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PILOT 1

SMART LED LIGHTING IN PORTS

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Authors: Matthäus Wuczkowski, Manager Sustainability and Innovation, Niedersachsen Ports GmbH & Co. KG – Port of Emden; Kai-Uwe Kaiser, Niedersachsen Ports

Approved by: Wim Stubbe, Project Leader for DUAL Ports

Table of Contents

About DUAL Ports

DUAL Ports is an Interreg North Sea Region project that was started in December 2015, with a duration of 3 years. In December 2018, DUAL Ports was extended until 2021 with an increase in partners, pilots and budget. DUAL Ports is based on the operational pilots in Regional Entrepreneurial Ports (REP's). DUAL Ports will be measured in the concrete success of the pilots and the pilots' renderability to other REP's.

DUAL Ports addresses the Interreg Program's objective of promoting resource efficiency and stimulate the adoption of new products, services and processes to reduce the environmental footprint of regions around the North Sea.

A Series of Pilot Reports

DUAL Ports consists of 16 pilot projects and 16 partners from the port industry, knowledge institutions and tech business within sustainable energy. In a series of publications, we are introducing each of the pilot projects highlighting the experiences, results and learnings from their work. Knowledge sharing is vital for the continuous development of sustainable energy and the publications of DUAL Ports pilot projects will be a source for further work.

For more information about Pilot 1: Smart LED Lighting in Ports, please contact the DUAL Port partner:

Matthäus Wuczkowski, Manager Sustainability and Innovation
Niedersachsen Ports GmbH & Co. KG Port of Emden
Telephone: +49 441 35020-613
E-mail: mwuczkowski@nports.de

Summary

Niedersachsen Ports GmbH & Co. KG is owner and operator of five seaports, seven island supply ports, plus three regional ports along the German North Sea shore. The company's goal is to reduce the CO_2 emissions within their ports. Aside from energy-efficient measures and the promotion of renewable energies, there is a focus within the ports on lighting. About one quarter of the energy consumption in modern ports can be attributed to lighting. Therefore, switching the lighting to more contemporary light sources can contribute tremendously to the lowering of the energy consumptions and to the reduction of CO_2 emissions. Within the scope of DUAL Ports, a pilot project for smart and resource-saving lighting at the Port of Emden was implemented.

In 2019, the lighting system was installed and tested as a smart and innovative LED system on a track facility, which serves as a automobile transshipment hub. At this location, the track field, consisting of six tracks, is used for shunting, staging, and the loading and unloading of car trains.
Motion sensors as well as light and rail sensors capture the situation at hand and control the lamps accordingly. In addition, the system features a remote control and can be operated remotely via an app. This ensures that light is provided wherever and whenever needed, and in whatever light strength is actually required. The various lighting scenarios permit each area to receive the optimal and necessary amount of light for any type of operation (shunting, loading, no operation, etc.). At this point, we are utilizing the potential of digitization, in order to save on resources, streamline processes within the port, and to unburden the environment.

With the help of demand-driven amounts of light from the modern LED lamps and through the largest possible degree of automation aided by sensors, we were able to reduce the energy consumption by 43%. Therefore, the new lighting installation is an integral part of a sustainable, future-oriented and innovative project, and it falls perfectly in line with the DUAL Ports project portfolio.

Project Description

The Project's Objective

This project was aiming at developing a new, innovative, and sustainable lighting concept for a track field in the Port of Emden. One of the goals focused on the creation of a modern transshipment logistics solution, in which work safety conditions would be improved through a streamlined lighting concept. To achieve this, the minimum requirements for lighting had to be fulfilled. In summary, this project aimed at testing how to reduce energy costs and CO_2 emissions with the help of smart solutions.

Problem Definition

For safety reasons, good lighting within the port areas is crucial. Traditional lighting systems, however, usually only have a short life span and are to blame for high energy consumption and thus high CO_2 emissions. Therefore, the outdated system had to be replaced with a completely new system.

The rail track field at Eichstraße (see Image 1) is some 800 m long and is located in the eastern port area of the Port of Emden. On an area of some 19,400 m2, the feeder track is split in harp formation into six parallel tracks, oriented from west to east.

Image 1: Location of the Track Field Facility at the Port of Emden

The three northern tracks (# 1 through 3) form the core of the track field. This is, where the loading area for the automobile transshipment is situated. Of those, the two outer tracks are connected to both of the loading ramps (railhead ramps). The middle track serves both as locomotive diverting track and as traveling lane. The three southern tracks (# 4 through 6) serve as shunting and staging tracks.

