Innovations in lighting are timely, urgent and require a multidisciplinary perspective. The Intelligent Lighting certificate program is designed to train engineers from different backgrounds, uniquely equipped to face the challenges in lighting innovation.

Key themes: multidisciplinary, user-centred, sustainable, integrative, innovative.
Introduction
The lighting domain is changing radically. Three major developments have spurred this revolution: (1) society’s growing awareness of the need to save energy, (2) recent insights in light’s pathways through the brain – the discovery of a 5th photoreceptor - and its impact on human health & functioning, and (3) the introduction of LED, a low power, flexible light source, offering potential for miniaturization, embedding, and advanced dynamic control. All these developments have direct implications for users and society at large.

The Secret Life of Light USE is designed to raise awareness of the impact of light on human functioning to equip engineers from different backgrounds with the necessary insights in psychological and biological lighting needs and with tools to address such needs, and to face the challenges in multi-stakeholder lighting innovation. This USE sequence is coordinated by the Intelligent Lighting Institute (ILI).

With the introduction of LED, a low power, long lifetime, highly colour flexible light source emerged, offering potential for miniaturization, embedding, and advanced and dynamic control: Lighting has gone digital. We can now offer more rich and complex dynamic, interactive, tailored light conditions to optimise human performance, health and wellbeing, and balance human needs with environmental impact of lighting applications.

“Light, which was captured in a bulb, is liberated as it were. On several levels relating to light – functional, emotional, biological, social, cultural and regarding control and durability – there are new possibilities and challenges.”

The aim of the Liberation of Light is to provide students with the necessary knowledge to make an electrical lighting design, and allows for doing research in the light area. It prepares the student for entering further classes in the ‘Engineering Intelligent Lighting’ program. In the advanced quartile of the Liberation of Light trajectory we offer in-depth technical knowledge in the lighting domain. This knowledge is vital for making a good lighting design and includes technical and physical knowledge on the creation of light as well as its interaction with the physical environment. Students will get acquainted to all necessary topics both in theory and practice.

Intelligent Lighting Institute (ILI)
The TU/e Intelligent Lighting Institute (ILI) was established in 2010 to investigate novel intelligent lighting solutions that will come within reach by the large-scale introduction of LED technology. ILL’s mission is to search for revolutionary lighting solutions. It does this using an interdisciplinary approach that takes society as its laboratory. Well-being and sustainability are given top priority in all facets of its research and resonate throughout all of the strategic programs. In addition ILL aims at providing scientific evidence for the claims that go with these novel lighting solutions.
**Multidisciplinary character**

The scientific lighting domain is inherently multidisciplinary. Six departments currently participate in ILI: Built environment, Electrical Engineering, Industrial Design, Industrial Engineering & Innovation Sciences, Applied Physics, Mathematics & Computer Sciences. The certificate program aims to bring together these disciplines also on an educational level.

Competences and expertise required to ensure the development of effective, healthy, sustainable and easy-to-use lighting technology and applications include:

<table>
<thead>
<tr>
<th>USE aspects</th>
<th>Technical aspect</th>
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</thead>
<tbody>
<tr>
<td>• Perception</td>
<td>• Lighting technology</td>
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<tr>
<td>• Interaction design</td>
<td>• Distributed systems control</td>
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<td>• Human factors</td>
<td>• Building physics</td>
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<tr>
<td>• Psychology of light</td>
<td>• Computational intelligence</td>
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<td>• Biology of light</td>
<td>• Media processing</td>
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<tr>
<td>• Understanding, measuring, and designing</td>
<td>• Simulating building performance</td>
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<td>for preferences &amp; effects</td>
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</tbody>
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- Aspect | Lighting technology |
- Aspect | Distributed systems control |
- Aspect | Building physics |
- Aspect | Computational intelligence |
- Aspect | Media processing |
- Aspect | Simulating building performance |
Content of the Program

**USE trajectory**
“The Secret Life of Light”

**Technical trajectory**
“The Liberation of Light”

**Exploration**
- 1. Light and Experience
  - Quartile 1

**Specialization**
- 2. Advancing Light for Human Functioning
  - Quartile 2
- 3. Secret Life of Light
  - USE project
  - Quartile 4 (or Quartile 3 if necessary)
- 2 Physics of Light and Lighting Design
  - Quartile 3
- 3. Liberation of Light
  - Technical project
  - Quartile 1 (or Quartile 4 if necessary)

**Application**

**Certificate Program**
“Engineering Intelligent Lighting”
Exploration
The exploratory course Light and Experience aims to familiarise students with basic insights in developments in light sources, lighting controls, and or growing insight in light’s psychological, biological, and social effects. Students will get acquainted with both theoretical and practical understanding of user needs and preferences, light’s effects on health and behaviour, interaction with light and the many stakeholders around innovative light applications. We start with ‘base camp’: one week of introduction into light as a physical phenomenon, the visual system, and lighting design. Students will then explore three themes around intelligent lighting: 1) Light for health and wellbeing; 2) Smart urban lighting; and 3) New interaction styles with light.

