State of the art industrial lighting

In 2015 DSM, Arlanxeo, Borealis, OCI Nitrogen, Fibrant and AnQore decided to have a total replacement of their industrial lighting system at the Chemelot location (one of the largest chemical sites in Europe) with the state of the art Tubular Professional Performance Lighting [TPPL] fixtures and the PSPL light-as-a-Service solution.

The main reasons behind their choice for this unique and innovative product were:

- *Reduction of Total Cost of Ownership (TCO)* due to significant energy saving (typically 80%) and practically maintenance free fixtures;
- *Increased safety* due to cold LED technology, intrinsic safe fixture design, hardly any maintenance activities (i.e. less safety risks), high quality and comfortable lighting for operators and technicians, guaranteed constant lumen output over lifetime and ability to connect additional light capacity to current alarm systems;
- *Sustainable solution* due to significant lower energy consumption (reduction of carbon footprint), less waste because of long life time of TPPL fixtures, elimination of light pollution during both day and night, and fully recyclable design;
- *More focus* on core business due to outsourcing of entire lighting system
- *Increased insight* in functionality, status and history of lighting system;
- *No investment required* due to 'light-as-a-service' lease option;

The total solution with TPPL fixtures is the proud result of an open innovation process by PSPL, Dietal, Luminext, Van den Pol, Sitech Services and other partners.

The PSPL solution [hardware & infrastructure]

The PSPL solution consists of three main elements:

A. **Field equipment** (TPPL fixtures):
- o The Atex IECex certified Bluetooth Smart connected TPPL LED fixtures;
- o Control accessories converting wired controls to wireless network groups and vice versa;

B. **Communications network** (Bluetooth Smart network):
- o Local wireless connectivity: The Bluetooth Smart network;
- o Long range wireless connectivity: 3G/4G/LTE: mobile operators;
- o Long range cabled connectivity: ISP (local LAN + ISP);

C. **Central IoT system** (Cloud services):
- o Installer & user feedback services (Graphical user interface);
- o Cloud based control (control strategies, reporting and monitoring;
- o Commissioning tools for installers and service engineers;
- o Cloud services platform (connectivity to outside world).

## A. Field equipment (TPPL Fixtures)

The TPPL fixtures are developed with and produced by Dietal. Dietal is a private company, established in 1979 in Auvergne (Fr), with production facilities in France and Romania. It is one of Europe's largest OEM fixture manufacturers and preferred supplier of major European brands due to their in-house innovation capabilities and excellent cost management.
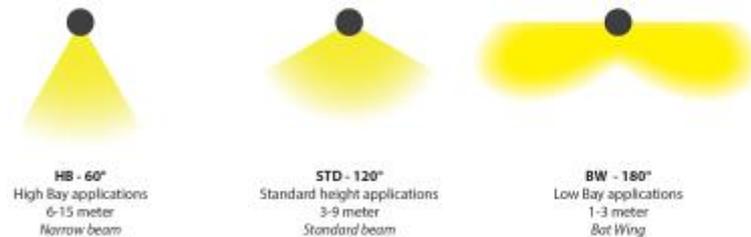
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TPPL MODELS

TPPL lighting covers a wide range of fixtures, for nearly all possible situations in industrial plants. The fixtures can differ in length, lumen output and optics, and are available in three basic models.
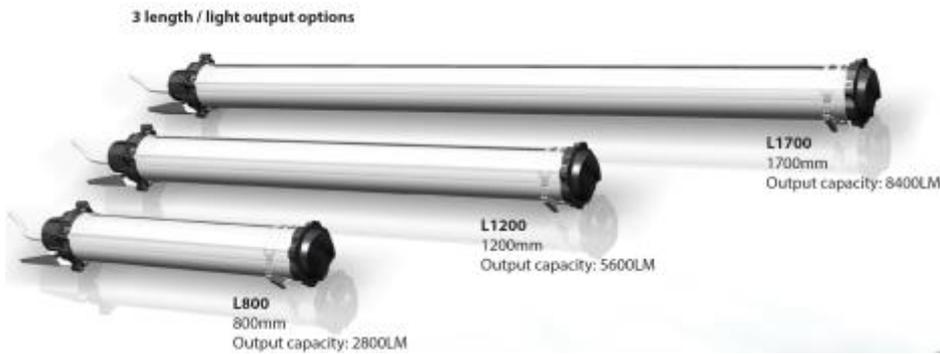
For each basic model there are three optical setups, depending on actual positioning and application:

Furthermore, there is a special Ex version for hazardous environments, next to the basic IQ standard for non-hazardous areas:

- **Ex version**: Atex IECex certified, sealed for life, Bluetooth Smart connected, Twilight dimming integrated;
- **IQ version**: IQ= Industrial Quality; same build quality and specifications as the Ex, only specific Atex IECex certification elements are omitted;

Note: all models are available in an -EC option for extremely cold (-40 .. -20 degrees Celsius) environments.