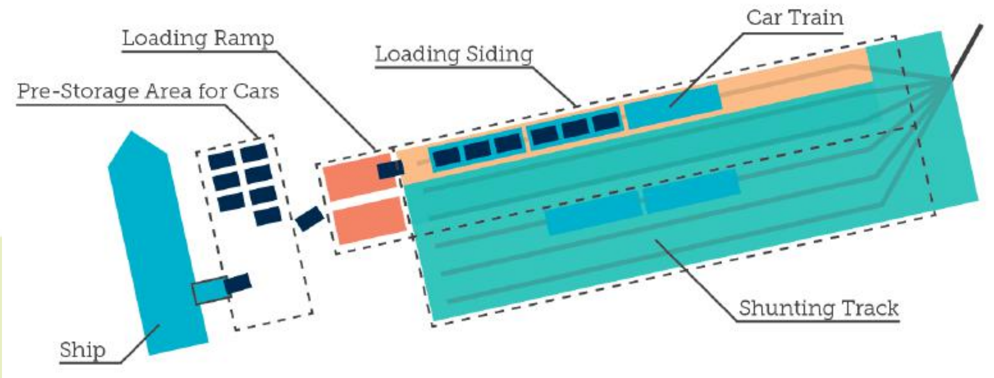


Image 2: Areas of the Track Field

Initial Situation Before Retrofitting

Prior to the swap-out, track field 21 was illuminated by 21 single masts along the road. Those were conical steel pipe masts with a dual lamp cap. They were equipped with traditional sodium steam lamps that were typically used for lighting in the port area or at train tracks. The distance between the masts was circa 40 m. With an output of 70 Watts, those lamps would reach a median lighting strength between 1 and 8 lux, which was even further reduced by the shadowing effect of parked trains. The lighting performance could not be dimmed or stepped up/down, and the lamps were automatically turned on or off via a photoelectric light switch. There was no additional sensor technology, such as timers or rail track pressure switches, installed.

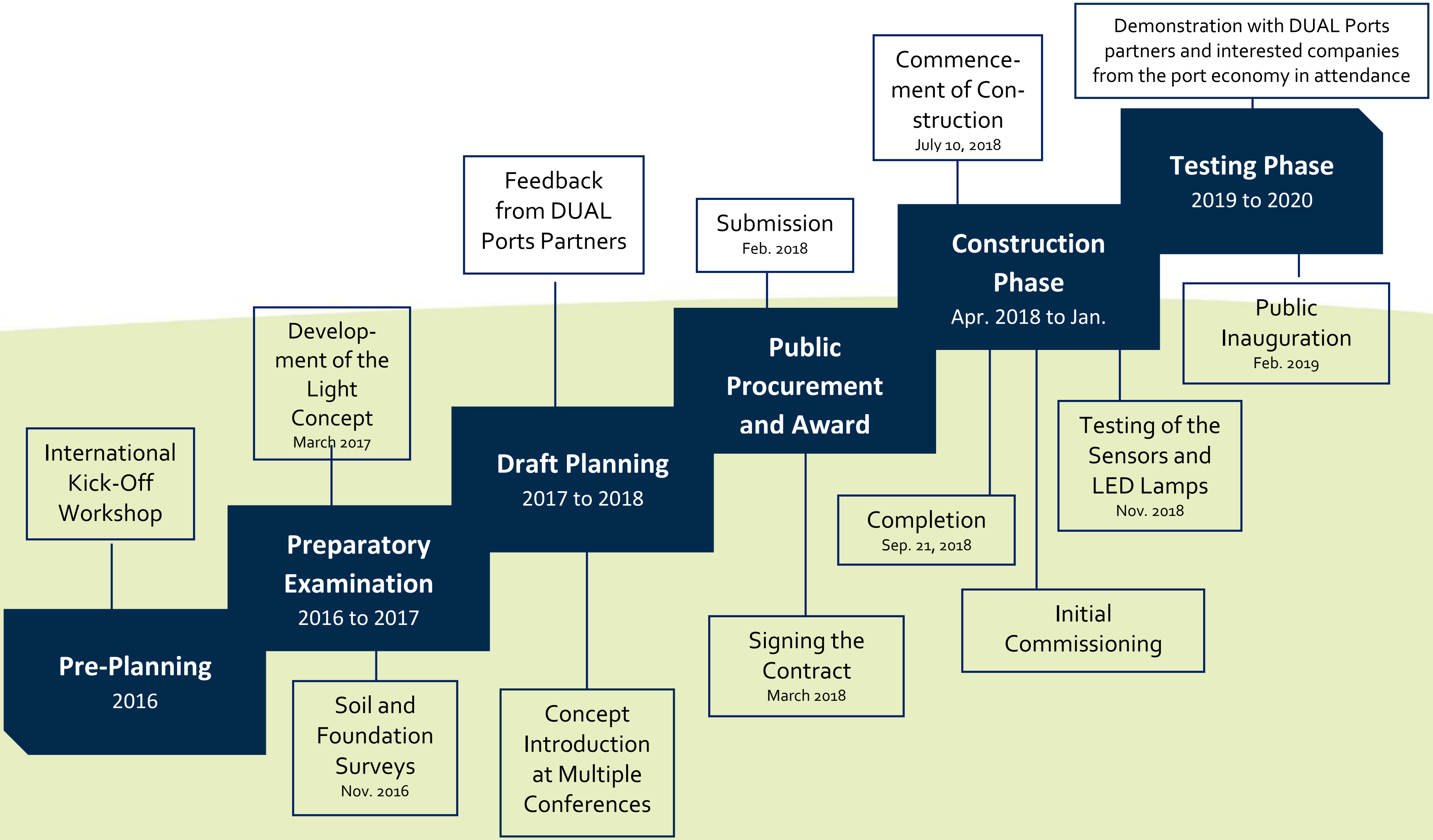
Eventually, this resulted in an insufficiently illuminated track field, which prompted the construction of a new, state-of-the-art system. This required observing the lighting requirements pursuant to DIN 126464-2 (Light and Lighting – Lighting of Work Places – Part 2: Outdoor Work Places). In addition, the technical structure view did no longer allow lamp masts between the rail tracks, since walkability between parked trains was now required. Even the installation of new single masts on the side of the tracks was dismissed, because it would create too many shaded areas. It was therefore essential to create a completely novel lighting concept that did not curtail the structure gauge.

