



FP7-ICT-2013-11-619249

**Accelerate SSL Innovation for Europe**

## **Deliverable**

# **D2.5 Map of green business development opportunities for SSL**

Dissemination Level:	RE
Deliverable type:	Other
Due Date of deliverable:	M9
Completion date of deliverable:	05.11.2014
Lead beneficiary responsible for deliverable:	Lund University
Related work package:	WP2
Author:	Reine Karlsson, LU reine.karlsson@luopen.lu.se
Co-authors:	Markus Johannesson, Tove Karlsson, Håkan Lagerquist, LU Jos Kunen, Marc Steen, TNO Anne Vick, LightingEurope Peter Bracke, KU Leuven

Document history:

This report builds on the first year's SSL-erate dialogues, primarily among the WP2 partners; internally, around the Task 2.3 Application workshops, see D2.3, and in a variety of outreach activities e.g. feedback on presentations at Light and Building, at the Swedish Energy Agency, within a CEEBEL advanced lighting course, at the Copenhagen Matchmaking and at LpS2014. The first draft was compiled in June in dialogue with the WP4 Open Innovation workshop preparations, in July we initiated a dialogue with WP5 about web-related outreach considerations. During September and October we have got feedback on the successive drafts: Nils Erkamp, Joram Nauta, Marc Fontoymont, Thomas Lindhqvist, Jessika Luth Richter, Fergus Lynch, Vicenc Moline and Peter Raynham.

Revision	Date	Status
V0.1	25.07.2014	First draft
V1.0	05.11.2014	Final
V1.1	07.11.2014	Updated Final
V1.2	12.11.2014	Updated Final

**Disclaimer:**

The material contained in this document is provided for information purposes only. No warranty is given in relation to use that may be made of it and neither the copyright owners or the European Commission accept any liability for loss or damage to a third party arising from such use.

**Copyright Notice:**

Copyright SSL-erate Consortium 2014. All rights reserved.

## Preface

*It is a great pity that there is so little dialogue about the positive customer value of the new lighting. For almost all other products; you buy a new thing because you really like the new product, e.g. sofa or TV. Very few people talk about the new lighting as something they really want. For lighting we tend to limit our interest to the energy saving and life-cycle cost.*

Helena Ahlkvist Johansson, Lighting Informant  
Swedish Energy Agency, 2012

SSL is enabling lighting environments that are more beautiful and pleasurable than ever before. The digital age provides a diversity of functional opportunities to create lively atmospheres that are attractive and promote health and wellbeing and is therefore a vital opportunity for people in Europe. The combination of SSL and ICT, including sensors, hard- and software, big data and user interfaces, enables a completely new freedom-of-action. The blue diodes with light conversion phosphors have become cost-efficient as replacement light sources. It is now also technically feasible to start to use dynamically controllable multi-colour diode arrangements and OLED in tunable light engines.

There is a lot of, old and new, hardly activated in any broad scale, essential knowledge about the significance of the character and quality of our visual living and working environments; for functional visibility, health, wellbeing, circadian and mood lighting, attractiveness and human contacts.

There is great business potential for intelligent human-centric lighting and the new lighting is a societal and business development opportunity for the competent renewal oriented regions and business actors that can activate appropriate investments. But, so far it has been rather difficult to get started with significant business growth for value enhancing lighting installations. One basic hurdle is that there is limited public awareness about the human significance of intelligent human-centric lighting. Then there is uncertainty and skepticism, e.g. about quality, actually useful lifetime and colour stability of LED.

It is difficult to specify new functionalities, which deviate from the traditional lighting standards, in a clear and understandable way. From innovation point of view there is a principle risk for price competition from inferior products and solutions. There is obvious need and market potential for serious competent renewal oriented business actors.

SSL-erate is aiming to support value-enhancing deployment of high-quality solutions, as illustrated by the figure 21s' values enhancing business development (from the project application) and a 4-fields chart from the SSL-erate kick-off meeting (figure 22), see chapter 8. The Green Business Development Maps in chapter 2 are based on the same line of transformative thinking, which is described in chapter 8.

It is vital to build awareness about the human significance of better lighting and also to enable the market actors to better distinguish between good and bad solutions, for each specific context. This report describes a map of potential business volumes for the traditional lighting market segments and presents a set of conceptual dialogue tools for the needed business transformation.

## Table of Contents

<b>Executive Summary</b> .....	<b>5</b>
<b>1 Introduction</b> .....	<b>6</b>
1.1 Structure and content .....	6
1.2 New possibilities with SSL .....	7
<b>2 Green Business Development Map</b> .....	<b>8</b>
2.1 GBDM – Drivers, Opportunities and Barriers .....	9
2.2 GBDM – A Life Cycle Cost Perspective .....	14
2.3 GBDM – Innovation potential of the HCL and ILS market .....	15
2.3.1 The Innovation Ambition Matrix.....	15
2.3.2 Assessment of the innovation potential of the HCL and ILS market.....	17
<b>3 GBDM support tools: SSL-erate concepts</b> .....	<b>22</b>
3.1 Unique Selling Proposition with SSL.....	23
<b>4 GBDM support tools: Business Potential for SSL</b> .....	<b>25</b>
4.1 Business potential for various market segments .....	25
4.1.1 Residential.....	25
4.1.2 Lighting for work places .....	26
4.1.3 Education.....	28
4.1.4 Health Care.....	28
4.1.5 Outdoor.....	29
4.1.6 Architectural.....	30
4.1.7 Automotive.....	30
<b>5 GBDM support tools: Stakeholders</b> .....	<b>31</b>
<b>6 GBDM support tools: Green as a competitive advantage</b> .....	<b>32</b>
6.1 Traditional Green Process tools .....	34
6.2 Traditional Green Assessment Tools .....	37
<b>7 GBDM Dialogue tools</b> .....	<b>38</b>
7.1 Limitations in the current methods of light measurements .....	38
7.2 Ability to clarify the added user values .....	39
7.3 SSL-erate lighting characteristics.....	40
7.4 “Meaningful” as a tool to clarify the societal value .....	42
<b>8 The SSL-erate transformative innovative perspective</b> .....	<b>43</b>
<b>9 The GBDM support tools: Collaboration methods</b> .....	<b>45</b>
9.1 SSL-erate business experiments.....	45
<b>10 Conclusion</b> .....	<b>46</b>
<b>References</b> .....	<b>47</b>

## Executive Summary

This report concerns deliverable D2.5 “Map of green business development opportunities for SSL”. The overarching ambition of the D2.5 report is to enable better synergy between Sustainable Development Investments, Enhanced User Value, Business Development Opportunities and more Meaningful Green Jobs. The presented Green Business Development Map, tools and examples aim to trigger customer interest, create a starting point for development of a unifying conceptual framing and build-up of awareness about human and societal sustainability values of human-centric lighting.

The quality and dynamics of the natural light has a significantly higher human value than the electrical light used. The combination of SSL, sensors, hard- and software, user interfaces and the evolving new knowledge enables a new level of freedom of action for intelligent user adapted solutions. The controllability of SSL and the supervision enabled by ICT creates possibility for a new level of variation, e.g. daylight variation and colour control that influence our mood.

A reliable company that can demonstrate the benefits of their products has a principal advantage in today’s uncertain lighting market. A lot of lighting customers need help to be able to make appropriate selections of the new lighting products and systems. To build dialogue between customers, companies and multidisciplinary researchers, and ICT and SSL experts it is necessary to focus on and build concepts around the user value.

In energy saving procurement with weak specification of the lighting quality the focus tends to be on cost minimization and the energy saving itself. This is problematic for the user appreciation. Furthermore, this reduces the interest to make further investments in SSL and thereby also the possibility to accelerate the SSL-based energy saving investments.

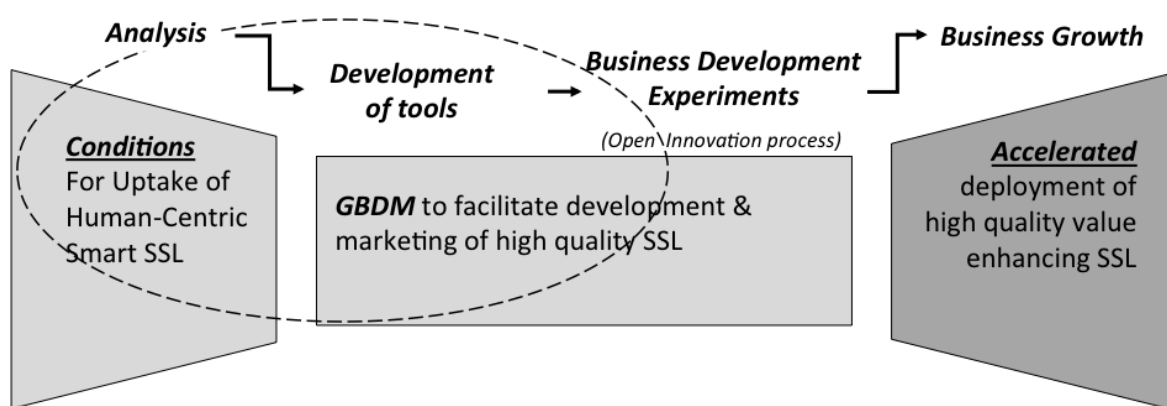
A mapping of energy using processes provides an overview of the on-going activities, what they deliver and how much energy they use, and can be used as guidance for development of more effective system solutions. The most energy consuming part often also provides an important user value. A mapping of the flows of scarce materials provides insight into the interoperation-ability between different actors and the systemic effectiveness of various parts of the value chain. From a customer point of view it is better to buy from people who know what they are doing.

Enhancement of the ability to specify the light that the customers want and need and minimization of all parts of the light that is disturbing or useless is the best basis for acceleration of the deployment of SSL and also the best from sustainable development point of view.

# 1 Introduction

This report concerns deliverable D2.5 “Map of green business development opportunities for SSL”, the Green Business Development Map (GBDM) in the remainder of this report. The report is built upon investigations, know-how in the WP2 team and intense dialogues among SSL-erate project partners; expert interviews, workshops, applications workshops documented in the preceding deliverables D2.2, D2.3 and D2.4. An essential input to this report is also provided by recent market studies on the business potential of SSL and, more specifically, Human Centric Lighting and Smart lighting in Europe; as well as a strategic opportunity analysis of the Smart City market.

Figure 1 depicts the SSL-erate approach to accelerate the lighting related innovation and uptake of high quality SSL in Europe.



**Figure 1:** Structure of the SSL-erate activities from analysis and development of the GBDM and tools aiming to support SSL-erate business development experiments to accelerate the deployment of more advanced SSL solutions.

This report focuses on the development of the SSL-erate Green Business Development Map and the associated tools for transformative business development, the dotted ellipse in figure 1.

## 1.1 Structure and content

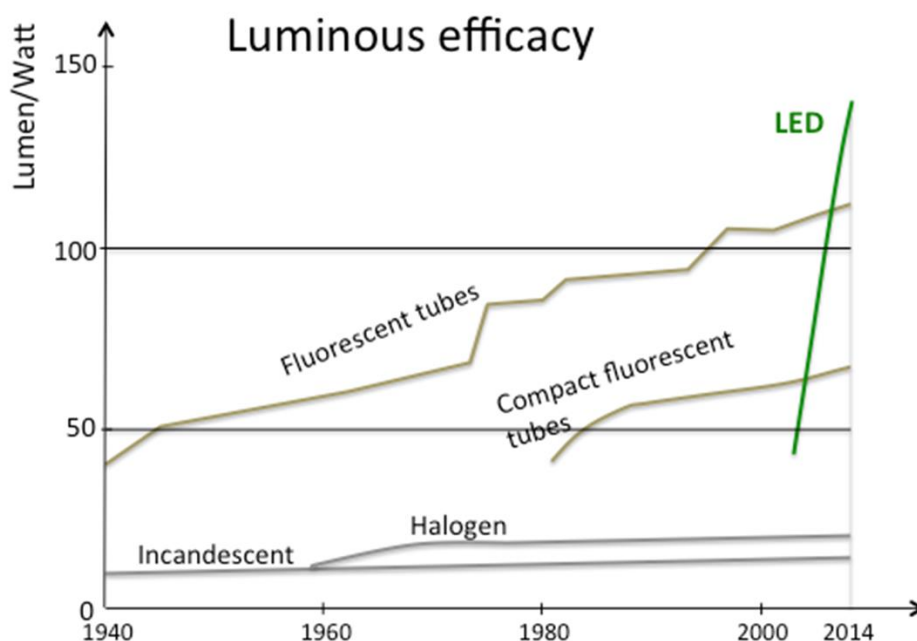
This report consists of two parts. Chapter 2 presents the GBDM, a map of green business opportunities for various market segments. Then, chapters 3 to 10 present the conceptual foundation and various support tools for green business development.