CLASSIFICATIONS

IP (EN 60529)

Regarding the protection against intrusion of foreign objects or matter, the TPPL fixtures are graded IP66 meaning that they are dust tight and can be hosed down with powerful water jets.

IK (EN 62262)

As for the protection against external mechanical impacts, the fixtures are rated IK8 which means the enclosure is capable of sustaining the impact of a free falling 1.7kg mass from a height of 300 mm.

Atex IECex (directive 1999/92/EG)

The fixtures are currently certified for both gas and dust environments with the following specifications (example of gas given):

  II 2 G Ex e ib mb IIC T5 Gb

II   Equipment group: above ground;
2   Atex category: Zone 1: area where an explosive atmosphere is likely to occur in normal operation (up to 10% risk time over installation and powered operating duration);
G   Explosion risk due to possible gas mixtures;
Ex   Explosion-proof electrical equipment;
e   protection concept for cable connection compartments: increased safety: no sparking sources or high surface temperatures;
ib   protection concept for wireless modules and light engines: intrinsic safe: limited potential ignition energy and surface temperature;
mb   protection concept for power supply driver: encapsulation by potting: prevents intrusion of flammable gasses;
IIC   Gas sub group: Hydrogen / Acetylene;

T5 Max surface temperature of equipment 100°C (applicable for flammable substances with ignition temperatures between 100°C and 120°C);

Gb Equipment protection level: suitable for gases in zone 1 *and 2*.

TPPL DESIGN & CONSTRUCTION

Sealed for life

The main body of the fixture is created in a multi feed extrusion process. This enables the use of different materials with specific properties whilst creating a single structure removing the risks of leakage or failure of the total enclosure. For the fixtures a combination of two specific components was used. The light emitting side of the fixture is extruded from a clear and diffusing structural polycarbonate layer. For the other half of the fixture a thermal conductive polycarbonate is used. Both sides are coated with a UV and humidity stabilizing polycarbonate shielding. The resulting body is an IP66 enclosure which enables users to power clean the fixtures with water.

Atex IECex intrinsically safe

Apart from the sealed for life construction around the main electronics, the selection, layout and sealing of the components is such that the fixture is still safe even if the system would overload or short circuit while the housing is fatally damaged from the outside. This means that there is a multilayer safety strategy and the system remains thus intrinsically safe even when the external housing is broken.

### Single ended connection and wiring feed-through

To ease installation and wiring of the fixtures, the electronics are designed to use a single ended power connection. It is also possible to daisy chain the fixtures using a feed-through connection. This means multiple fixtures can be wired to each other in series which minimizes the wiring for power supply. Due to the Bluetooth Smart network, there is no additional wiring needed apart from the normal power supply. The feed-through wiring generates internal heat within the internal compartment and consequently reduces the maximum ambient temperature with 3-5 degrees Celsius.

B. Communications network [Bluetooth smart network]

The TPPL fixtures are capable of communicating with each other by using a Bluetooth Smart mesh network, and each fixture is able to establish multiple routes to the central network (3G gateways/LAN). If any fixture loses its connection to the network, it will fall back into its fail-safe mode of twilight control, thus guaranteeing sufficient lighting at that location. The absence from the network will be detected since the fixture will fail to report its status. The fixture will continue to attempt to reconnect to the network. The failure will be noticed by the monitoring system (see C.)

By using Bluetooth gateways the wireless network is integrated into the central network. At least two gateways are present within each wireless network group. The integrity of the entire network (Fixture, Bluetooth and LAN/3G) is routinely checked by the system using a loop test to address each fixture. Fixture are required to respond to the central network via a different gateway than the one used to call it. The correct completion of this test ensures that the fixture is connected and that the Bluetooth Smart network is operating reliably.

