EnLight - Next Generation Intelligent and Energy Efficient Lighting Systems

The "Solid State Lighting Revolution" has given lighting and controls new significance. Research projects have become necessary to explore new opportunities and set free the full potential of the new technology. Perhaps the most extensive research in this direction was performed by the EnLight consortium. Frank van Tuijl from Philips Lighting introduces the project and explains why it was initiated and what the aims were. Furthermore, he provides some background information about the five selected technical articles.

The lighting industry is undergoing a radical transformation, driven by rapid progress in solid-state lighting and semiconductor technologies as well as changing societal needs for sustainability, improved energy efficiency and CO_2 reduction. To serve the latest business requirements and drive R&D, these changes need to happen quickly and take place in an open-innovation ecosystem [1].

Recent advancements in solid state lighting (LED), the "LEDification of lighting", have led to breakthroughs in light source efficiency and lifetime. However, the real revolution, the digitization of lighting is yet to come and will involve a paradigm shift from a lighting component approach to an application centric approach [2].

To achieve this, a consortium of 27 leading European companies and academic institutions have been working together on the project [3], a pre-competitive three-year ENIAC-JU R&D program to develop technology breakthroughs for energy-efficient and intelligent LED lighting solutions. Partners include a number of leading European companies in the lighting industry (including Philips and Osram), the semiconductors industry (NXP and Infineon) and the lighting controls industry (including Insta and Legrand), plus universities and research centers from across the semiconductor and lighting value chain.

Energy Saving through Intelligence

The main goal of the project was to exploit the full potential of solid-state lighting through breakthrough innovations on non-conventional, energy efficient, intelligent lighting systems beyond today's common lighting control applications. The aim was to achieve 40% energy reduction compared to today's LED retrofit systems.

The project had three technical objectives:

- Optimized LED lighting modules: Improved optical design, thermal management, driver integration and realization of a communication interface
- Future, non-conventional luminaires: Allowing for freedom of design, integration of novel features, architectural flexibility and serviceability, unrestricted by retrofit solution constraints
- Intelligent lighting systems: Providing means for data mining, smart sensors, sensor fusion and interfacing with Building Management Systems (BMS)

EnLight explored next generation intelligent lighting systems, with the goal of improving light source energy efficiency (i.e. electrical efficiency of LED drivers and power supplies, optical efficiency and thermal efficiency) and control system intelligence to provide the right light, in the right amount, at the right place and at the right time.

As a “Green Field Approach”, the project addressed the second solid state lighting (SSL) transition wave, overcoming restrictions of legacy technology and infrastructure. The project examined the integration of electronics and controls into luminaires, with a focus on optimal utilization and integration of LEDs, optics, sensors and heat management systems.

The goal was not just to improve efficiency through reduction of the junction temperature and improved light output ratios [4] but to take a next step towards the shape and functional integration of the luminaire, breaking completely free from the conventional form factors associated with traditional lighting. The notion of a luminaire was taken much farther than could be imagined with traditional light sources. In this respect, the objectives are clearly beyond those of the Zhaga program, which focuses on the standardization of mechanical, electrical and thermal interfaces on the components level.

And finally, a third digitalization wave is associated with controls and sensors, which may be part of the luminaire and make the luminaire ready for the Internet of Everything.

Breakthrough Innovations

Breakthrough innovations in the following areas were achieved, taking a disruptive step into the future of lighting.

Distributed intelligence

Inspired by the Internet-of-Things, the project partners explored a novel distributed rules-based intelligence system allowing each individual luminaire to make lighting decisions based on presence, occupancy events or ambient light information detected by its own integrated sensors, or events and information from other nodes in the network (sensor, luminaire or user control). To enable this, a few additional Zigbee cluster libraries were defined.

Distributed intelligence enables deep energy savings with optimal user centered comfort. Without the need of a central controller, it reduces installation and commissioning effort and increases robustness, flexibility & scalability over lifetime. The inter-luminaire architecture is described in the article “Lighting System Architecture for Distributed Intelligent”.