Chapter 3 defines project concepts and describes the unique selling proposition of SSL. Chapter 4 gives an overview of market segments for interesting business opportunities. The stakeholders are summarized in Chapter 5. Chapter 6 gives traditional green process and assessment tools that can facilitate the dialogue between suppliers and customers of Smart Human Centric SSL solutions. In Chapter 7 dialogue tools are presented to clarify added user values and to relate to a positive societal development. SSL-erate is described in Chapter 8 from a transformative innovative perspective. Chapter 9 introduces business experiments. And Chapter 10 concludes the supporting second part of the report.

## 1.2 New possibilities with SSL

SSL offer new radical technical opportunities. The magnitude of the possible transformation makes it difficult to assess which applications will become the most interesting and what the willingness-to-pay will be for various types of new lighting functions. So far one mainstream interpretation is that lighting product decision makers will choose LED lighting when the payback time is two to three years<sup>1</sup>. However, there is a risk that the established level of willingness-to-pay will delimit the innovation opportunities. SSL-erate is aiming to enable innovation for higher user values.

LED technology is becoming superior to all other commercially used lighting technologies in terms of lumen/W (efficacy); see Figure 2. As described by Haitz's law the cost per lumen falls by a factor of 10, and the amount of light generated per LED package increases by a factor of 20, every decade.



**Figure 2:** Luminous Efficacy development for LED in relation to traditional Light Sources

The efficacy improvement for the LED itself is expected to level off, due to physical limits. However, the driver circuitry is becoming less costly and the need for cooling is decreasing. Furthermore, the technical developments also improve the possibilities for integration with more advanced ICT and optic solutions.

SSL, being a semiconductor device, makes the combination/integration with ICT much easier. This opens up a new level of freedom of action to dynamically control light quality and colour composition, e.g. enabling the simulation of the natural light. A number of scientific studies show that light in the range 460-500 nm has a more pronounced awakening effect than light in other parts of the visible spectrum. Another example of a potentially higher user value is that the appreciated red character of dimmed incandescent bulbs becomes technically more and more feasible with SSL.

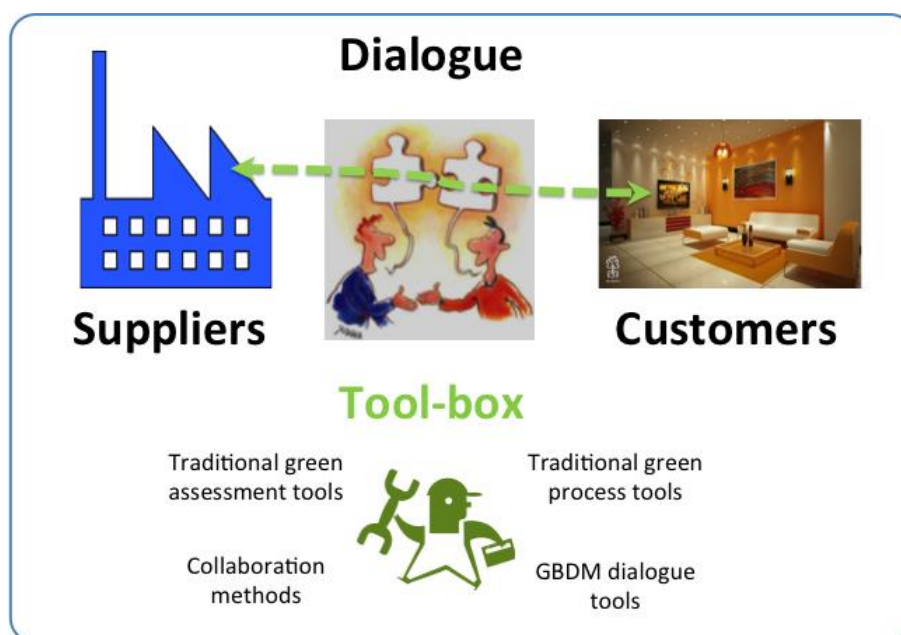
On an over-arching level it is relevant to note that the light in nature varies much more than the electric indoor lighting so far. In many ways it is superior to make use of the daylight and it is also relevant to avoid light pollution at night and from glary disturbing light sources. The efficiency and the controllability of SSL provides a radically new freedom-of-action.

<sup>1</sup> McKinsey's Global Lighting Professionals and Consumer survey, 2011

## 2 Green Business Development Map

The aim of the SSL-erate GBDM is to support innovative business dialogue between suppliers and potential customers to facilitate the SSL-erate business experiments and SSL business growth. The GBDM is intended for sustainability oriented business actors that are aiming to develop and sell SSL-based products, solutions and services, with higher added value for users and society.

The basic conditions to start an innovative path of business development is to have a sellable idea and access to relevant resources; money, knowledge, IPR, technology and people. Furthermore, it's fundamental to find potential customers and to develop appropriate relations in open-minded dialogues. The GBDM starts with Figure 3, which shows the value-enhancing dialogue between the suppliers of new SSL-based solutions and customers with potential interest in more meaningful lighting functionalities. Figure 3 illustrates a possible introduction page for an online GBDM.



**Figure 3.** SSL-erate is aiming to support investment enabling dialogues between actors that represent the supplier/development/production/factory side and the customers and users that are interested in better visual living conditions, e.g. in their "living room".

The following sections present an overview of a number of subject areas relevant to be prepared to talk about and the potential business development volumes for various market segments.



## 2.1 GBDM – Drivers, Opportunities and Barriers

Figure 4.1 shows drivers for investment in smart human centric lighting. Figure 4.2 depicts business opportunities and Figure 4.3 business development barriers. The volumes of the respective “spheres” illustrate the sum of the HCL (Human Centric Lighting) and ILS (Intelligent Lighting Systems) expected 2020 market volumes. The figures are based on a LightingEurope, ZVEI and AT Kearney market study for Human Centric Lighting (HCL)<sup>2</sup>, a McKinsey market study for global General Lighting Systems (GLS)<sup>3</sup>, automotive OICA and IHS information<sup>4</sup> and a market study by Frost and Sullivan<sup>5</sup> (See Table 1 below).

The background for the selection of the drivers, opportunities and barriers presented in figures 4.1, 4.2 and 4.3 has a basis in the project work, e.g. the WP2 application workshops and the reports D2.2, D2.3 and D2.4. The health and wellbeing aspects are also related the WP3 work.

The volumes of the market segment spheres in Figures 4.1, 4.2 and 4.3 are proportional to the sum of the numbers in HCL and ILS columns in Table 1. The basis for the Table 1 numbers is explained in Table 2.

The figure 4.1-3 diagrams do not have any specific scales on the x- and y-axes, and the positions for the spheres are not structured in any specific way. Further down the same market segment “spheres” have been positioned in relation to product improvement and kind of market development, see Figures 9.1 and 9.2.

---

<sup>2</sup> *Human Centric Lighting: Going beyond Energy Efficiency*, An introduction to the LightingEurope, ZVEI, and A.T. Kearney market study, 2013

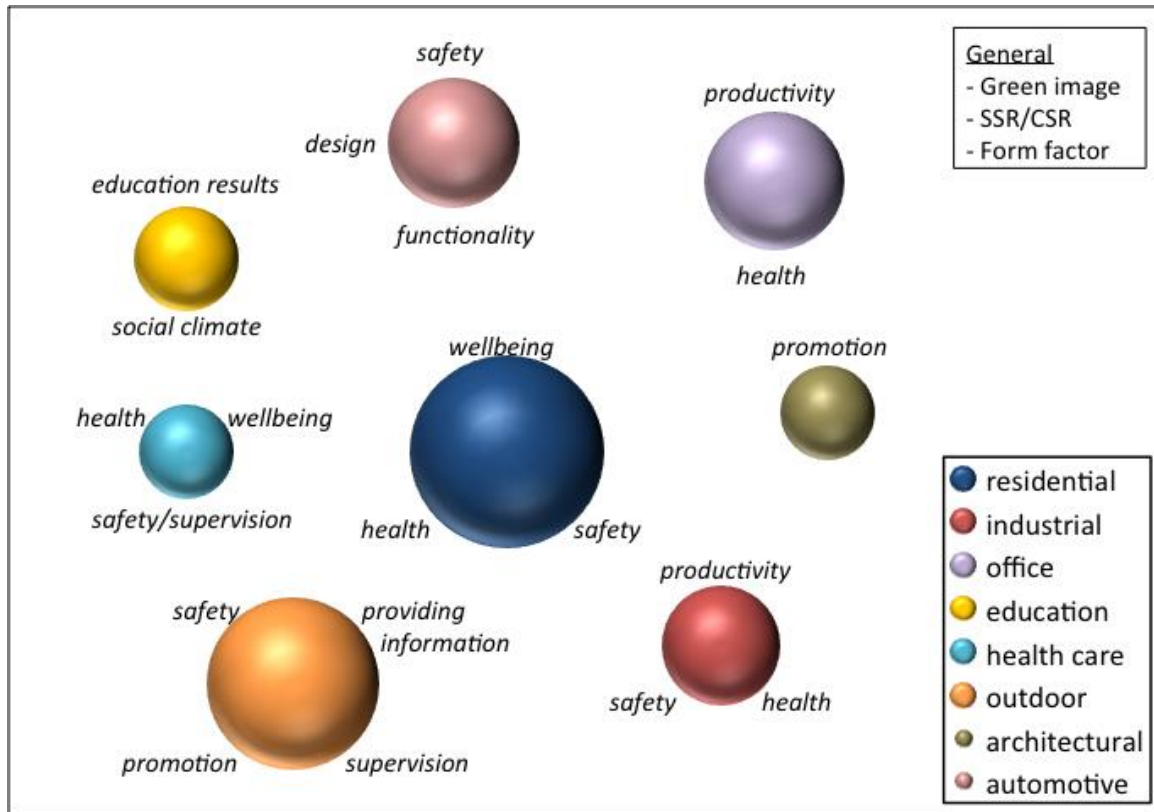
<sup>3</sup> *Lighting the way: Perspectives on the global lighting market, Second edition*, McKinsey, 2012

<sup>4</sup> OICA: <http://www.oica.net/category/production-statistics/>;

IHS: <http://www.ihs.com/products/automotive/index.aspx>

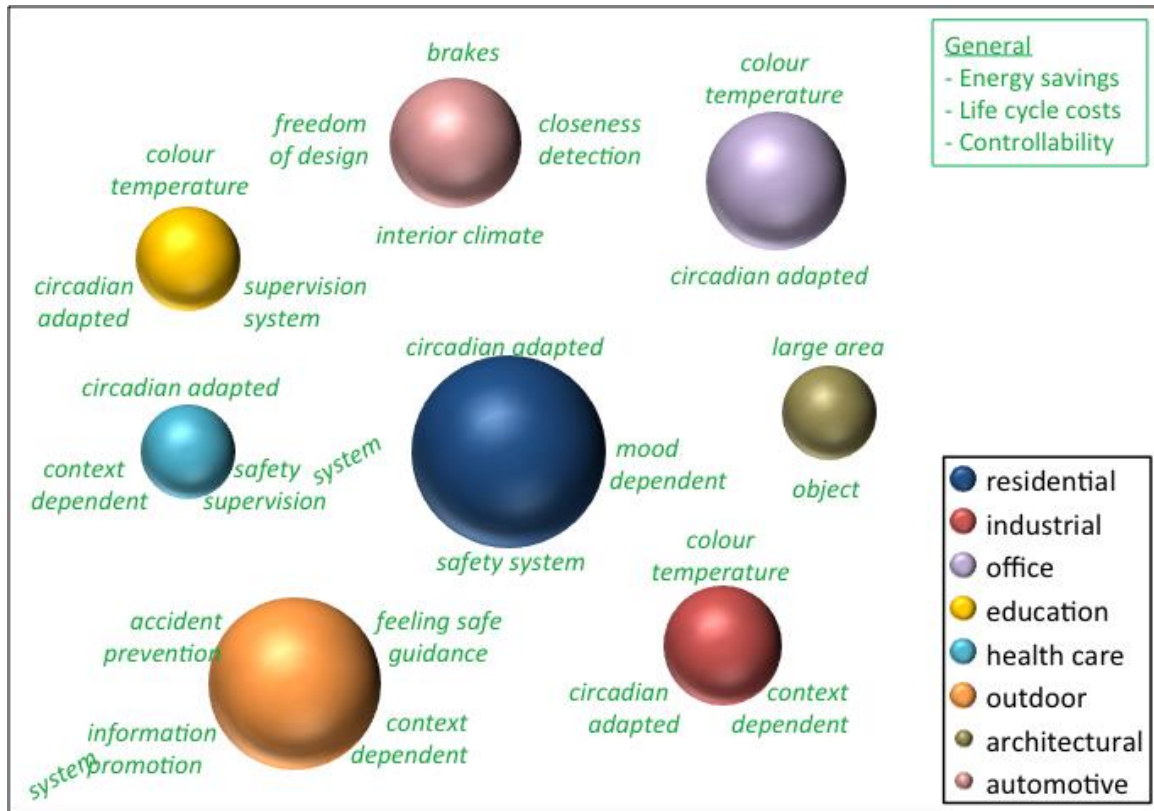
<sup>5</sup> *European Lighting Equipment Market: Opportunities by Vertical Application Sector*, Frost and Sullivan, 2011

Figure 4.1 presents an overview of existing and evolving development drivers related to the various market segments. The drivers include both societal and customer interests that a company can relate to in their marketing and creation of interest.