From within the user interface rogue fixtures can be recognized thanks to smiley traffic lights. Fixtures which correctly communicate with the network will have a positive green smiley. Fixtures which can communicate with a single router (loop test negative) are indicated with a neutral orange smiley and finally the fixtures which fail to report to the network are indicated with a negative red smiley.
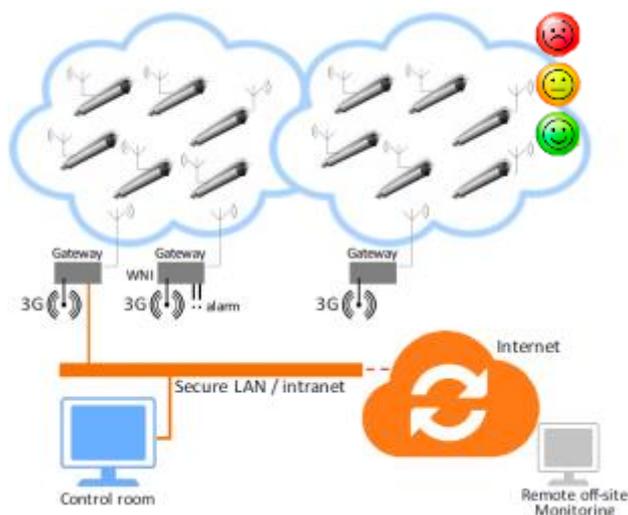
C. Central systems [cloud services]

User interfaces

For an effective user interface it is essential to define the various users which interact with the TPPL system. These users may range from installers and service providers to asset owners and end users.

During the initial face of the project (implementation of the fixtures), installers can benefit from the commissioning app which uses Bluetooth connectivity to enable them to easily configure fixtures and assign fixtures to groups at the spot. This can be done with any Windows, Android of IOS device whilst in proximity of the Bluetooth Smart network.

During the period that the fixtures are operational, the graphical user interface app gives insight in the history and performance of the fixtures, the communications network and the various control strategies. It also enables the user to change control settings, depending on authorization level of the user.

PSPL also uses the graphical user interface app for product and performance tracking. Periodic evaluation and analysis of the data may lead to further improvement plans for the installed lighting system.

Configuration and control

Depending on the type of user, there are multiple apps to one's disposal which enable him to interact with the fixtures and infrastructure. One of such apps is the *commissioning APP* for the installer. This app can directly log on to the Bluetooth network and configure fixtures while on the very location of the fixtures.

This makes it possible to test and calibrate light levels for fixtures while directly assessing the results.

Monitoring

The Graphical user interface app enables users to monitor the status of their lighting and view the history of their usage and performance. In general, the Graphical user interface facilitates the following monitoring:

- **Condition monitoring** (light, temperature, power supply, connectivity, lamp status);
- **Performance monitoring** (burning hours, lifetime, energy consumption, failures);
- **Asset monitoring** (remaining lifetime, actual financial value, lumen output performance (e.g. i.r.t. fouling)).

Maintenance

Information obtained via the monitoring of the systems enables development of a maintenance program customized to the actual use and performance of the fixtures. For example, bad performing fixtures (mostly by suspiciously high ambient temperatures or high external pollution levels) can be examined remotely in comparison to fixtures in the close proximity of the suspected fixture.

Pollution of the fixtures can be monitored and appropriate measures can be taken based on this information. Any failure or defect can be analysed from within the app as well as from a remotely available protected website for service engineers.

A replacement program can be based on 'full load equivalent burning hours' monitoring. This means dim settings, internal and ambient operating temperatures and burning hours are all taken into account to forecast the remaining lifetime of a fixture, enabling proactive planning when its replacement is due.

CONTROL STRATEGIES

There are three different levels of control for the TPPL fixtures. The most rudimentary type of control is applied from within the fixture itself. This ensures that whatever the status of the infrastructure is, the fixture will still abide to these control rules. The second type of control is enforced from within the field network and the third and final type of control is applied from the central control or from the cloud.

First layer of control (within fixture)

Twilight control

Based on the level of ambient light measured by the fixture, the dimming is adjusted to ensure that any ambient light level below the desired (set) lux level will be complemented by the fixture. During daylight conditions, the fixture will be mostly off and during night time conditions it will be on, depending on available ambient light. The control is such that no sudden changes or switching effects can be seen by the human eye especially during twilight conditions between night and day.