Specialization
The specialized course Advancing Light for Human Functioning offers more in-depth knowledge in a number of domains, structured in modules. Modules adhere to one of the USE perspectives and give students a more thorough understanding of the user, societal issues, or entrepreneurship in the domain of light & lighting. All modules run twice. Students select two modules from the set:

- The basis of light perception and experience,
- The appraisal of light – measuring & understanding consumers’ reactions,
- Sensory design,
- Interaction design for intelligent light, and
- Business aspects of intelligent lighting solutions.

During the final two weeks, students write a research proposal integrating the insights gained from the chosen modules.

Application
In the final phase of the Secret Life of Light USE sequence, students select a project team (±5 students) and assignment during an exciting matchmaking event. Every team will work for an ILI partner (client) and will have (at least) one ILI coach. For each thematic programme, clients and ILI staff together define a small number of challenges, which clearly refer to the USE components. This renders a set of 6-9 challenges/projects to choose from.

Assignments may have a research or design orientation. Research assignments consist of an investigation and a formulation of a vision. Design assignments consist of a design exploration, prototype design, and evaluation. Whether research or design oriented, the assignments should be grounded in a basic understanding of the user, contextual, and technical requirements of innovative light applications, and involve empirical data gathering and analysis, i.e. user-research. Examples of a research and a design-oriented project can be found in Application section of the deliverables for the USE sequence.
Exploration (same as Secret Life of Light)
The exploratory course Light and Experience aims to familiarise students with basic insights in developments in light sources, lighting controls, and or growing insight in light’s psychological, biological, and social effects. Students will get acquainted with both theoretical and practical understanding of user needs and preferences, light’s effects on health and behaviour, interaction with light and the many stakeholders around innovative light applications. We start with ‘base camp’: one week of introduction into light as a physical phenomenon, the visual system, and lighting design. Students will then explore three themes around intelligent lighting: 1) Light for health and wellbeing; 2) Smart urban lighting; and 3) New interaction styles with light.

Specialization
After an introduction in the physics of light, optics, photometry and colorimetry, several lamp types are introduced and discussed: classical light sources like incandescent and halogen lamps, but also plasma lamps, LED and OLED. The chemical processes - for example the role of phosphors - are addressed. In addition to knowledge on light sources, the course introduces luminairs and intelligent lighting control. Last, students are introduced to a calculation program to enable them to predict lighting conditions in an environment.

Application
In the third phase of the Liberation of Light technical trajectory, students work in teams. Every team will work for an ILI partner (client) and will have (at least) one ILI coach. The client and ILI staff define a selection of challenge, each embedded in one of the program lines.
All assignments consist of a thorough exploration, prototype design, and prototype testing. In each assignment there should also be a clear and explicit consideration of the user perspective. The technical character of projects may vary and have an emphasis in for instance architectural lighting design, innovative controls & interaction, dynamic lighting applications, or energy efficiency/smart materials.
Students start with an orientation on their assignment (PACT analysis). In the second week, project mentors & program managers organise a dedicated in-depth workshop for all the groups in their particular challenge. Then each group continues with their own assignment. The assignments should be grounded in a basic understanding of the user, contextual, and technical requirements of innovative light applications, and original technical research and design work.
Certificate program Engineering Intelligent Lighting

Target group
The program is aimed at all BSc students of TU/e as well as external students.
The program is offered in English.

Workload
The workload consists of 20 ec. At least 5 ec have to be followed on top of the regular BSc program. The USE program consists of 3 sequential courses and so does the technical coherent package. Both lines consist of the same explorative course, a deepening course and a project.
The requirements of the certificate are:

- Successfully obtain (1) the explorative course, (2) both advanced courses, and (3) one project (USE or technical, free choice)
- Doing at least one of the courses over and above the regular study program (in other words extra or on top of the 180 ec of the total BSc program).