**Figure 4.1:** Green Business Development Map – Drivers

Figure 4.2 shows an overview of existing and evolving business development opportunities that can be used in the various market segments. The opportunities include both technical aspects and new and enhanced user values.



**Figure 4.2:** Green Business Development Map – Opportunities

Figure 4.3 presents an overview of barriers and hurdles for value enhancing business development, in various market segments. The barriers include a number of uncertainties and problems as a basis for funding for investments. The challenges also include various forms of inertia in the existing value chains and ways of thinking.

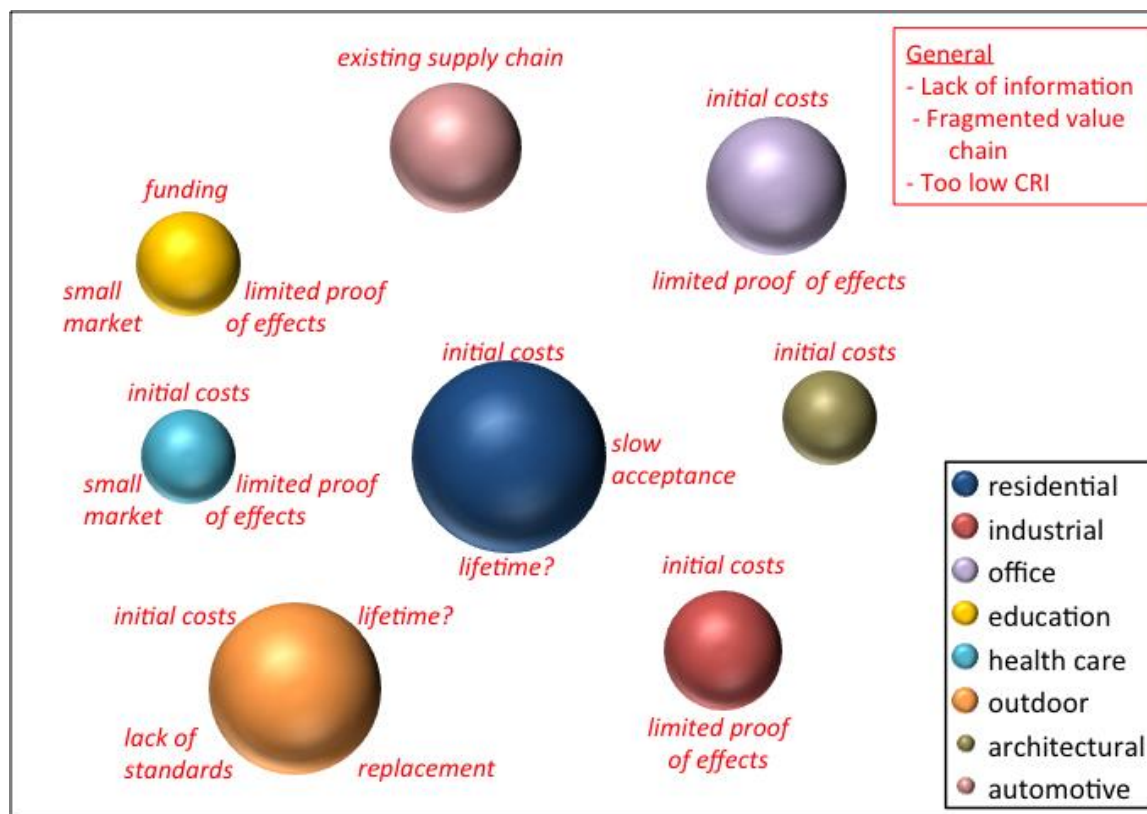


Figure 4.3: Green Business Development Map – Barriers

Table 1: Predictions for 2020 of General Lighting Services (GLS), SSL, Human Centric Lighting (SSL-HCL) and Intelligent Lighting Solutions (SSL-ILS) market volumes globally, and in Europe.

2020 (bn Euro)	Global				Europe			
	GLS	SSL	SSL-HCL	SSL-ILS	GLS	SSL	SSL-HCL	SSL-ILS
residential	31,6	23,0	1,9	1,2	8,4	6,1	0,70	0,31
office	15,0	8,0	1,0	1,6	2,9	1,5	0,20	0,30
shop	8,3	6,0	0,03	1,5	1,5	1,1	0,01	0,28
hospitality	5,6	5,0	0,04	1,3	1,2	1,1	0,01	0,28
industrial	5,4	2,0	1,0	0,40	1,4	0,52	0,26	0,10
outdoor	11	8,0	0,50	2,0	3,5	2,5	0,16	0,63
architectural	5,6	5,0	0,61	1,0	0,92	0,82	0,10	0,16
education	(4)	(2,4)	(0,60)	(0,48)	(1)	(0,6)	0,15	0,12
health care	(4)	(2,4)	(0,40)	(0,48)	(1)	(0,6)	0,10	0,12
automotive	18,0	6,0	3,0	0,30	2,7	0,90	0,45	0,05
backlighting	1,0	1,0	0,50	0,50	0,0	0,0	0,0	0,0
<b>total</b>	<b>101</b>	<b>64,0</b>	<b>8,6</b>	<b>9,8</b>	<b>22,5</b>	<b>14,5</b>	<b>2,1</b>	<b>2,3</b>

( ) included in respective office and residential numbers

**Table 2: Base of predictions for 2020 of GLS, SSL, SSL-HCL and SSL-ILS) market volumes globally, and in Europe.**

2020 (bn Euro)	Global				Europe			
	GLS	SSL	SSL-HCL	SSL-ILS	GLS	SSL	SSL-HCL	SSL-ILS
residential	31,6	23,0	1,9	1,2	8,4	6,1	0,70	0,31
office	15,0	8,0	1,0	1,6	2,9	1,5	0,20	0,30
shop	8,3	6,0	0,03	1,5	1,5	1,1	0,01	0,28
hospitality	5,6	5,0	0,04	1,3	1,2	1,1	0,01	0,28
industrial	5,4	2,0	1,0	0,40	1,4	0,52	0,26	0,10
outdoor	11	8,0	0,50	2,0	3,5	2,5	0,16	0,63
architectural	5,6	5,0	0,61	1,0	0,92	0,82	0,10	0,16
education	(4)	(2,4)	(0,60)	(0,48)	(1)	(0,6)	0,15	0,12
health care	(4)	(2,4)	(0,40)	(0,48)	(1)	(0,6)	0,10	0,12
automotive	18,0	6,0	3,0	0,30	2,7	0,90	0,45	0,05
backlighting	1,0	1,0	0,50	0,50	0,0	0,0	0,0	0,0
<b>total</b>	<b>101</b>	<b>64,0</b>	<b>8,6</b>	<b>9,8</b>	<b>22,5</b>	<b>14,5</b>	<b>2,1</b>	<b>2,3</b>

( ) included in respective office and residential numbers

Base for numbers			
from reports	A	B	C
calculated			
estimated			
		B: McKinsey 2012, Exhibit 12	C: McKinsey 2012, Table 5
	A: McKinsey 2012, Table 2		education Frost & Sullivan 2011
	education based on numbers		health
	health in Europe		automotive: OICA & IHS website 2020: 15% production in Europe
			D: LightingEurope 2013 (conservative)
			outdoor architect. estimate
			e=C*(B/A)
			education 0,6*C
			health
			0,6: average share
		f=B*(D/e)	
		g=x%*B	
	residential	5%	outdoor 25%
	office	20%	architectural 20%
	shop	25%	education 20%
	hospitality	25%	health care 20%
	industrial	20%	automotive 5%

## 2.2 GBDM – A Life Cycle Cost Perspective

The renewal of the lighting sector is, on the one side, related to the new technical opportunities and, on the other side, to the existing lighting sector and the traditional ways of thinking about lighting. The presented estimates of potential business volumes for various market segments in Table 1 have been based on McKinsey data. The McKinsey report builds on the market statistics for general lighting services (GLS) that focuses on product sales and installation contracts. In a Life Cycle Cost (LLC) perspective the operational (energy and maintenance) cost for lighting has to be considered as well. Maintenance cost is difficult to predict as it depends on the specific applications. Energy cost can be estimated based on electricity prices and electricity used for lighting.

For traditional lighting the total energy cost is a number of times higher than the total investment cost for the lighting products, whereas for intelligent SSL solutions it is the other way around, because of increased efficacy. In 2011, the world's electricity generation was about 22,000 TWh<sup>6</sup>, the estimated electricity for lighting was around 2950 TWh<sup>7</sup> and the average European household electricity price was about 0,179 €/kWh<sup>8</sup>. With those numbers the total yearly global cost for lighting electricity is estimated to be in the order of 500 billion € compared to 101 billion € for the GLS investment estimated by McKinsey.

In Figure 5 the development of GLS investment and energy cost is schematically shown. The investment cost are (loosely) based on the McKinsey data, while three cases are considered: (i) GLS without, for the time being, considering SSL systems, (ii) GLS including replacement of traditional lighting by SSL and installation of new SSL systems, (iii) total GLS market, now additionally including HCL and ILS systems.

For GLS without SSL systems the factor of 5 found above for the 2011 ratio of energy cost and investment cost is used to calculate energy cost for the entire period. When SSL replacement and installation of new SSL systems kick in around 2012, the investment cost start to rise and the energy cost to drop, showing the energy saving potential of SSL investments – the political ambition in Europe.

When HCL and ILS find solid ground, which is the ambition of SSL-erate, investment cost and energy cost for lighting systems will be on the rise again. Energy savings, resulting from the switch to SSL, will, at least, partially be lost, but in return value enhancing lighting will become more and more available.

Figure 5 highlights the market volume for the enhancement of user values that is enabled by HCL and ILS. The new level of possible investment cost is related to the new higher user values and also to the energy effectiveness resulting from the possibility to provide the right light, in the right place, at the right time.

The total investment cost for HCL and ILS represents a significant amount of knowledge intensive service and installation jobs, i.e. green jobs. To oversimplify, WP2 suggests that we should try to change the European usage of lighting related money from expenses for electricity to investments in lighting solutions for better quality-of-life.

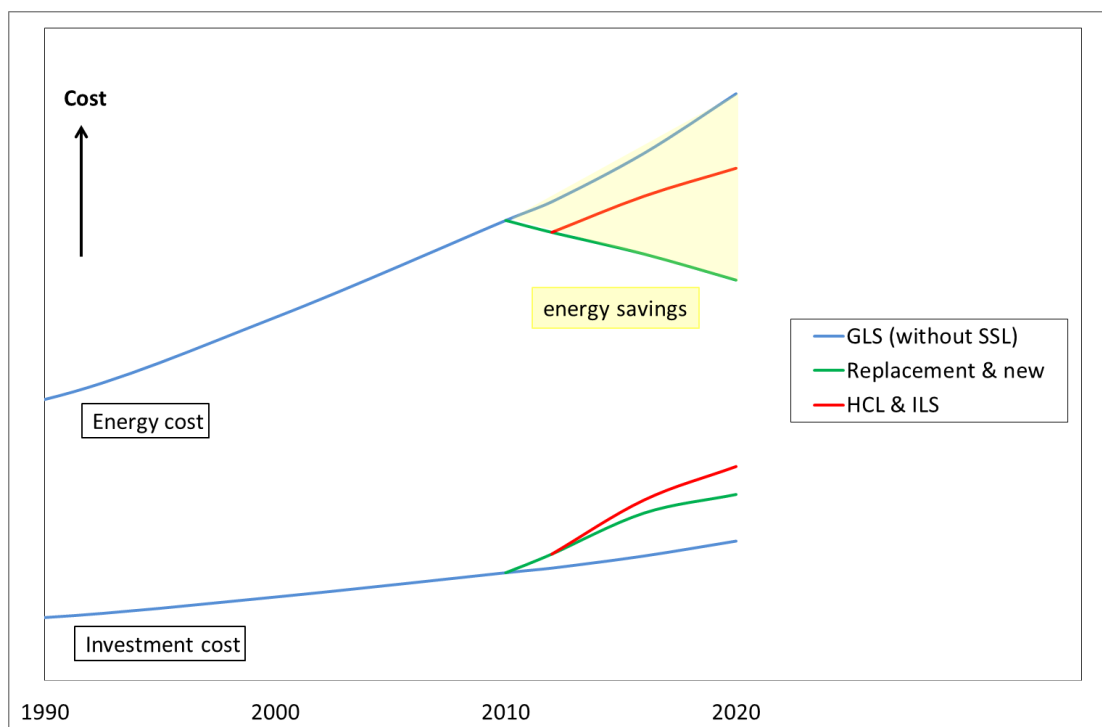
The LLC perspective of Figure 5 is used as a basis for the business development suggestions being prepared for SSL-erate deliverable D2.6.