Image 3: The Initial Situation on the Track Field

The Process – From Concept to Completion

The initial project planning was started in 2016. Preparatory construction and foundation soil analyses and the drafting of a lighting concept carried over into the next year. In 2017 and 2018, the project's concept was finalized. Even during the planning phase, the feedback from the DUAL Ports partners was appreciated and the project was introduced in various conferences. In early 2018, the public procurement process went underway. It was followed in March of 2018 by the signing of the contract documents.

In April of 2018, the preparatory construction work for the project commenced. Since the construction had to be performed during normal rail and transshipment operating hours, the operation and operating safety had priority and could not be restricted. Therefore, the construction period had to be aligned with the main utilization times of the transshipment operation and with the plant holidays of the Volkswagen plant (from 7/9/2018 until 8/3/2018). Due to this, the necessary complete closure of the rail track area was scheduled for that period. The official inauguration, with press in attendance, was held on February 20, 2019. You can see the entire process workflow on page 6.



Pre-Planning
2016
International Kick-Off Workshop
Preparatory Examination
2016 to 2017
Soil and Foundation Surveys
Nov. 2016
Develop-ment of the Light Concept
March 2017
Draft Planning
2017 to 2018
Feedback from DUAL Ports Partners
Concept Introduction at Multiple Conferences
Public Procurement and Award
Submission
Feb. 2018
Signing the Contract
March 2018
Construction Phase
Apr. 2018 to Jan.
Commence-ment of Con-struction
July 10, 2018
Completion
Sep. 21, 2018
Initial Commissioning
Testing of the Sensors and LED Lamps
Nov. 2018
Testing Phase
2019 to 2020
Demonstration with DUAL Ports partners and interested companies from the port economy in attendance
Public Inauguration
Feb. 2019

Results

Execution of Construction – New Light Installation

Summary:
14 Light Gantries With
65 Catenary Suspended Luminaires
11 Masts With
16 Mast Lamps
6 Electric Distribution Cabinets
1200 m Cable Trays

The new system is based on the latest LED technology, paired with a smart lighting and control concept. It consists of 14 light gantries with a total of 65 catenary suspended luminaires, and of 11 masts with a total of 16 mast lamps. In this concept, the LED lamps are equipped with smart light controls. The light gantries (see

Image 4) consist of two galvanized steel pipe masts with a height of some 15.5 meters and are connected with each other by a guy wire and a lower suspension cable. The light gantries are placed at a distance of max. 45 m from one another and have an average length of 25 m.
On the crossways-supporting light gantries, LED catenary suspended luminaires of the safety class SKII were deployed that feature wide angle optical lenses and a DALI module. The lamps were attached to guy wires from mast to mast to illuminate the space between the tracks. Here, the light's spot height measures 12 m. In addition, in the area of the railhead ramps and in the area between the end of the traveling lane and the entry rail switch, 16 single masts, topped with LED cap lights (conical shape steel pipe masts with a height of 8 m at the railhead ramp, everywhere else with a height of 12 m) were installed.