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Coordinator</th>
<th>Number of ec</th>
</tr>
</thead>
<tbody>
<tr>
<td>0HEUA0</td>
<td>Light &amp; experience</td>
<td>Dr.ir. F. Beute</td>
<td>5</td>
</tr>
<tr>
<td>0HSUA0</td>
<td>Advancing light for human functioning</td>
<td>Dr.ir. Y.A.W. de Kort</td>
<td>5</td>
</tr>
<tr>
<td>0HK30</td>
<td>Physics of light and lighting design</td>
<td>Ir. M.P.J. Aarts</td>
<td>5</td>
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<td>And one of the following projects:</td>
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<tr>
<td>0HAUA0</td>
<td>Secret life of light USE project</td>
<td>Dr. ir. Y.A.W. de Kort</td>
<td>5</td>
</tr>
<tr>
<td>0HK40 (TBD)</td>
<td>Liberation of light technical project</td>
<td>Ir. P.P.J. Aarts</td>
<td>5</td>
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</tbody>
</table>

Pass/Fail
The certificate program is successfully completed when the student passes every element of the certificate program by obtaining a 6 or higher or by fulfilling the requirements and by having a total package of at least 185 ec. The successfully completed certificate program will be signed by the dean of the Department of Industrial Engineering and Innovation Sciences.

Learning Goals
- Knowledge of light as a physical phenomenon, light sources, and its behaviour in physical spaces.
- Knowledge of the perception and human factors of light, and awareness of the multifaceted nature of light’s effects on human functioning
- Basic knowledge of distributed control, operating systems, computer networks, sensors & signal processing,
- Awareness of the challenges for lighting design and control in terms of system transparency and user interaction
- Basic skills and expertise to synthesize and apply the knowledge in these various disciplines, either in formulating and performing applied research, or in developing and designing innovative applications within the multidisciplinary domain of intelligent lighting.
Example projects for USE

Project description | Secret Life of Light USE project
Research Project: Trusting with your eyes?

Background
The role of light in our environment has been linked to our well-being and health. Light influences various aspects of our life, from our mood and sleep patterns to our productivity and decision-making processes. Understanding how light affects us can help us design more effective and efficient environments.

Research Objective
The objective of this project is to investigate how light influences human behavior and decision-making processes. The project will explore the relationship between light exposure and various cognitive and emotional outcomes, such as mood, attention, and creativity. The research aims to provide insights into how lighting design can influence human behavior and contribute to improving the quality of life.

Keywords
- Human behavior
- Cognitive outcomes
- Light exposure
- Lighting design
- Mood
- Attention
- Creativity

Project description | Secret Life of Light USE project
Research Project: Daily living for daily living

Background
Our daily lives are heavily influenced by light. From our sleep patterns to our mood, light plays a crucial role in shaping our daily routines. Understanding how light affects us can help us design more effective and efficient living environments.

Research Objective
The objective of this project is to investigate how light influences daily living. The project will explore the relationship between light exposure and various daily living outcomes, such as productivity, mood, and sleep patterns. The research aims to provide insights into how lighting design can influence daily living and contribute to improving the quality of life.

Keywords
- Daily living
- Light exposure
- Productivity
- Mood
- Sleep patterns
- Lighting design
Two major pathways

Introduction

Importance
- Be able to reproduce the same results
- Forbes et al. (2008) *: There is insufficient evidence to assess the value of light therapy for people with dementia. Most of the available studies are not of high methodological quality and further research is required.

(focus on the Activity – people satisfying a Need) Science

What? – usefulness, “do-goals”, tasks, functionality, specificity
(focus on the Action – people pursuing a Goal) Design

How? – usability, interaction, senso-motoric, feasibility
(focus on the Interaction – people performing a task) Engineering

SFD Mission and Vision

- New functionalities into polymer materials towards new applications or solutions in – sustainable energy – water & air – personal comfort and healthcare
- Integration of these new polymers into devices to employ their functionality

Integration along three dimensions

- Function integration
  - Add/upgrade functionality
  - Eg. presence detection, auto calibration, light on demand,...
- Technology integration
  - Collapse of LIR-06A
  - Eg. collapse of LIR-06A collapse of LiN2-Ch2
  - Eg. integration of discrete electronics into SFP and liquid LiC
- Value chain integration
  - Logical light based on decoupling points in value supply chain
  - Eg. (LiN2) at OSS supplier, L23-A at assembly factory