---

<sup>6</sup> <http://www.iea.org/publications/freepublications/publication/KeyWorld2013.pdf>

<sup>7</sup> <http://www.iea.org/textbase/npsum/III.pdf>

<sup>8</sup> [http://epp.eurostat.ec.europa.eu/statistics\\_explained/index.php/Energy\\_price\\_statistics](http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Energy_price_statistics)



**Figure 5:** Development of investment and energy cost for lighting in Europe. Three cases are considered: GLS without SSL systems, GLS including SSL replacement of traditional lighting and new SSL installations; GLS including as well value enhancing human centric lighting (HCL) and intelligent lighting solutions (ILS) systems.

## 2.3 GBDM – Innovation potential of the HCL and ILS market

To be able to describe the character of various fields of more and less innovative business developments we have selected the Innovation Ambition Matrix<sup>9</sup>. The matrix makes a distinction between transformational developments and gradual ones close to the core of the existing business activities.

The Innovation Ambition Matrix is a framing for comparison of different business ventures, from innovation point of view. Here we use the matrix to compare the character of the development situation for different SSL business segments.

### 2.3.1 The Innovation Ambition Matrix

The figure 6 innovation ambition matrix was developed as an assessment tool for allocation of innovation funding between different initiatives. The innovation ambition matrix acknowledges that the novelty of a company’s offerings and the novelty of its customer markets are a matter of degree. We have overlaid three levels of distance from the company’s current, bottom-left reality. These three levels are **Core**, **Adjacent** and **Transformational**. The Core is optimization of existing products for existing customers, Adjacent expansion from existing business into “new to the company” business, and Transformational innovations for markets that do not yet exist.

<sup>9</sup> *Managing your innovation portfolio*, Nagji & Tuff, Harvard Business Review (The Magazine), 2012

The map image, shown as a background in the established core business area illustrates that in this area there are value chains to adhere to, concepts, measures and established ways of specifying the light. In the transformational area there are no “roads” to follow. In the intermediary, adjacent field it is possible to relate to the old way of thinking. However, there is also a risk that new ideas get caught by old mental models.

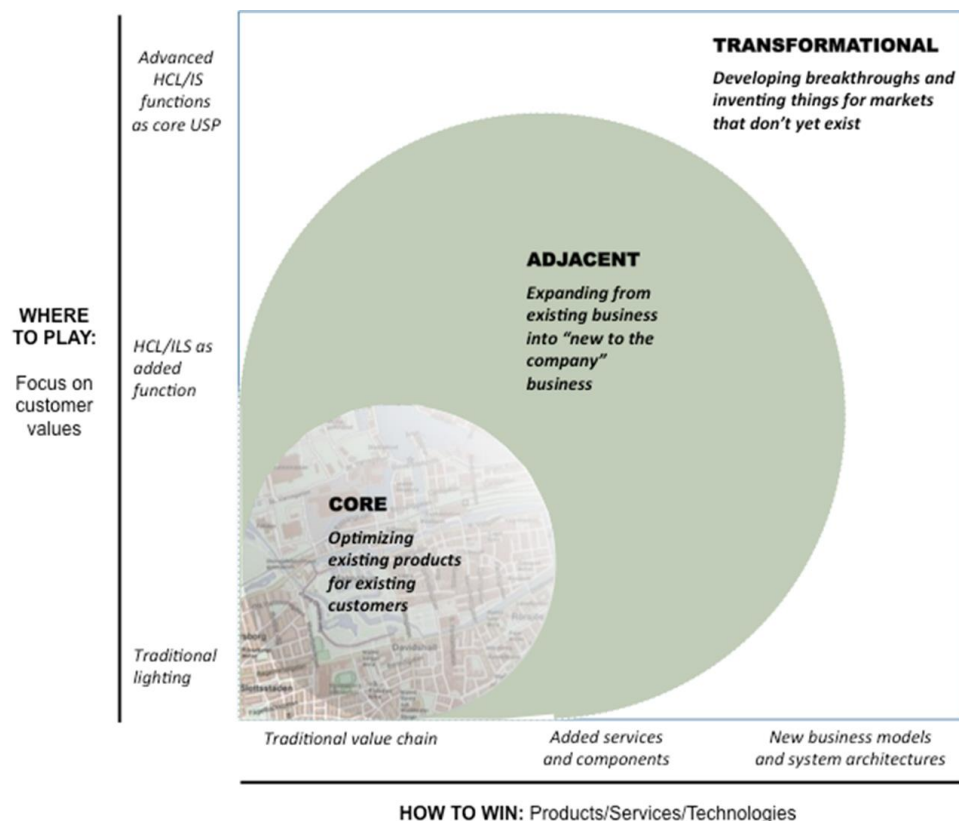


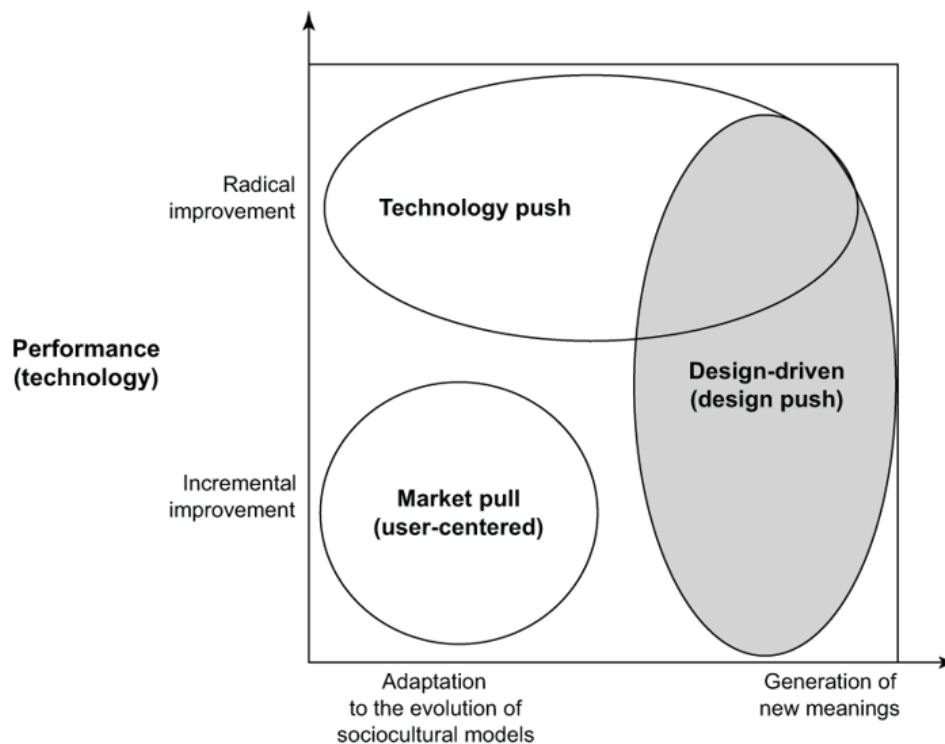
Figure 6: The structure of *innovation ambitions matrix*

The SSL-erate project is aiming for products/solutions/functions on a more sophisticated level, to provide user values that exceed what we are used to think about and what the traditional market has to offer. To facilitate dialogue between renewal oriented customers and renewal oriented suppliers there is a need to develop the common conceptual framing.

When we use the established lighting concepts, measures and refer to traditional application areas e.g. public space lighting and traffic lighting we tend to think in terms of traditional solutions. Who will create the market e.g. for human centric light, context dependent light or living light? New kinds of functionalities that are related to a new meaning of what lighting can provide will normally not be asked for by the public, simply because they have never seen them. The importance of radical renewal is often forgotten or ignored. Figure 7 illustrates the link between technology push, design driven innovation (design push) and market pull (user-centred). Solid State Lighting and ICT enable a huge freedom of action that can provide new levels of added value. So far the development has been driven by technology push and also by the banning of the old technology. This has given some radical improvements in the functionality (y-axis) but hardly any generation of new meanings (x-axis). The lighting knowledge on the user side (market pull) is rather limited and the perception of what lighting is and could be is strongly determined by the way we traditionally are used to think about lighting. Consequently, most customers hardly have any foundation to aim for, desire or



specify significantly new kinds of lighting. This is why it is so difficult to get started in the transformational area in figure 6.



**Figure 7:** Design-driven Innovation – Changing the Rules of Competition by Radically Innovating what Things Mean.

### 2.3.2 Assessment of the innovation potential of the HCL and ILS market

It is a challenge to select appropriate scales for characterizations of different innovations. We need to specify which dimension of renewal we are evaluating, in each specific innovation potential assessment. The unique selling proposition for the Outdoor segment, for example, is not health and wellbeing, but rather the intelligent solution. However, the installation of street lighting that is disturbing peoples’ night sleep is questionable from wellbeing point of view. For most applications there are interrelations between different dimensions and the following presents the innovation potential for different market segments, both in the Human-centric dimension (Figure 9.1) and also in the intelligent systems dimension (Figure 9.2). Here we start by defining those dimensions.

#### **Definition of Human Centric Lighting**

The HCL business development goal is rather difficult to define. At one extreme it tends to be delimited to the now scientifically known circadian effects of the daily variation of the relative amount of 460-500 nm light. At the other extreme the description of HCL tend to include all kinds of light that in some way is said to be better for and/or more appreciated by humans. However this later alternative would tend to include virtually all lighting – nobody says that they are producing lighting that is not good for humans. In this report we use the definition:

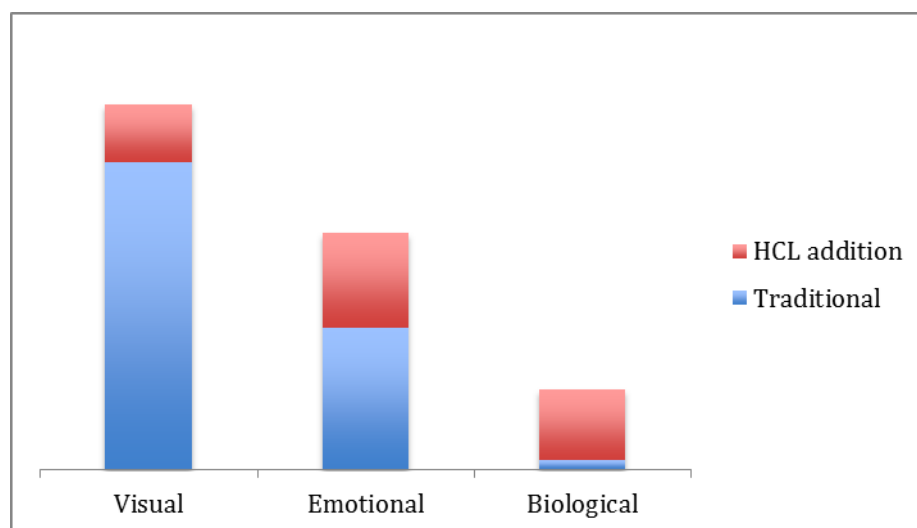
***Human centric lighting here is all kinds of light that improves the sum of the visual, biological and emotional aspects, compared to the kind of light that adhere to the traditional lighting perspective.***

This innovation dimension is related to the understanding of what the users need and want. The human centric light today includes circadian light patterns, dynamic color control and new forms of dynamic user adapted lighting design and control.

The biological nonvisual effects are one possible starting point for HCL. However, the human centric light also includes wellbeing considerations in a broader sense. Furthermore the visual functionality should be at least as good as before and a better visual functionality also is a human centric advantage.