Inverted lumen maintenance

This control strategy ensures that the fixture will provide a consistent light level throughout its lifetime. This patented principle for measuring the actual attributed light by the fixture, will correct the output if this was to deviate from its intended (set) level. This means that a fixture is set to a specific light level at commissioning and will always control itself to retain that light level. External and internal influences, such as fouling, ambient temperature, ambient light levels and ageing effects over lifetime will be compensated for. To be able to ensure this feature, an extra light output margin is applied to the selection of the output light level of each fixture. Over the course of its lifetime each fixture will need to use gradually but increasingly more of this margin in order to provide a constant light output. For new fixtures at least 25% overdrive gain is available.

Thermal auto protective dimming and -shut off

In order to prevent the failure of a fixture, it is enabled with a protective dimming feature. If the fixture's external ambient temperature exceeds 50°C it will automatically dim to max 33% of its full capacity output. If the external ambient temperature exceeds 60°C, the fixture will shut down until it is cooled down below 55°C, after which it is allowed to operate at the auto protective dimming level of max 33%.

Second layer of control (field network)

Manual override

Within the field network, control devices can be integrated which can manually override any given control status of the fixtures. This enables an operator to obtain better lighting (higher output levels) for a specific task for a limited period of time.

Alarm & Care centre contact input

Third party systems can be integrated into the PSPL solution in such a way that an alarm can trigger a certain reaction of the lighting system. These alarms can be prioritized and the interaction with the system can vary depending on the type of alarm.

Presence detection and people tracking

Third party systems can be integrated into the PSPL solution to enable presence detection or people tracking.

Third layer of control (cloud based)

Clock and calendar

Using a user friendly graphical interface, a user can select specific timeframes in which the light is to be set to a specific dim level. Apart from regular dimming schedules, the user can create exceptions to the calendar for specific weeks or days.

Demand driven control

This feature assures that lighting is only provided to the level and on locations where and when this is necessary. Whenever there is no demand for light or only for low level light, no energy is wasted and light pollution is therefore minimized.

Control panel

Operators are able to log into the PSPL control panel and perform all control activities for which they are authorized. The control panel provides status and performance information of the lighting system. The control panel also allows operators to manually switch the control mode per defined light group.

SMART LIGHTING FEATURES

The PSPL solution has many unique intelligent features which ensure optimal safety and performance, maximum lifetime and minimum energy usage.

Safety
* Emergency protection override All protections disabled by "local override";
* Automatic twilight control. Twilight control is automatically activated when connectivity between fixture and back-office is lost; in this mode the fixture can safely operate without the need to be wirelessly connected;
* When the 110 or 230V AC input of the LED driver is switched over to a DC emergency power supply, the fixture will run in emergency mode. The output light level at the emergency mode is reduced to 25% of its nominal light level.

Performance & reliability
* Firmware upgrade over the air / over the network for all field equipment including the TPPL internal power supply;
* Full DALI IEC 62386-102 and DALI IEC 62386-207 compliant control interface.
* RS485 local interface with high resistance to lighting current surges and fast transients;
* Integrated ambient temperature sensor with warranty monitoring (prolonged exceeding of maximum temperature faults the warranty);
* Thermal auto-protective dimming and auto-protective switch-off;
* System monitoring and reporting: functional electronics self-test;

Lifetime & constant lumen output
* Lifetime tracking by Full Load Equivalent Burning Hours;
* Inverted Lumen Maintenance constant light output over lifetime;
* Inverted Lumen Maintenance 10% remaining output at end-of-Life.

Energy usage
* Automatic twilight regulation by smooth dimming & smooth regulation;
* Integrated ambient light sensor with external tube pollution warning detection
* Energy monitoring: kWh consumption monitoring;
* Demand driven control: light is provided in the exact amount needed;
* At least 80% energy savings versus conventional long life fluorescent lighting;

Ease of installation

- QR code scanning to identify and commission fixtures;
- Direct visual feedback to installer through LED indication of status of fixture;
- Local user interface for fast commissioning and end-of-life indication;
- Automatic firmware update distribution over the Bluetooth network.

The PSPL Proposition

The building blocks of the PSPL proposition include the TPPL fixtures, installation work, all required services during contract period and suitable financing.