Digital modular luminaire architecture

A novel Plug-and-Play intra-luminaire bus architecture and communication protocol was created that allows the development and management of a portfolio of re-usable and easily exchangeable luminaire building blocks. The intra-luminaire communication bus is built on an I^2C physical layer, using ILB as the communication protocol. The building blocks include LED light engines, embedded sensors, high- and low-power supplies, and embedded controllers. The modular approach makes it easier to manage the diversity and complexity of luminaires throughout the supply chain, decouples lifecycles of independent modules/technologies and enables market players to contribute, differentiate and compete. The “Lighting System Architecture for Distributed Intelligent” and “The Building Blocks for Intelligent Future Luminaires” articles describe the intra-luminaire architecture and the modular building blocks.

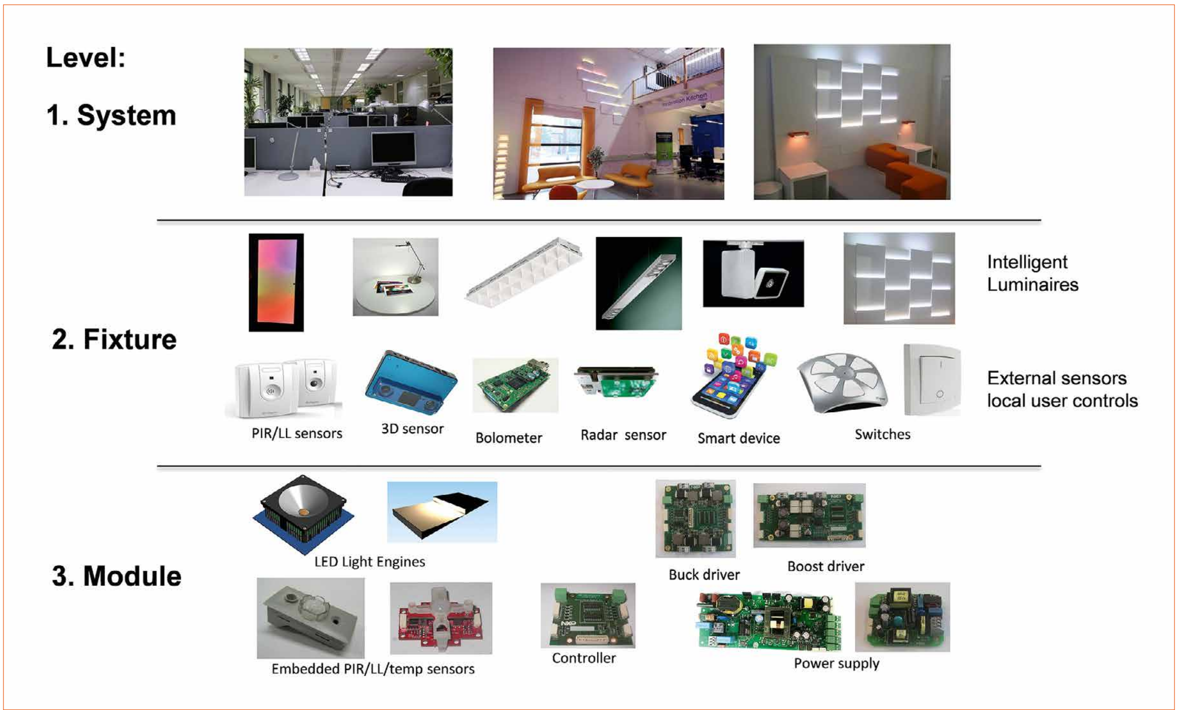


Figure 1: System hierarchy and building blocks

Figure 2: Office and hospitality demonstrations (from left to right: Office demonstration - Philips; office demonstration - VTT; hospitality demonstration - Osram)

Technical Highlights

The consortium partners developed EnLight-compatible building blocks at module, fixture and system level as illustrated in figure 1. These contributions included modules, intelligent luminaire and e xternal sensors and local user controls.