The blue in the figure below illustrates the share of interest in traditional lighting aspects and design priorities, that hardly has included the now topical way of expressing the melatonin related biological considerations. However it is not new that we try to get it dark in our sleeping rooms.

The red parts show the possible HCL additions. It is questionable whether lighting is human centric light when the biological adaption should lead to significant reductions of the visual functionality.



**Figure 8:** The change of perspective from traditional lighting (blue) to HCL (red).

### **Definition of Intelligent Lighting Systems**

The technology of today is enabling virtually unlimited development potential for ILS and synergies with development of smart buildings and smart cities. One dimension is to enable supervision and user and context dependent lighting control functionalities that surpass the traditional fixed dimming schedules. The other dimension is to enable utilization of lighting related data and system solutions as a part of the evolution of smart buildings and smart cities. In this report we use the definition:

***Intelligent Lighting Systems focus on multifaceted utilization of smart systems, both to create more intelligent lighting and for value enhancing development of lighting related installations in synergy with other smart systems.***

This innovation dimension is related to creative developments of and additions to smart system solutions, in the spirit of the Digital agenda for Europe [2010]. ILS is focusing on systemic developments.

### ***Synergies between HCL and ILS***

The creation of positive interaction between HCL and ILS can enhance the total business potential. SSL has a strong connection to knowledge-intensive development of the user value, and ILS is strongly linked to technology-oriented system knowledge. It might be argued that there is a risk for double counting of activities that relate to both HCL and ICL. But from innovation point of view this synergy may enlarge the markets for both HCL and ILS.

### ***Three dimensions for characterization of development processes***

To be able to understand the development circumstances it is relevant to assess the present position, the development velocity and also the acceleration of the development process, i.e. the degree of innovativeness. Explanatory remarks for Figure 9.1 and 9.2:

*Development velocity:* The arrows describe the change of position for the development frontiers from now (2014) to the expected position in 2020. The respective changes of position describe the development velocities. In this perspective SSL-erate is aiming to accelerate the deployment of value enhancing SSL.

*Start position:* The present position of the market frontier for each respective market segments is shown by a small circle.

*2020 position:* The sphere's positions show the estimated position for the respective market segments in 2020.

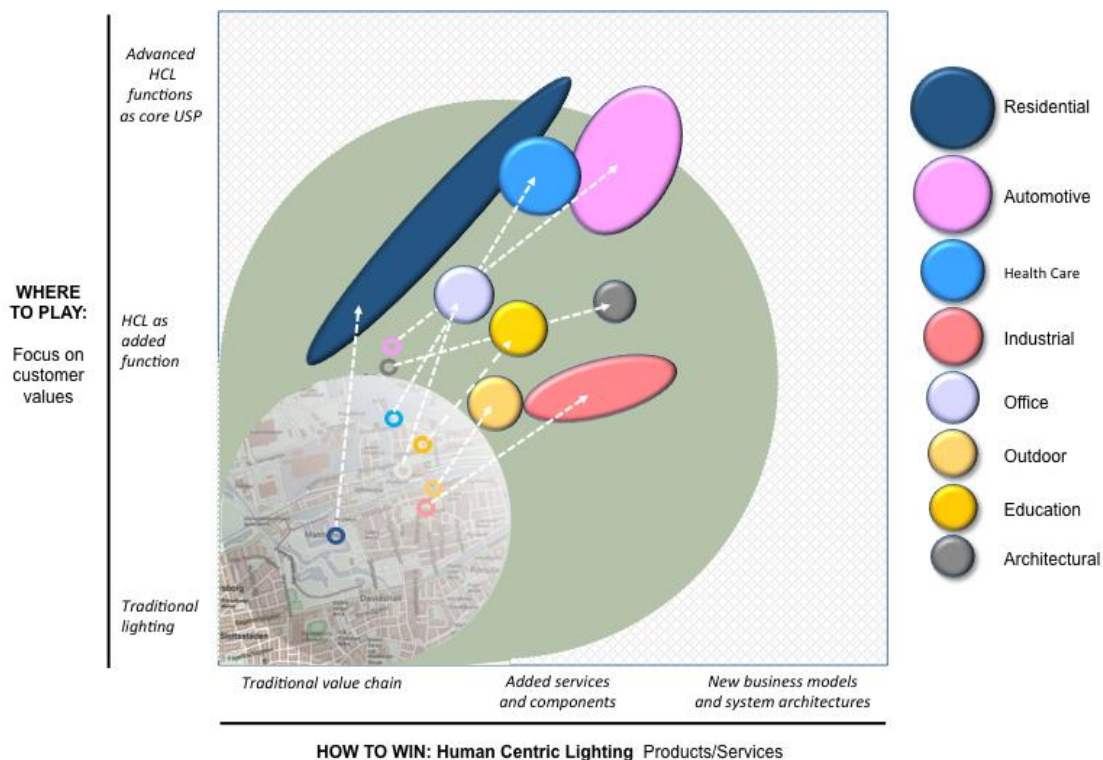
*The shape of the "sphere"* illustrates the character of a market segment and its sub segments in relation to variation of end user values and innovation level of product/service

### 2.3.2.1 Innovation Business Potential for HCL in Europe

The green business development potential is related to both the added values that HCL can provide (fulfillment of visual, biological and emotional needs) and to Intelligent Lighting control and supervision (enabling effective dynamic provision of the right light, in the right place, at the right time).

The HCL customer value takes a starting point in relevant knowledge about the human needs of various dynamic lighting effects, whereas the starting point for the ILS customer is the controllability options.

The business potential for HCL in Europe is shown in in Figure 9.1

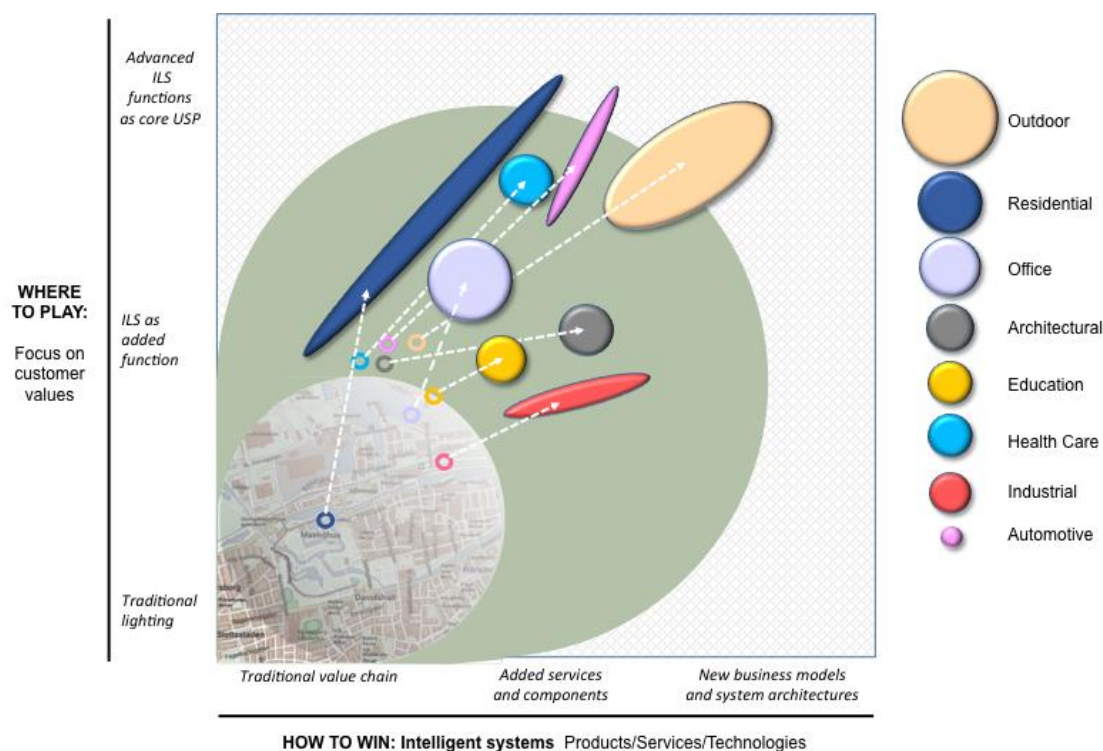


**Figure 9.1:** Possible market development potential for Human Centric Lighting, HCL, from the present positions (shown as small circles) to the estimated “sphere” positions in 2020. The volumes of the “spheres” have been selected to show possible LLC potentials and they deviate from the numbers in table 1.

### 2.3.2.2 Innovation Business Potential for ILS in Europe

The development of intelligent supervision and control system flexibility is a vital aspect of Smart Buildings, Smart Cities and the progress of the digital age. This dimension starts with the ambition to create ever more advanced flexibility and freedom-of-action, to intelligent lighting solutions and also to make use of the Smart Lighting investments as one dimension of the enhancement of the prioritized development of ever more advanced integrated ICT-systems.

Figure 9.2 depicts the business potential for ILS in Europe.



**Figure 9.2:** Possible market development potential for Intelligent Lighting Systems, ILS, from the present positions (shown as small circles) to the estimated “sphere” positions in 2020. The volumes of the “spheres” have been selected to show possible LLC potentials and they deviate from the numbers in table 1.

The intelligent system innovations of Figure 9.2 are aiming to progress in a smart city perspective. The goal here is that the Smart Lighting shall grow in synergy with the buildup of other smart systems, making use of information from other systems, enabling intelligent lighting control while part of intelligent networks.

- Outdoor and Automotive are already working from a dynamic systems perspective
- Some industrial/infrastructural facilities are aiming for integration in smart systems
- Some Hospitality and Architectural segments can gain from the interconnection with external systems
- Shops and Offices are expected to be rather slow in the integration with external developments
- The broad Residential market is expected to be slow in the take up of smart systems although there is significant relevant floor space.

### 3 GBDM support tools: SSL-erate concepts

**USP:** The Unique Selling Proposition (USP) is the unique product benefit a company offers its clients in comparison to its competitors. It can contain a superior functionality, better service, more advanced technology which brings a value in itself, low price, etc. If several companies provide the same USP, a company could utilize an Emotional Selling Proposition (ESP) to differentiate itself, appealing to what a client wants to buy.

**Added user value:** The improved and enhanced value perceived by the user of a product or service.

**Attractiveness:** A comprehensive characteristic of the customer functionality and feeling of ambience that the solution is aiming for.

**Human centric lighting** has a starting point in tuneable SSL that increases our comfort or wellbeing. It is one of the concepts that the European lighting industry is using to articulate the higher user value enabled by SSL. From a philosophical sustainable development point of view this is an anthropocentric perspective, which is good from the added value point of view.

**Smart lighting:** Smart lighting with a basis in SSL and ICT opens up for ever more advanced context dependent, dynamic user adapted lighting. A solution that delivers the right light in the right place at the right time and minimises all disturbing and useless light provides the best user value and also the best solution from sustainability point of view.

**Context dependent lighting** is a term sometimes used to articulate what characterises a lighting environment with higher user value. The context refers to the provision of the right light at the right place at the right time for the user or users in question.

**Business development:** The creation of long-term value for an organization regarding customers, markets and relationships.

**Energy saving:** Energy saving related to lighting consists of energy efficiency (technology related) and energy effectiveness (controllability related).

**Green business:** SSL-erate relates to the growing awareness about the social and societal significance of human-centric lighting. Knowing now that character and quality of light is important for health and wellbeing it is a Societal Social Responsibility (analogous to Corporate Social Responsibility) to invest in better lighting. There is big political interest in the energy saving potential of SSL. Furthermore, it is a vital societal priority to create “green jobs”.

**Sustainable development:** In this report the definition in the Brundtland report, *Our common future*, 1987, is used:

*Sustainable development is a **process of change** in which the exploitation of resources, the direction of investments, the orientation of technical development and institutional change are all in harmony and **enhance** both current and future potential to meet human needs and aspirations.*

Please note that “sustainable development” is often used in a more narrow sense.