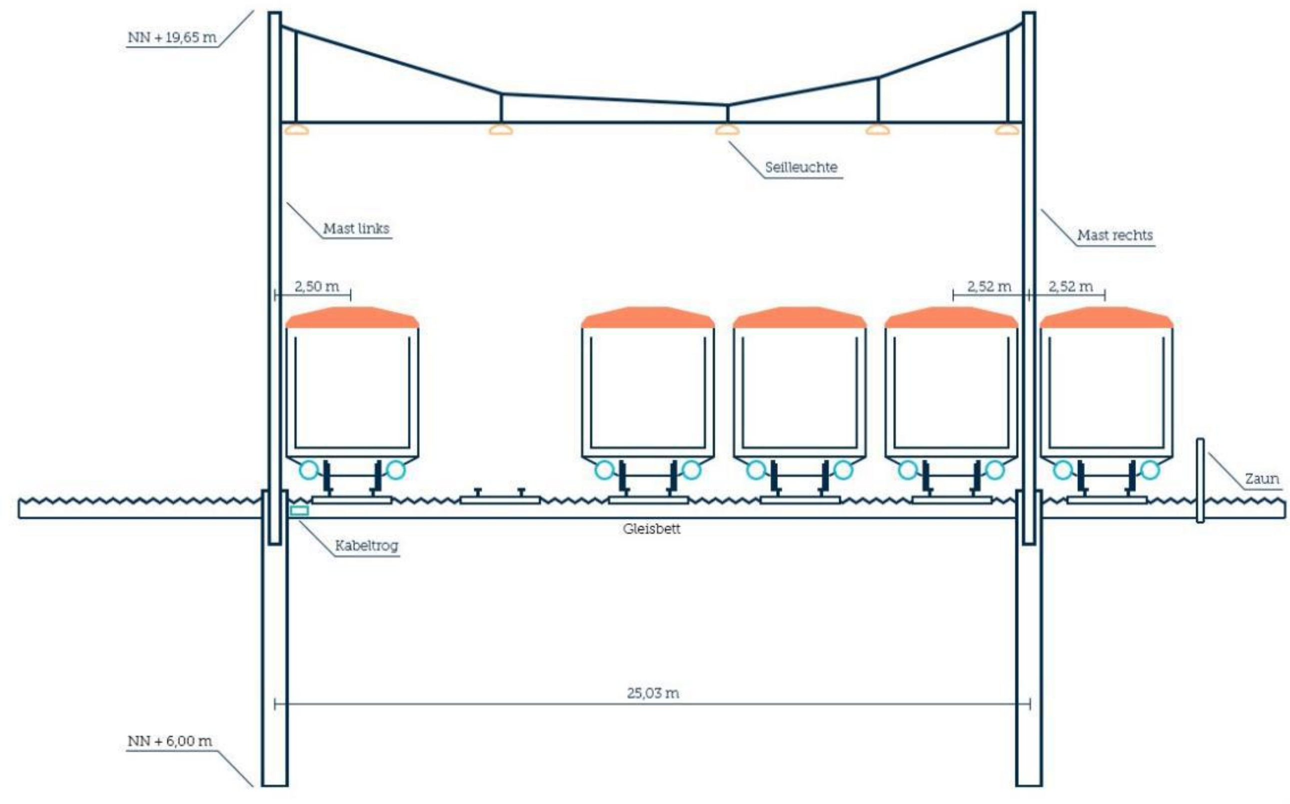


Image 4: Cross-Cut View of a Light Gantry

Image 5: The New LED Light System

Installed LED Lamps

In this project, state-of-the art LED Lamps were installed. They are the basis for a smart control, since LEDs are easily programmable.

LED Wire Lamps for Wire Gantries

LED Lamp Caps for Single Masts

What are the Advantages of State-of-the-Art LEDs?

A direct comparison of the LED (light-emitting-diode) lamps with the traditional sodium high pressure vapor lamps (SON) confirms the benefits of the LED technology (see Table 1)

Table 1: Comparison LED and SON

	LED	SON
Output	100-200 W	70 W
Nominal Light Stream	10,000 to 20,000 lm	6,600 lm
Efficiency	100 to 200 lm/W	95 lm/W
Color Temperature	2,700 K – 8,000 K	2,000 K
Life Span	100,000 h	20,000 h
Warm-Up Time	None	Yes
Controllable/Dimmable	Yes	Limited
Costs of Acquisition	Higher	Lower
Operating Costs	Lower	Higher

Not only does the LED technology consume less electricity, but it is also much more dimmable and controllable. The initial investment to purchase the technology is higher, but it becomes relatively low, when factoring in the long life span and low maintenance.

And even the real-life comparison test for the visual perception of colors and contours between those types of lamps shows that the LED technology offers extensive benefits (see Image 6). LEDs have a brighter rendering and improve the color and shape recognition of objects. Particularly these factors are important when it comes to improving the work safety in ports.

Image 6: Visual Perception in a Comparison

Within the scope of a bachelor thesis, this was also covered in a survey about subjective perception. All of the surveyed subjects perceived the LED light as more pleasant. Even the safety perception of the workers was improved by the new lighting.

In a simultaneously executed study with bremenports it was also proven that LEDs have additional environmental benefits. They contain no hazardous waste or pollutants, and they are more insect-friendly. The reason for this is that LEDs do not emit ultraviolet rays and therefore attract fewer insects. In comparison to cool-white LEDs, soft-white LEDs are even more beneficial in regard to this (link to the complete study in German https://www.nports.de/media/Unternehmen/Nachhaltigkeit/NPorts_LED_LEP_Bericht.pdf).

Deployment of Smart Solutions

The elementary building blocks for a smart lighting system are LEDs, since they can be easily controlled and programmed. The clear advantage is that not only individual lamps, but entire strings of lamps can be dynamically adjusted.
The second building block for a smart lighting system is the light management, based on various lighting scenarios. That building block makes it possible to program complex scenarios for different activities on the track field. This is the only way to ensure that merely such amount of light is emitted, as is needed for the individual situation. In Germany, the amount of commensurate lighting for outdoor work places is stipulated by a standard. The scenarios that were developed in the course of this project are based on this standard (DIN EN 12464-2) and envision different light strengths for different activities:

- Base Lighting During Darkness: 5 lux
- Lighting During Shunting: 15 lux
- Lighting During Loading: 30 lux (at the loading tracks)
  150 lux (at the loading ramp)

The third building block for a smart lighting system is the deployment of sensor technology. It ensures that the required light settings are triggered and adjusted as automated as possible (for instance through motion sensors, light sensors (photoelectric sensors), pressure sensors on the tracks).
The center piece of the lighting management is the control technology. Thanks to the DALI module, any of the 81 lamps can be addressed, dimmed, and programmed individually. This ensures the integration of the individual lighting scenarios and the sensors into one holistic lighting management system. The system can be monitored and controlled manually on site or from a remote location (through remote control) via a PC or by smart phone (through a web browser).