Modules

Specific technologic innovations included compact multi-channel LED drivers and power supplies with high electrical efficiencies (up to 90-95%) over the whole dimming range, electronic designs for low standby power, compact embedded sensors (ambient light, occupancy, ambient temperature), LED light engine designs for high LOR (Light Output Ratio, up to 90%) and high thermal efficiency.

Intelligent luminaires

Philips contributed the (mini)-PowerBalance and TaskFlex intelligent luminaires as the lead carrier platform for this development. The PowerBalance luminaires were equipped with 4-channel LED strings for tunable white applications and the combined PIR/light level/ temperature multi-sensor.

Osram developed an extendable RGBW decorative tile concept and novel luminous door concept, while Insta contributed the Glow, a suspended intelligent luminaire with both task and ambient light. The "New Form Factor Luminaires and New Light Effects" article gives an introduction into the novel luminaire concepts.

All luminaire types were built from the same plug-and-play building blocks developed in the project, showing that with only a limited set of intra-luminaire modules, a large variety of luminaires can be constructed across different module suppliers and luminaire makers. The building blocks are described in the "The Building Blocks for Intelligent Future Luminaires" article.

External sensors and local user controls

At fixture level System-on-Chip (SoC) implementations for advanced and cost effective image and radar sensors for reliable occupancy, presence and activity detection were developed by several academic and SME partners (University Perugia, Institutes TNO, Fraunhofer-EAS, CEA-Leti and SME Eagle Vision). External sensors and user controls were developed by Plugwise, AME and Legrand. They are described in the "Peripheral Devices for the Right Light" article.

System Demonstrations

Three system demonstration pilots in the office and hospitality application domains were realized at three different locations (Figure 2), each using 60-120 EnLight compliant ZigBee nodes (intelligent luminaires, external sensors or user control) without any central controller.

Sophisticated energy saving strategies were demonstrated, such as task tuning, personal control, occupancy control and daylight harvesting. As both embedded sensors and external sensors provide information to the luminaires, granular control strategies have been tested centered around users using light bubbles, local daylight regulation and personal control with smart integrated desk lights. Comfort enhancing features using tunable white and colors were also demonstrated including circadian rhythm in the open office and scene settings with ambient colors to support activities in the meeting room.

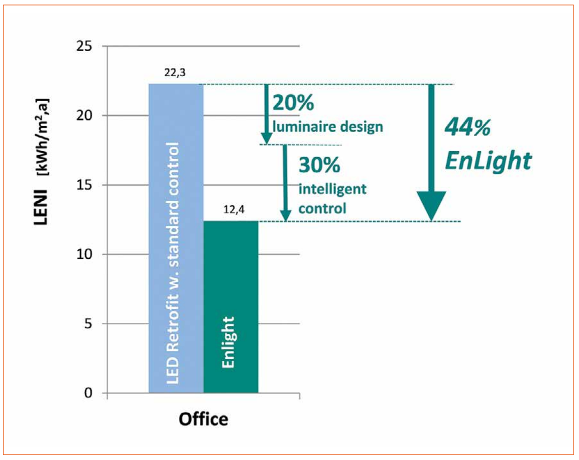
Validation of energy efficiency and user comfort results

For evaluation, the Lighting Energy Numeric Indicator (LENI) described in standard EN 15193 was used: Energy performance of buildings - Energy requirements for lighting as the indicator of the energy performance. This measures the actual annual energy consumption of the lighting system (in kWh/m^2 per year) taking into account the installed power of the luminaires, the lighting controls strategy and system parasitic power.

The results from the three representative office and hospitality pilots realized in the project confirmed significant energy savings of between 44% and 81% compared to current LED retrofit applications with a standard room occupancy-based control strategy.

The office pilot demonstrated overall energy savings of 44% with an average contribution from the sophisticated granular control strategy of 30% and an overall lumen efficacy improvement of 20%.