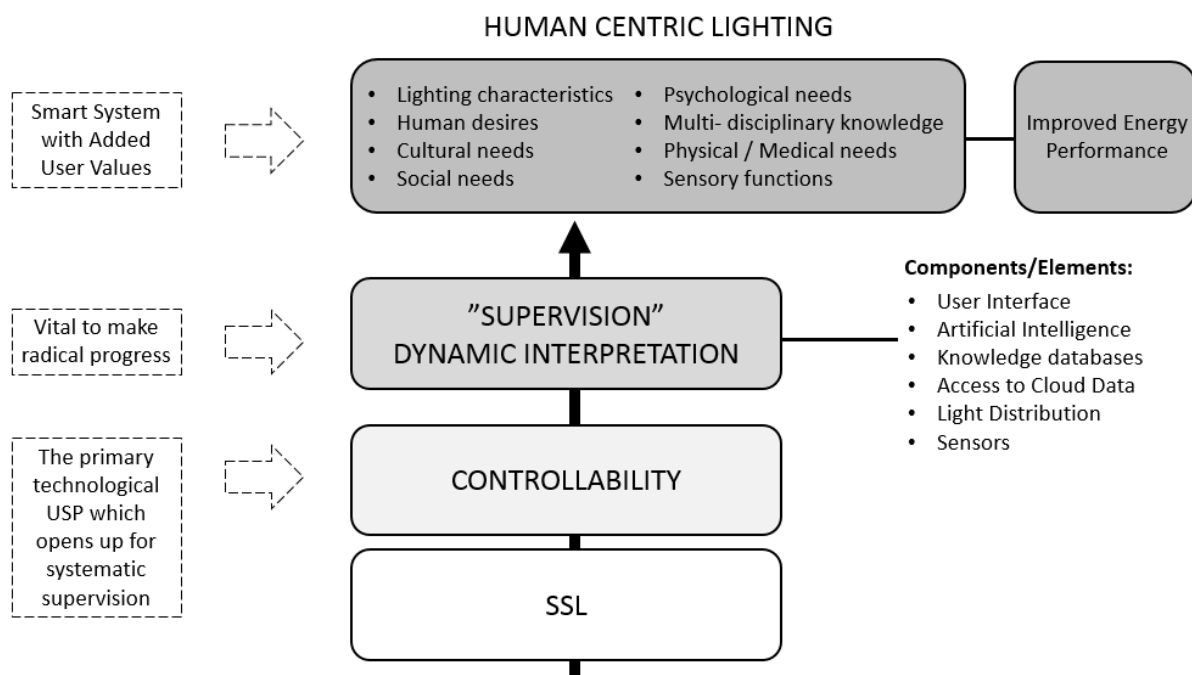
**Meaningful:** In addition to meaningful investments, meaningful business endeavours and meaningful jobs, it is also relevant to use “meaningful lighting”, e.g. reading light when there is a need to read and activating light when it is needed to wake up. In SSL-erate we have started to use this conceptualization as a tool for more coherent dialogue about the synergy between sustainable development, enhanced user value, business opportunities and green jobs.

**SSL (Solid State Lighting):** SSL refers to a type of lighting that uses semiconductor light-emitting diodes (LEDs), organic light-emitting diodes (OLED), or polymer light-emitting diodes (PLED) as sources of illumination. SSL enables not only much more effective light engines but also a much more advanced situational supervision and lighting control.

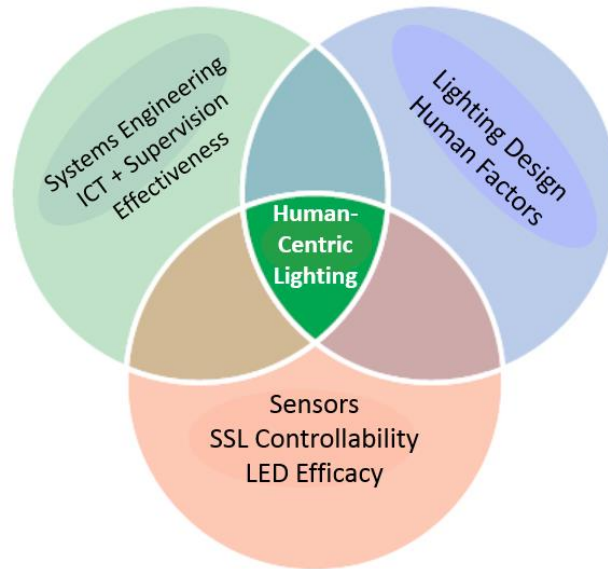
### 3.1 Unique Selling Proposition with SSL

The primary SSL USP is the controllability of illumination, e.g. of the spectral distribution.

The combination of SSL and ICT enables huge opportunities for user adapted solutions, such as systematic supervision (see Figure 10.1 and 10.2), and for improved energy performance.



**Figure 10.1:** Unique Selling Propositions for SSL



**Figure 10.2:** Human-Centric lighting as a synergy between Lighting Design/Human factors, the physical SSL-controllability and the ICT-based potential for value enhancing Systems Engineering.

Controlling illumination with ICT can create a certain lighting atmosphere at any time. However, the way humans experience light and are affected by light has not been determined beyond any doubt. Multi-disciplinary knowledge has to be acquired to know what light is needed at a specific time. Furthermore, there is need for a common language to describe the different light conditions. To invest in healthier and better user adapted lighting is a Social Corporate Responsibility (SCR) and an investment for sustainable development.



## 4 GBDM support tools: Business Potential for SSL

This chapter identifies market segments that can benefit from the effects of Smart and Human Centric Lighting. In addition, a tool to assess the innovation potential for different market segments is presented. This chapter is mainly built upon market knowledge gained from expert interviews, workshops and application workshops documented in D2.2, D2.3 and D2.4.

### 4.1 Business potential for various market segments

The market segments in this study relate to the structure in a recent McKinsey study<sup>10</sup> and also to a recent study of the development potentials for Human Centric Lighting<sup>11</sup>. The underlying market model to single out the segments below is based on relevant floor space for HCL made available through new buildings and renovations. The majority of HCL and ILS installations are expected to be in renovated buildings the years to come.

- Residential
- Industrial
- Office
- Education
- Health Care
- Outdoor
- Architectural
- Automotive

The indoor market segments have particular potential to work with HCL in a health and wellbeing perspective.

#### 4.1.1 Residential

We spend most of our time inside buildings and consequently character and quality of the artificial indoor lighting is vital for our health and wellbeing. One group that need good lighting and spend a lot of time indoors is elderly people, see figure 11.

We live longer and light has the potential to enable elderly people to live their lives independently at home as long as possible and to offer a high quality of life in elderly care centers. Daylight combined with artificial light with appropriate intensity and colour temperature during day, and low light levels during night in order not to disturb sleep will be valuable improvements. Elderly people can have significant visual problems; over 15% in the UK are registered as "visually impaired". One way to solve this is to provide more light sources with lower luminance.

Detecting & sensing devices should be used to control lighting and could also give information about the status of a room and its inhabitants. Such information is already in use for monitoring elderly in third & fourth generation systems of domotics/gerontechnology through pattern recognition.

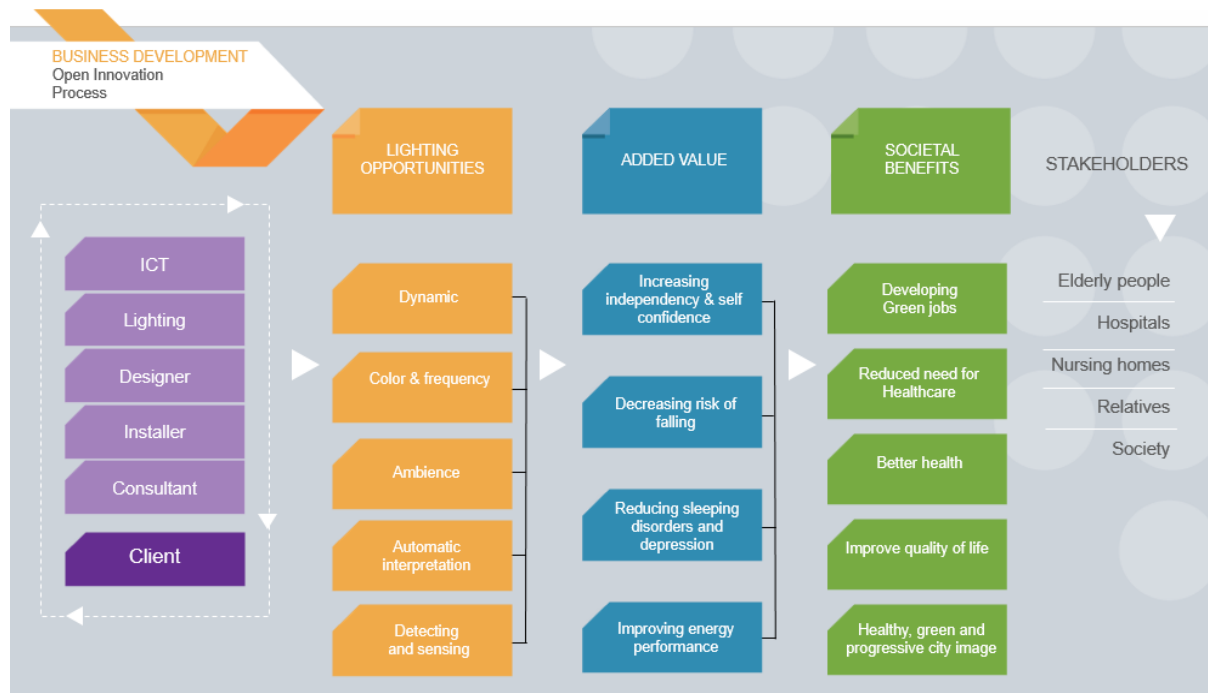
---

<sup>10</sup> *Lighting the way: perspectives on the global lighting market* - 2<sup>nd</sup> Edition. McKinsey, 2012

<sup>11</sup> *Human Centric Lighting: Going Beyond Energy Efficiency* - An introduction to the LightingEurope, ZVEI, and A.T. Kearney market study, 2013

Illumination of appropriate intensity at night-time is important to lower risk for injuries. To illuminate specific objects, corners, and edges when needed is good for the user as well as for energy savings.

The visual ergonomics is important. For example, it has been noticed that several elderly people have problems to change bulbs, have poor lighting at the kitchen counter and in the hall, have difficulty to access light switches, because it is crowded, and electrical outlets if they are sitting close to the floor etc. This is important to consider when changing to a new system.



**Figure 11:** SSL creating added values and meaning for elderly people

#### 4.1.2 Lighting for work places

An increasing number of people suffer from work related stress symptoms leading to mental distress, depression and absenteeism. Humanly better light environments have great potential to develop and improve the functionality and working environment in all kinds of working places, figure 12, from ordinary office places to control room environments.

It is now obvious that light affect our health and wellbeing and therefore it is a Corporate Social Responsibility (CSR) to take care of our employees' health and wellbeing by giving them the best possible light. It is about branding as a knowledgeable company that cares.

The right light, in the right place, at the right time has the potential to improve the health and wellbeing at many working places and contribute to less absenteeism.

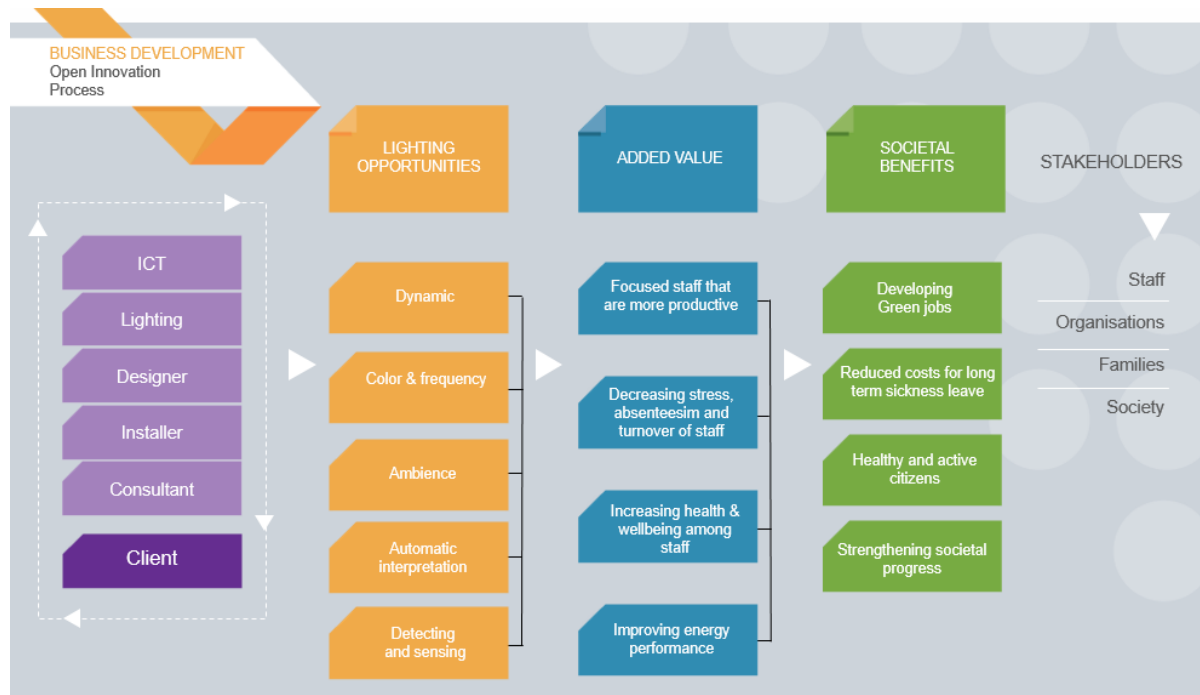


Figure 12: **SSL creating added values and meaning at workplaces**

#### 4.1.2.1 Industrial

The lighting strongly affects the employees' working position. Studies in visual ergonomics have shown that by adapting the lighting, it is possible to avoid pain in back and neck in workplaces where physical tasks are performed.