The individual building blocks ensure that the light is adjusted as demand-oriented as possible and that energy resources are spared. (See
Image 7). The lighting management is described in detail below.

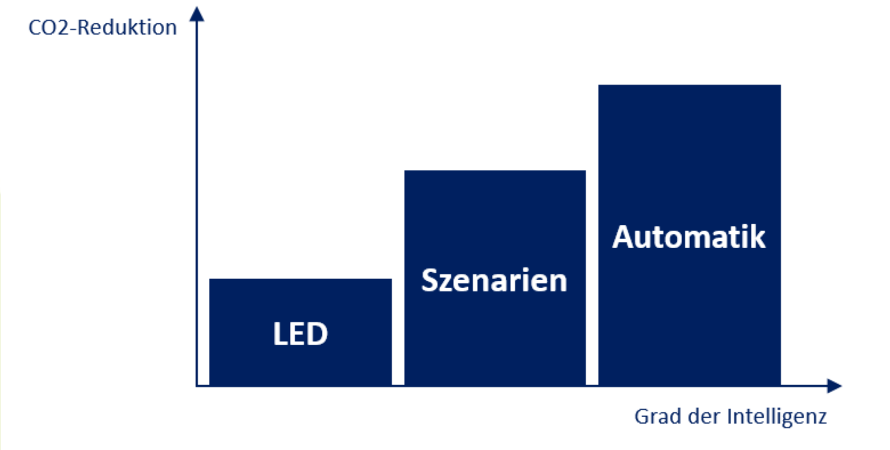


Image 7: Components of a Smart Lighting System

Programming of Lighting Scenarios – The Right Light for Any Occasion

There are various work activities on the track field, each requiring different lighting. Sometimes, trains are traveling, sometimes there is no train traffic. Sometimes, unloading takes place on a track, in other scenarios, there are shunting activities at the same time as the unloading occurs. The developed lighting concept takes any of those situations into consideration. Table 2 defines five scenarios and their respective sub-scenarios. We will introduce you to some choice scenarios in detail.

Table 2: Scenarios

Scenario 1 – Loading Only, No Shunting	
Scenario 1a	Loading on Track 1
Scenario 1b	Loading on Track 3
Scenario 1c	Loading on Tracks 1&3
Scenario 2 – Shunting Only, No Loading	
Scenario 3 – Loading & Shunting	
Scenario 3a	Loading on Track 1 Plus Shunting
Scenario 3b	Loading on Track 3 Plus Shunting
Scenario 3c	Loading on Tracks 1&3 plus Shunting
Scenario 4 – No Operation/Base Lighting	
Scenario 5 – Maintenance	

During operational idle time (scenario 4), the facility is illuminated with a light strength of 5 lux for safety reasons. For shunting operation, the mean illumination strength is increased to 15 lux (see Image 8 – Scenario 2). Upon demand, the lighting strength at the railhead ramp is also increased to 15 lux with the help of a motion sensor.

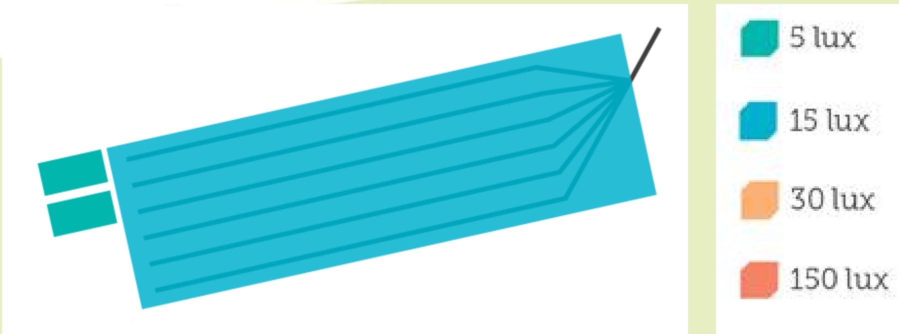


Image 8: Lighting Example – Scenario 2

In the scenario 'loading without shunting' (Scenario 1), the loading area is illuminated with a mean lighting strength of 30 lux. For the area of the railhead ramp, 150 lux are required, while for the remainder of the track field, an output of 5 lux is sufficient. Image 9, for instance, shows Scenario 1a, in which loading occurs only on track 1, and there are no shunting activities.

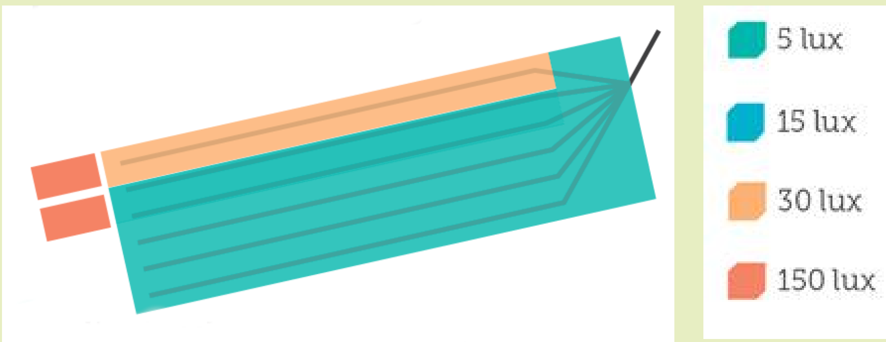


Image 9: Lighting Example – Scenario 1a

When there is a combined loading and shunting operation, see Image 10, a median lighting strength of 15 lux is switched on. Scenario 5 is also used, when maintenance work is performed.