Fixtures

The base of the proposition is the fixture and all hardware necessary for the infrastructure of the control system. As mentioned earlier, the TPPL fixtures are manufactured by Dietal, one of Europe's largest manufacturers of lighting fixtures. Other type of fixtures can be incorporated in a project as well. Apart from the fixtures, the following hardware will be provided in the project:

- WNI units to integrate third party systems in the field (switches, sensors, alarms);
- 3G / LAN gateways to connect the Bluetooth mesh wireless network to the backbone of the IT infrastructure. This can be 3G or LAN.

Installation

PSPL also manages the installation of the hardware and implementation of the control software required to install, configure and effectively use the total lighting system. Actual installation can be done with a customer preferred contractor (e.g. house contractor) trained by PSPL or with a contractor provided by PSPL. Together with the customer a specific safety execution plan will be put in place.

Services

All services needed to provide control over and insight in the actual performance of the lighting system, are implemented by our IoT partner Luminext. The user control interface ('control panel') provided is web based and can therefore easily be accessed from any (control room) computer or iPad that is connected to the internet. Authorization levels for various users (e.g. operators, technicians, engineers etc) can be defined by the customer.

Periodically performance reports can be issued, which provide overview of key performance indicators (KPI's) like energy consumption, energy saving (compared to 'old' situation), burning hours, expected remaining life time of fixtures, (technical) failures, replacements etc.

Other services (in case of complete outsourcing) include:

- Helpdesk
- 24/7 monitoring
- Replacement services

Financing

PSPL can offer attractive financing for purchase, installation and maintenance of our lighting solutions. The financing options include financial and operational lease. Operational lease is basically a kind of renting, which offers several advantages:

- No investment required
- No impact on your balance sheet
- Possible fiscal benefits

Main prerequisites for operational lease are that the contractual lease period is max. 75% of the expected product life time and max. 90% financial components, i.e. min. 10% other items like maintenance, service costs etc

TOTAL COST OF OWNERSHIP

The Total Cost of Ownership (TCO) of lighting refers to all costs related to purchase, using and maintaining the lighting system. Energy costs mainly depend on local electricity costs (Europe typically between 5 and 15 €ct/kWh), the number of burning hours and possibilities of user demand control and the overall system efficacy (lumen/watt) of the light fixtures. Maintenance costs comprise all costs related to (ATEX) inspection and replacement, including lamp/fixture costs, man-hours for replacement, required scaffolding, management and administration etc. Important factors that influence this are lifetime (i.e. failure rate) of lights, which determines the frequency of replacement, the positioning (esp. height) of fixtures and of course local labor rates.

The typical energy savings for the PSPL solution is over 80% and direct maintenance savings are typically more than 95%.

Drafting a business case is helpful in assessing financial attractiveness of the PSPL solution for example either own investment or lease scenarios, compared to the existing situation. In the figure below an operational lease, full light-as-a-service scenario is presented, which shows direct OpEx savings (typically > 20%).
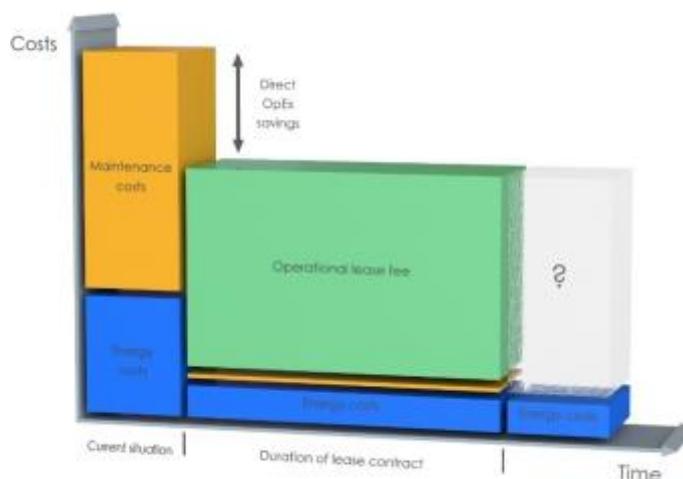
Note: Financial evaluations are not the only aspect to take into consideration for decision making; pls refer to the value drivers mentioned at the top of this whitepaper

Contact

If you wish any further information concerning the TPPL solution and proposition, please feel free to contact us:

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