Smart lighting can be used to improve the safety, signal maintenance need for machinery and equipment and speed up production in industrial facilities. It can work as a guiding means through indication of the way in industrial facilities, highlighting exits and emergencies.

The lighting in control room environments has been developed to not disturb the flow and transfer of information on screens, and to keep the operators as awake as possible all the time. It is now technically possible to use light to guide the sight and interest to what is most important at a particular moment. New research has shown that the variation of the amount of blue light is important for the synchronisation of our body's circadian clock which is particularly important for shift-workers. The right light at the right time can make shift working more attractive. By adjusting the light absenteeism can be reduced.

#### 4.1.2.2 Office

It has been shown that blue light is stimulating, because it decreases the levels of melatonin, and that use of this light in the morning can increase the productivity. On a more fundamental level, it is obvious that we as a species have evolved and appreciate the character and dynamics of the natural light.

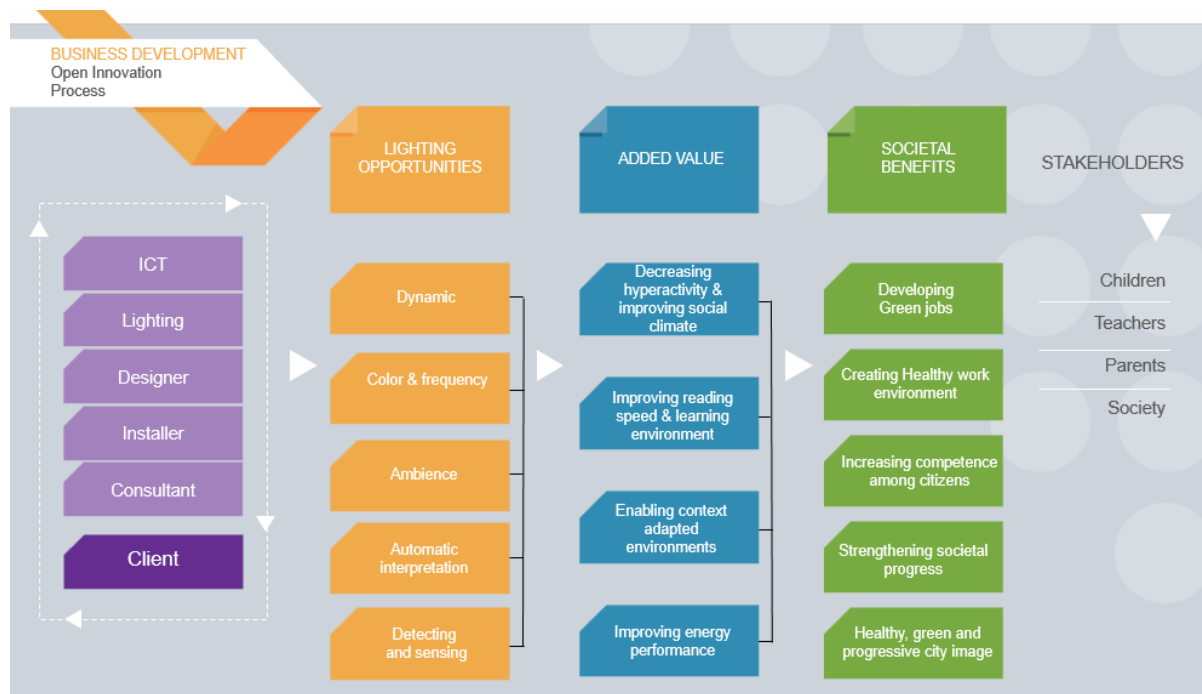
The light affects the hormonal balance in the body, especially cortisol and melatonin, and by creating a dynamic light that is suited to our biological clock the productivity can be increased.

### 4.1.3 Education

The lighting in most classrooms is not adapted to the new circumstances with screens and smaller working groups. The number of diagnoses (autism, hyperactivity etc.) is increasing and consequently a possible starting point for smart HCL systems is children with specific needs. Better lighting has the potential to improve learning results and the social climate, figure 13.

The awareness about the possible benefits with SSL is rather low and the main challenge to enter the school lighting market is the funding problems. To get the message across that human centric lighting has the ability to improve schools environments to promote both better results, and health and wellbeing is fundamental. Besides the students, the society as a whole benefits from better school results and future competencies.

Funding for improved lighting in schools is also an opportunity for a company to market themselves as caring for sensitive individuals (social entrepreneurship).



**Figure 13:** SSL creating added value and meaning in schools

### 4.1.4 Health Care

Light of the right intensity and wavelength can be used to improve visibility for surgeons, reduce anxiety and to speed up recovery time of patients. Light can also play a key role in the everyday life of doctors, nurses, cleaning staff etc. especially those who are working night shift. Blue light can be used to keep them alert and prevent mistakes and red light can be used to calm them down in a stressful everyday life. Healthy happy hospital staff is an asset to the hospital and its patients.

Light can have a key role to play in the preventative care. It can be used to prevent falling accidents by highlighting risk areas, such as door jambs and to improve sleep by controlling the light by lowering the light intensity and using the right wavelengths during night-time.

One thing that characterizes a hospital is that it can be associated with very strong emotions. It is essential to handle those emotions in a sensible way and lighting is a cost effective way to improve the wellbeing of the patients and relatives who are in or come in contact with the hospital. Such an effort can be the first step in taking patients from hospitals to health care centres.

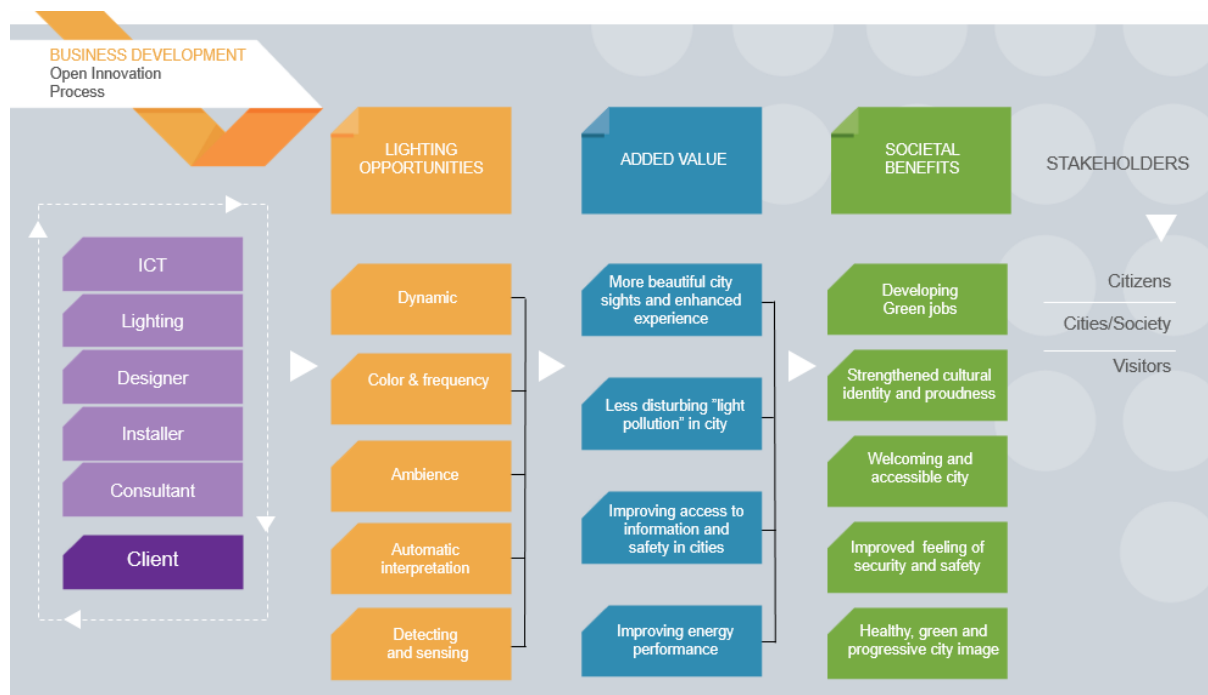
### 4.1.5 Outdoor

Many cities suffer from unattractive environments, information is often not easily accessible and to walk alone at night in a city environment is often perceived as unsafe or even dangerous. Smart lighting can be used to provide and enhance entertainment and beauty, function as an information bearer, as well as, improve safety and security in less populated areas at night time, figure 14. Smart Lighting can be a cost-efficient way to enhance the value of the city’s infrastructure and to promote the higher quality of life in Smart and Sustainable cities. It can help city visitors to find car parking space and to find direction and transportation to different parts of the city.

One large business area for SSL is street lighting. This is an interesting field of development for dynamic lighting control, connected to traffic management and traffic lights. The lighting for airports is more technically advanced, but the total volume is much smaller.

If the solution is highlighted/promoted as a tool to consciously move towards a more sustainable healthy, “green”, beautiful, progressive and caring society it may also improve the city image externally, as well as, among its citizens. This may affect the willingness of people to come to the city and to settle down.

The citizens should be engaged in a dialogue of how they would like to experience their city, e.g. what added values the intelligent lighting solutions should offer them, and how this could enforce and develop the cultural identity of the city. Healthier societies have the additional benefit of being less costly.



**Figure 14:** SSL creating added values and meaning in cities

### ***Case study – Amsterdam Arena***

Trials of smart street lighting are being installed in the vicinity of the Amsterdam Arena. Remote operation and sensors are used to adjust the lighting for a range of situations, e.g. dimming for adjusting to the weather and coloured lighting to control the flow of traffic and pedestrians. Movement sensors will be used to register if more or less light is needed and saved energy can be used for other functions, such as powering the Wi-Fi network or measuring air quality. The smart street lighting project is part of the Smart Lights in Metropolitan Areas project and the project will be extended to the Amsterdam Poort shopping centre and the nearby residential area.

## **4.1.6 Architectural**

Smart lighting is visible innovation which literally shows that the city is investing in smart systems to improve the infrastructure. A beautiful architectural lighting design makes the city an attractive place to be and provides evidence that the city has time and money to invest. Smart lighting is a cost efficient way to significantly improve the image of the city.

It is important to enable lighting designers, system engineers and light researchers from different fields to develop together solutions that are appreciated from user point of view as well as make use of the potential for energy savings that are inherent to the public space. Fine-tuning of street lighting and other types of lighting in the public space, such as the lighting of public buildings, the lighting in shop windows, media lighting, will yield the best result.

## **4.1.7 Automotive**

Luxury cars (and business airplanes) are leading development areas for more advanced functionalities, and not only for lighting. Particular for this field is that when a more advanced lighting feature can be used as a branding characteristic of a new car model it may help to pay for the whole car. Such a relation is not unique for cars; it is also possible to increase the value of a house by means of better lighting and better lighting is also a cost effective tool to make work-places more attractive. Still, the relation between advanced lighting and resulting business advantages seems to be much more noted for exclusive cars and airplanes than for most other applications.

This means that lighting in cars and airplanes can be used to showcase the benefits of the new lighting, which can make other areas more interested to invest in lighting. Lighting can be used to improve the safety, comfort and attractiveness of the vehicle.

Lighting can be used to demonstrate the ability of the car to supervise, sense movement and prevent accidents. Smart lighting is visible innovation.

## 5 GBDM support tools: Stakeholders

The arena for sustainability oriented business development has a variety of actors. In addition to renewal oriented suppliers and customers for the human-centric lighting functionalities themselves, it is highly relevant to consider the green actors, policies, facilitators and funding opportunities. These resources and control measures are available at different levels and in different dimensions.

Several customers, both public ones like cities, and their internal stakeholders, and also various companies and other private customers have a number of green priorities, here primarily energy savings and also recycling, waste management and also continuously increasing interest in preventing light pollution. This has particularly potential for the social sustainability dimension: Now that we know that the character and quality of light is important for health and wellbeing it has become a SSR (societal social responsibility, analogous to CSR) to invest in better lighting.