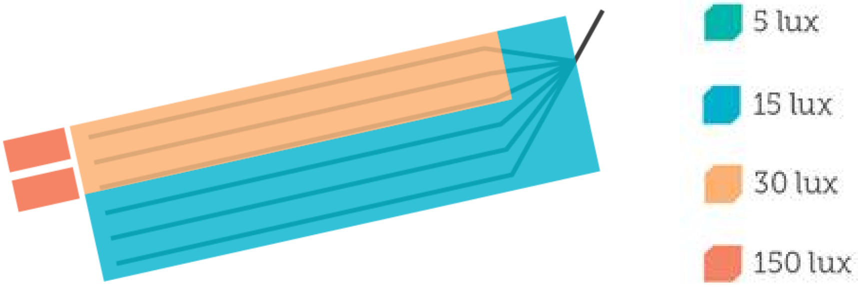


Image 10: Lighting Example – Scenario 3c

A dynamic light adjustment that follows the action on the track field has the potential to save energy costs and to counteract 'light pollution'.

Sensors Help With Automated Light Control

The control of the individual light scenarios is performed with the help of a control circuit with integrated DALI communication. The lighting strength on the track field is constantly measured by sensors and automatically switched on as needed. But it is also possible to manually switch on or off lights at the control panels or by smart phone or computer. Communication between the individual sensors and the lights is performed through DALI.

DALI – Digital Addressable Lighting Interface – is a standardized, digital interface that is used for the transmission of control signals for light technology devices. Through all connected DALI components, it is able to control the light or light scenarios by assigning and equally defining each lamp individually. For the successful implementation of these light scenarios, it is necessary to wire electronic ballasts and connect them via the programmable logic controller (PLC) with each other. It is possible to address up to 64 operating devices individually and to assign them freely into 16 light groups and 16 light scenarios. Aside from switching the lighting devices, single parameters (such as the dimming level) can be queried.

The utilization of sensors ensures that the necessary light adjustments are dialed in as automated as possible. Therefore, the following sensors were installed:

- A rail track contact at the entry rail switch. This contact is crucial for activating the scenario 'Shunting Operation' (track contact sensor)
- A motion sensor at the railhead ramp for increasing the light levels from base lighting (motion detector)
- Nine light sensors for light dimming (light sensor)
- A photoelectric switch with a light sensor;
- A digital timer switch (astro time switch).

In addition, there is a fallback level in place in case of an outage/maintenance of the automated system.
Two of the installed sensors can be seen in Image 11.

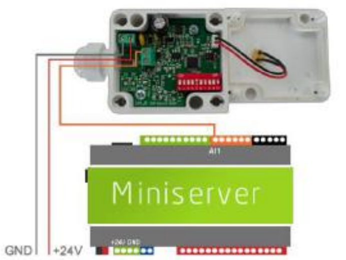
	**Rail Contact** The rail track contact registers the passing of a locomotive onto the track field and automatically switches on Scenario 2 (shunting operation).
	**Light Sensor** The light sensor measures the brightness on the track field in lux. If a previously defined value is exceeded or not met (e.g. 15 lux), the system will adjust the lamps up or down accordingly. This way, a potential over- or under-illumination can be avoided.

Image 11: Sensors for Light Control

One of the challenges for the measurement of lighting strength is the placement of the sensors. If you place the sensors at ground level and you measure the lighting strength as a value of the light directly shining onto the measuring surface, you may encounter very strong external influencing factors that can falsify the result: Switching off, caused, for instance, by rail cars or vehicles, or by dirt on the measuring surface. In order to minimize these detrimental influences, we have placed the measuring surfaces of the sensors downwards so that they only register the reflected light from the area's surface. By measuring the actual amount of light, and guided by the measurement value from the (indirectly) measuring sensor, a correction value is empirically calculated. The programmable logic controller factors in this correction value with the measuring signal so that the actual lighting value at the area's surface is displayed. The location of the various sensors can be seen in image Image 12.