The hospitality pilot demonstrated even larger overall energy savings of 81%, with a 67% average contribution from the control strategy and 42% from luminaire efficacy improvement. The large difference between the office and hospitality results was



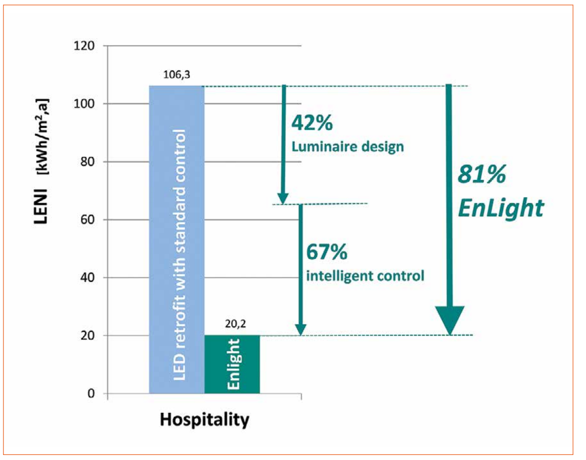


Figure 3:
Energy saving results for office (left) and hospitality (right) demonstrations

due to the higher lighting power density, lower occupancy and use of decorative but less efficient luminaires in the hospitality application.

As the resulting energy saving for the total installation for each of the pilots was more than the targeted 40%, the primary challenge of the project was accomplished.

From a lighting comfort perspective, based on key lighting parameters such as lighting quality, brightness (glare) and room appearance, the new developed system delivered a comparable performance with respect to reference non-retrofit LED lighting installations.
While significant differences in lighting comfort were not statistically proven, qualitative analysis results showed an 80% preference for the EnLight system over a state-of-the-art LED reference system.

The LENI energy values measured overall for office are 12.4 kWh/m^2 per year compared to 20.4 kWh/m^2 per year for the LED retrofit baseline. These results amply exceed the best in class scores of the building energy performance benchmarks (i.e. EN 15193 [5], ASRAE [6], Title 24 [7]) and score the maximum of LEED [8] credit points. The hospitality installation surpassed even green building performance norms with a 45% better saving performance (20.2 kWh/m^2 per year).

The energy efficiency and user validation results are described in the “Granular Lighting Control Enables Significant Energy Savings with Optimized User Comfort” article.

The Road Ahead

EnLight developed a novel, decentralized and modular system architecture for next generation intelligent lighting systems, empowering the next generation smart lighting systems.

Driven by granular control strategies, the new system demonstrated significant energy savings without compromising and even improving light quality and user comfort. The substantial additional energy savings for lighting will lead to a reduction of global CO_2 emission. This is an important step to meet the EU directive 2010/31/EU for a near zero energy building performance in 2020.

By building on Europe’s leadership in semiconductor and lighting technology and exploring future ecosystems featuring the intra-luminaire bus and decentralized rule-based intelligence, this new concept is helping shape the lighting market for the coming years. It enables new lighting solutions that were not possible with conventional lighting technology.

This creates opportunities both for large companies and SMEs. Fuelling new growth opportunities in LED Lighting applications, this project will lead to the creation of new lighting solutions that inspire and enable designers in ways conventional lighting never could.

References:
[1] http://www.eniac.eu/web/downloads/projectprofiles/call3_enlight.pdf
[2] Dr. Kees van der Klauw: „The Paradigm Shift in Lighting” ISS Europe 2013, Milan (2013)
[3] EnLight: http://www.enlight-project.eu
[4] The ratio of luminous flux emitted by the LED light source and that emitted by the entire luminaire system.
[5] EN 15193:2007 Energy performance of buildings - Energy requirements for lighting
[6] ANSI/ASHRAE/IES Standard 90.1-2007
[7] http://www.energy.ca.gov/2012publications/CEC-400-2012-004/CEC-400-2012-004-CMF-REV2.pdf
[8] Leadership in Energy and Environmental Design (LEED)