protocols

Open protocols

Ongoing work

Data manipulation for the functional controlled light and energy metering

The concentrator (ILON 100), with integrated internet server, handles information from both the functional controlled lighting and the energy meters. All information is transferred and stored in the Echelon LNS database. For safe data transfer between the LNS database and iLon, RC4 encryption of Lon Talk identifications keys is used.



Philips – Unilon Starsense System

Philips uses a superior system with the fabric name “Starsense” Starsense is based on the building automation solution “Unilon” which is build on the LNS database.

Kongsberg Analogic – Candelon System

Multilux/Kongsberg Analogic uses a superior system with the fabricname ”Candelon System”.

The communication unit S2000 has the following specification:

<http://www.analogic.no/dokumenter/975-0021-04%20Candelon%20S2000%20Datashet.pdf>

Kongsberg Analogic – Candelon System

Multilux/Kongsberg Analogic benytter et overordnet system under fabrikknavn ”Candelon System”.

Kommunikasjonsenheten S2000 har følgende spesifikaşjon (basert på følgende kilde):

<http://www.analogic.no/dokumenter/975-0021-04%20Candelon%20S2000%20Datashet.pdf>

d. Functionality (also from D5.2)

Summary

2. Support schemes

For the financing of this kind of projects it is possible to gain financial support from both national and international organisations. Below the European program IEE is shown.

Intelligent Energy – Europe (IEE) as part of the Competitiveness and Innovation Program (CIP) (2007-2013)

The objective of the IEE II Program is to contribute to secure, sustainable and competitively priced energy for Europe, by providing for action:

- to foster energy efficiency and the rational use of energy resources;
- to promote new and renewable energy sources and to support energy diversification;
- to promote energy efficiency and the use of new and renewable energy sources in transport.

It will in particular contribute to the Commission's proposed integrated energy and climate change package including the renewable energy road map and the Energy Efficiency Action Plan. Intelligent Energy – Europe II (IEE II) builds on the experience gained from its predecessor, the first Intelligent Energy - Europe (IEE) Program running from 2003 to 2006. This Program has become the main Community instrument to tackle non-technological barriers to the spread of efficient use of energy and greater use of new and renewable energy sources. IEE II should also help with faster and smooth implementation of energy-specific legislation.

For tender specifications and call for proposals visit:

http://ec.europa.eu/energy/intelligent/index_en.html