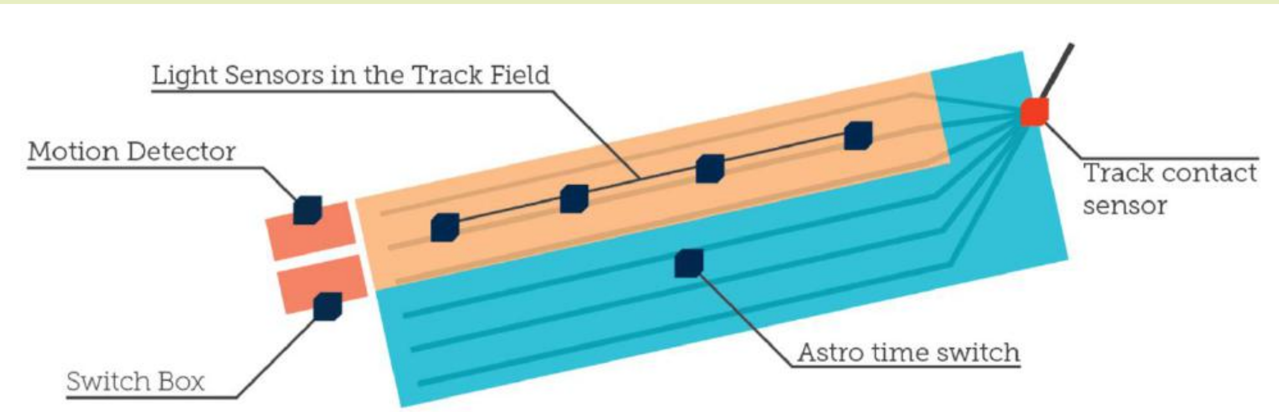


Image 12: Location of the Sensors on the Track Field

Electrotechnical Installation

The lighting system is divided into a main distribution hub (MDH) and six sub-distribution units (SDU) that are electrically powered by a three-phase alternating current (50 Hz). The main control elements (WAGO, Codesys, TCP/IP network) and the manual operation elements are located at the MDH and SDU 1 at the railhead ramp, respectively. SDUs 2 through 5 are placed at a distance of some 200 m from each other and contain the breakers and control units for the respectively assigned light gantry groups. SDU 6 was placed at the entry rail switch.

What Makes This Project Sustainable?

This project considers all three dimensions of sustainability (environmental, economic, and social aspects). Image 13 demonstrates that smart LED technology can do so much more than just reduce energy costs. Not only does it carry the promise of additional economic benefits and has a great potential for reducing the port's environmental foot print. It can also improve work safety through optimal lighting.

As a state-of-the-art lighting technology, LED have undergone a revolutionary development within the past few years, even since the inception of this project. One of the definite 'highlights' is the improvement of the efficiency of the lamps. Both, the luminous efficacy, and the life span have increased, while the costs have decreased. This has made this technology the ideal candidate for utilization within a port setting.

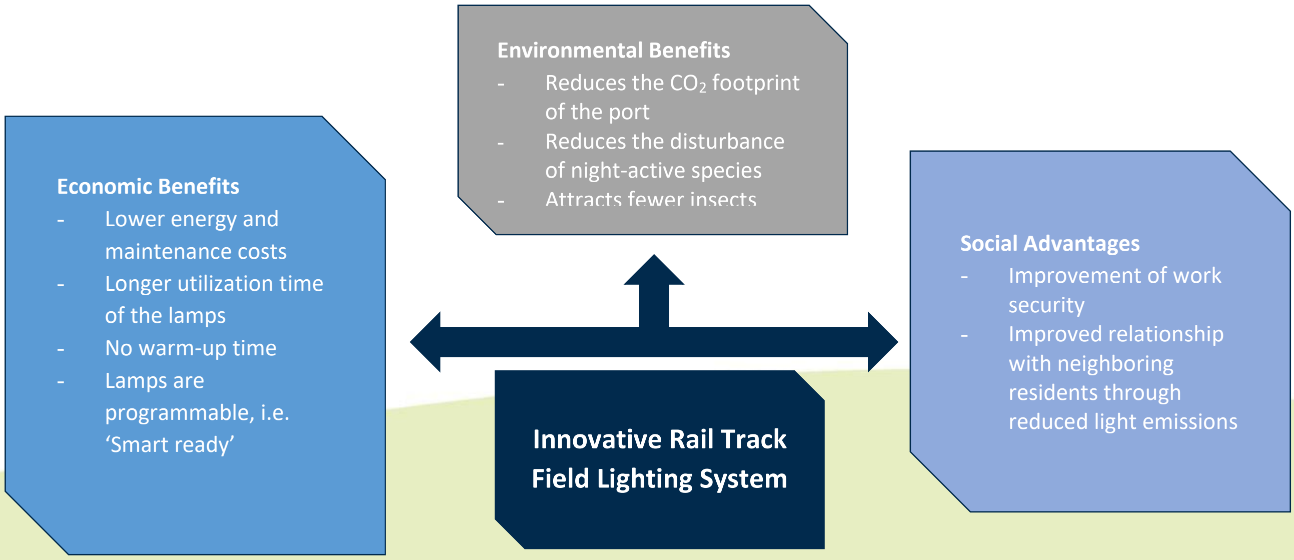


Image 13: Benefits in Terms of Sustainability

Data, Facts & Figures

Energy Savings

Monitoring of the system over multiple months revealed data that show, how much energy can be saved on an annual basis, when this technology is deployed. Benchmark reference was a status quo that had been envisioned in the initial planning, which is the equipment of the system, based on the lighting requirements at hand, with traditional sodium vapor lamps. Also, there was no control or regulation envisioned in this benchmark scenario (cf. Table 3 I.). The second column (II. LED Lamps) was based on data that show, just how much energy reduction could have been achieved by merely switching the lighting technology, without sensors and control technology. The results show that, by merely switching the technology, some 26% of energy, and thus a commensurate amount of CO_2 emissions, could have been saved. In the third consideration (LED Lamps, 'Smart'), the data for the actually implemented system in Emden are depicted. Not only is this system based on LED technology, but it is also equipped with sensor and control technology. Compared to the benchmark system, 43.1% of the CO_2 emissions can be saved. The control technology alone reduces energy consumption by some 17%. In addition, there are savings in terms of maintenance and operation costs, since LED lamps feature a longer life span and require less maintenance.

Table 3: Energy Savings Through Smart Lighting Management

		I. Traditional Sodium Vapor Lamps (SON) *Ca. 100 lm/Watt, simple circuit*	**II. LED Lamps** *Ca. 130 lm/Watt, simple circuit*	**III. LED Lamps, 'Smart'** *Ca. 130 lm/Watt, incl. sensors, incl. controllers*
Number of Lamps	65 catenary suspended luminaires	**10.60 kW**	**8.15 kW**	**8.15 kW**
	16 mast Lamps	**3.25 kW**	**2.5 kW**	**2.5 kW**
Installed Light Stream in Lumen		**1,384,500 lm**	**1,384,500 lm**	**1,384,500 lm**
Installed Output in kW		**13.85 kW**	**10.65 kW**	**10.65 kW**
Number of Annual Lighting Hours 2,200h				
-Portion of Which as Base Lighting 5 Lx	1,576h	**7,273.24 kWh**	**5,035.32 kWh**	**3,356.88 kWh**
-Portion of Which for Shunting 15 Lx	124.8h	**863.93 kWh**	**797.47 kWh**	**797.47 kWh**
-Portion of Which for Loading 30Lx/150Lx	499.2h	**6,911.42 kWh**	**5,316.48 kWh**	**4410.43 kWh**
Total Annual Energy Consumption		**15,048.59 kWh**	**11,149.27 kWh**	**8,564.78 kWh**
Annual Energy Costs	0.25 €/kWh	**€ 3,762.15**	**€ 2,787.32**	**€ 2,141.20**
Energy Costs in %		**100%**	**74.09%**	**56.91%**
CO_2 Savings in %		**0%**	**- 26%**	**- 43.1%**

Partners

Implementation Partners:
Gbr. Neumann GmbH & Co. KG
AME GmbH
DIGRA Logistik & Service GmbH
Furgro Consult GmbH
Ingenierbüro IDV
Institut Dr. Nowak GmbH & Co. KG
KMB Kampfmittelbeseitigungsdienst
LGLN-Regionaldirektion Hannover
Sellhorn Ingeniergesellschaft mbH

Cooperation Partners:
Port of Oostende
Port of Zwolle
Port of Vordingborg
bremenports
OFFIS
BLG
EUROGATE
EVAG Emder Verkehrs und Automotive Gesellschaft

Conclusion & Lessons Learned

LED Technology as Most-Efficient Solution for Port Requirements
The deployment of LED technology turned out to be an efficient and smart solution. Since the planning of the system introduced here, back in 2016/2017, the efficiency has improved even further. And even the costs have gradually come down. There is currently no better technology available for purchase that would suit the special requirements of port activities any better.

Digital Solutions Are More Prone to Faults During Implementation
The applied new technology is more prone to faults, and fault recognition and elimination is often times only possible with the help of special tools (such as digital programmers).

A Special Expertise for Maintenance and Upkeep Is Crucial
The technology that is applied here, requires a deeper knowledge and expertise by the staff. Employees must undergo commensurate training. Qualification of the staff for new IT-supported systems is a paramount task at NPorts so that such 'smart' systems can be deployed, operated, and maintained by NPorts' own personnel in the future.

Planned Lighting – A Sensible Prerequisite
DIALUX, the software utilized in this project, made it possible to plan and schedule, calculate and visualize light. That made it possible to mind energy efficiency, even in the planning phase, and it ensured that the area to be flooded with light was neither over- nor under-illuminated.

Other Findings
- Catenary suspended luminaires have proven to be a high-maintenance and expensive solution
- Due to the weather-sensitivity of the new control hardware, a heater had to be installed in the control cabinet.
- It turned out that the local variances at the eight measuring locations were more minute than initially suspected. For a satisfactory reporting of the results, three sensors would be sufficient and would also offer ample redundancy in case of failure of a sensor, and would enable a plausibility check of the measuring results.

For Niedersachsen Ports, the track lighting project that was introduced here, was their entry into the intense discourse with this topic of energy-efficient lighting. It represents the first large model system of its kind that was implemented in Niedersachsen Ports' 15 ports and it has given us some invaluable insights. Thanks to this LED-pilot project, the topic of smart energy lighting has gained great traction with us. To this date, numerous additional LED projects have been realized. The objective of the transformation of our entire lighting at all of our sites was included in our sustainability strategy, which was published in 2018. It is our declared goal to convert 100% of our lighting to LED by 2025 and, where it makes sense, to also deploy smart lighting technologies. A good indication that we are on the right track is the fact that up to 2020, we had already retrofitted some 20% of our 3400 points of light.

This is also a great opportunity to extend a heartfelt thank you to all of our DUAL Ports partners for the invaluable support and the exciting discussions around this project. We would also like to thank the INTERREG secretariat for their constructive support of this pilot, both financially and content-related. Last, but not least, we would like to thank all partners and colleagues, who supported us with the handling, preparation, and implementation of this project. We would also extend our gratitude to Mr. Ralf Kleinwechter of HIT HIGH TECH Ingenieurgesellschaft mbH for his technical and content-related support of the project and his help with the monitoring of this pilot and the documentation.