### ***Trade Unions and Clusters***

Looking at the innovation drive and facilitation itself organizations like trade unions, clusters and other innovation promoting actors are particularly interesting.

### ***EU, Nations and Regions***

In the political dimension EU, and most nations and regions, are promoting a number of green priorities. There is quite a lot of funding available for energy saving investments. Proper and clever utilization of these resources can make smart human-centric SSL truly attractive for Europe. Furthermore, the political interest in better SSL means that there is a kind of “stage” on which the leading actors, customers as well as suppliers, can flaunt their attractive workplaces and living-environments.

### ***Labour Unions***

In the quality-of-life dimension various user advocates, such as labour unions, can take a vivacious leader role. To explain, we start with an example; as you may know the TCO Certified label on terminal and computer screens has become a kind of quality label. The starting point for this development was that the Swedish Trade Union Confederation TCO took a principle position for better working environments, in particular for people that spend most of their working hours in front of computer terminal screens. The TCO actors and the leading screen suppliers together triggered new interest in better screens and introduced the TCO label. This “co-branding” resulted in better business development circumstances for the leading suppliers and better working conditions for numerous office workers, not only in Sweden.

### ***Non-Governmental Organizations***

TCO is promoting the interests of “their own workers”. However, also a number of other NGOs can take analogous roles for even larger user groups. For example, teacher unions and associations of headmasters may be able to boost their own roles as advocates for the pupil’s interest. The actors that develop a more significant role as advocates for the aging populations’ interest can make themselves quite influential the coming decade.

## 6 GBDM support tools: Green as a competitive advantage

The main ambition of the SSL-erate Green Business Development Map is to activate the Green, i.e. Societal Sustainable Development priorities as motives, resources and tools for accelerated deployment of SSL-based solutions with high user value. Therefore, we aim to enhance the usefulness of the existing green toolbox, containing Environmental Management System (EMS) and Quality Management Systems (QMS), LCA and LCC. We expect that the growing in those aspects will enhance the interest in context- and user-adapted SSL as an important tool for sustainable societal development.

In terms of European business volume and jobs, the consultation for the Green Lighting Paper<sup>12</sup> indicated that the end users of the value chain are most important. However, there is a need for leading knowledge and forefront technological insights to be able to make optimum use of the opportunities. Consequently it is important to be involved in developments for high-end applications, and innovative situations with adequate funding for innovation.

“The view taken by the majority of the industry stakeholders is that 95% of the value chain will be created in lighting solutions and only 5% in light sources.” This is vital for the European lighting sector and also for people that today are working in other sectors e.g. construction, facility management, energy services, control systems, ICT applications and numerous services where better lighting is a “tool” to attract positive interest. The political interest in innovation is strong support for public funding of renewal. This interest also supports an opening up of public procurement procedures and open dialogue between suppliers and customers. It is now possible to build advanced dynamic context-dependent user-adapted lighting systems, see Lighting the Cities<sup>13</sup>. This enables a new level of synergy between energy savings and higher user values.

To build positive interest it is vital to put the quality of the lighting as a first priority, and e.g. the Swedish Energy Agency has done this in their vision for the deployment of SSL. In this Eco design perspective energy analyses can be utilized as guidance for development of synergies between better lighting and energy savings. The goal is to develop system solutions that provide the right light, in the right place, at the right time, avoiding disturbing and useless light. An energy map that includes the lighting dynamics can be used as one of the tools for this system optimization.

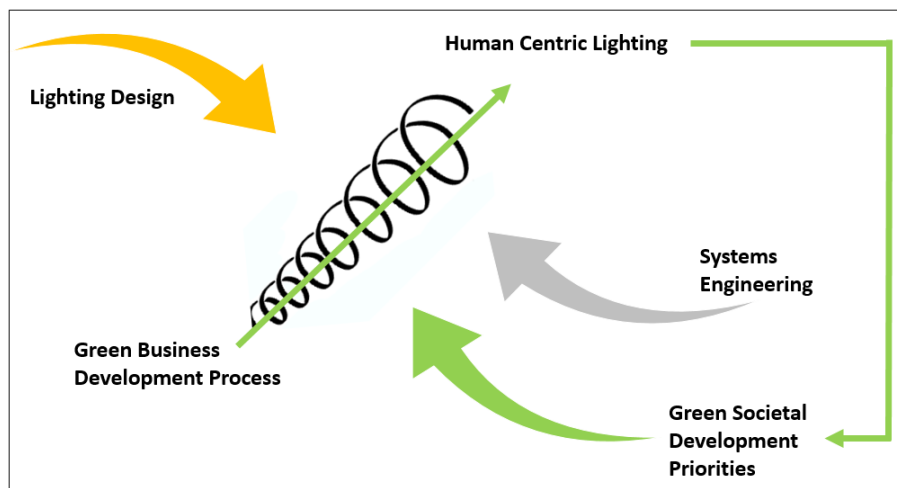
Figure 15 illustrates human-Centric lighting as a goal for the Green Business Development spiral driven by the SSL-erate Green Societal Sustainable development priorities. To achieve attractive results, lighting design continues to be important and to make qualified use of the new technology Systems engineering now also is important.

---

<sup>12</sup> *Green Paper - Lighting the Future: Accelerating the deployment of innovative lighting technologies* [COM(2011) 889], Results of the Public Consultation

<sup>13</sup> [http://cordis.europa.eu/fp7/ict/photronics/docs/ssl-cip/lighting-the-cities\\_en.pdf](http://cordis.europa.eu/fp7/ict/photronics/docs/ssl-cip/lighting-the-cities_en.pdf)





**Figure 15:** Human-Centric lighting as a goal for the Green Business Development spiral driven by the SSL-erate Green Societal Sustainable development priorities

In traditional lighting, the total cost of ownership (TCO) is in focus, dominated by energy and initial purchase cost. Besides the ability to save energy, perceived superior value is the actual SSL competitive advantage:

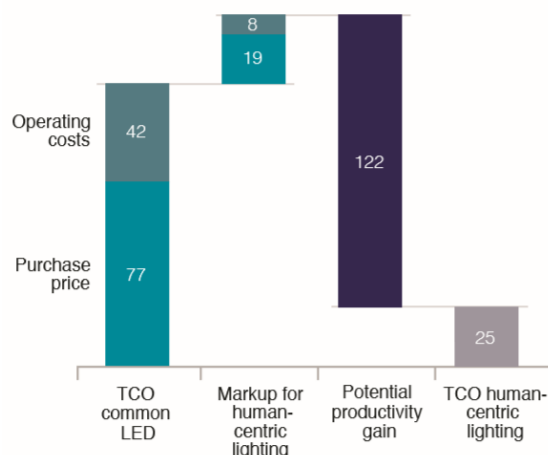
*Competitive advantage grows out of value a firm is able to create for its buyers that exceeds the firm's cost of creating it. Value is what buyers are willing to pay, and superior value stems from offering lower prices than competitors for equivalent benefits or providing unique benefits that more than offset a higher price. There are two basic types of competitive advantage: cost leadership and differentiation. (Porter, 1985<sup>14</sup>)*

The main science based SSL-erate development field is health and wellbeing. Smart and intelligent lighting solutions can provide new functional values that are more prone to use a differentiation strategy rather than a cost leadership strategy. Our intent is to move from 'Total Cost of Ownership' to 'Total Value of Ownership' in which besides TCO-factors also the new values are considered.

Figure 16 highlights the benefits with Human Centric Lighting compared to common LED lighting from a total cost of ownership perspective.

Figure 16 is based on a case study of a 1500 square meters factory workshop where the benefits with Smart Lighting not only related to enhanced mood of staff but also to financial benefits due to improved power consumption and productivity gains.

<sup>14</sup> *Competitive Advantage*. Porter, M. New York: The Free Press. (1985)



**Figure 16:** Total Cost of Ownership (TCO) of Human Centric vs. common LED lighting (in € k)<sup>15</sup>

## 6.1 Traditional Green Process tools

The traditional process tools, quality and environmental management systems (QMS and EMS), are an established way of working with the quality and environmental dimension, and describe the Open Innovation context.

QMS and EMS are closely related to increased business performance and higher quality of products and services. These methods are also linguistic tools to build a common understanding and consensus between SSL solution suppliers and customers.

SSL applications applied in the right way will increase a company's ability to not only reduce energy consumption and lower costs but also to create a higher-added, green value. These kinds of "green benefits" should be highlighted in the promotion of Smart Lighting solutions.

### **PDCA (Plan-Do-Check-Act)**

The PDCA cycle<sup>16</sup> (plan-do-check-act or plan-do-check-adjust) is a process oriented management method in four steps applied in business to control and make continuous improvement of processes and products which are closely related to quality management. In this context, the "SSL-erate lighting characteristics", see section 7.1.2, can provide:

- A support tool in the planning of new light environments. The lighting characters are a linguistic and visual tool box that gives a more concrete basis for clarification of the customer needs (Plan)
- A possible starting point for the design of atmosphere based light solutions (Do)
- The difficulties to measure and talk about the differences between different light environments result in difficulties to motivate investments in dynamic lighting. The lighting characters provide a starting point in the dialogue about and the evaluation of the customer needs (Check)
- A framing and reference point in the development of the linguistic toolbox (Act)

<sup>15</sup> *Human Centric Lighting: Going Beyond Energy Efficiency* - An introduction to the LightingEurope, ZVEI, and A.T. Kearney market study, 2013

<sup>16</sup> *The PDCA Cycle*. W, Edwards. The Deming Institute. <https://www.deming.org/theman/theories/pdsacycle>, 2014

### **Quality Management Systems**

Quality Management Systems highlight the importance of doing the right things at the right time in the right place. QMS and EMS promote the creation of not only higher end-user values but also of more successful and profitable business development.

Djupenström (2010)<sup>17</sup> has evaluated the European Foundation for Quality Management's (EFQM) leadership capability enhancement program (Pegasus) as a tool for sustainable development. She came to the conclusion that most of the EFQM criteria and the priorities in the Pegasus leadership training have some relationship to sustainable development priorities. The results of the evaluation suggested 18 improvement areas, whereof 16 were related to sustainable development priorities.

Porter and van der Linde showcased the evident synergies between business development and sustainable development in the article, *Green and Competitive – Ending the Stalemate*<sup>18</sup>. In addition, well-cited authors have highlighted the link between better results and lower costs<sup>19 20 2122</sup>.

### **Eco-innovation process**

Eco-innovation can happen where business meets the environment. The entire life-cycle of a product is taken into account, from production (or even the extraction of resources) to disposal. Material as well as energy is included in the assessment. An example of a tool made to integrate sustainability consideration in a company's design and innovation process is:

<http://www.ecodesignlink.be/en/sis-toolkit-1>

The following describes a green business development strategy developed by the Gent SSL-erate lighting Cluster (*Groen Licht Vlaanderen Cluster*), see also figure 17.

#### **1. Explore motivation and business case**

Initially a company's internal capacity and values, as well as the external societal environmental value drivers for eco-innovation should be explored and identified. The major potential value drivers, markets, customers segments, supply chain partners and legislation should then form the basis to explore and define a valuable eco-innovation strategy.

#### **2. Explore strategy**

The resource efficiency optimization potential is then explored within the company in terms of material content, energy consumption, performance, re-use, product life, and end of life. Based on this assessment a strategy for the company's value creation is chosen which economic and ecologic aspects are consistent. Key partnerships with actors in the value chain are established.

#### **3. Build pathway and action plan**

In order to explore which business model fits the chosen strategy, and how to assure maximum capture of value within the business model and through the product design, as well as what impact these choices would have on the organisation; a pathway and action plan should be outlined. The business model (step 4) and the product and service design (step 5) need to be explored.

---

<sup>17</sup> *Facilitating Sustainable Innovation through Collaboration*, Djupenström et al. pp 17-39, Springer Netherlands, 2010

<sup>18</sup> *Green and Competitive: Ending the Stalemate*. M, Porter & C, van der Linde. Harvard Business Review., 1995

<sup>19</sup> *Factor Four – Doubling wealth, Halving resource use*. Von Weizsäcker et al. Earthscan , 1998

<sup>20</sup> *Sensemaking in organizations*, Weick, K. E. Thousand Oaks, CA: Sage, 1995

<sup>21</sup> *Organizing and the process of sensemaking and organizing*. Weick et al. Organization Science, 16(4), pp 409-421, 2005

<sup>22</sup> *The practice of adaptive leadership: Tools and tactics for changing your organization*. Heifetz, R. Boston: MA: Harvard Business Press, 2009

**4. Explore business model**

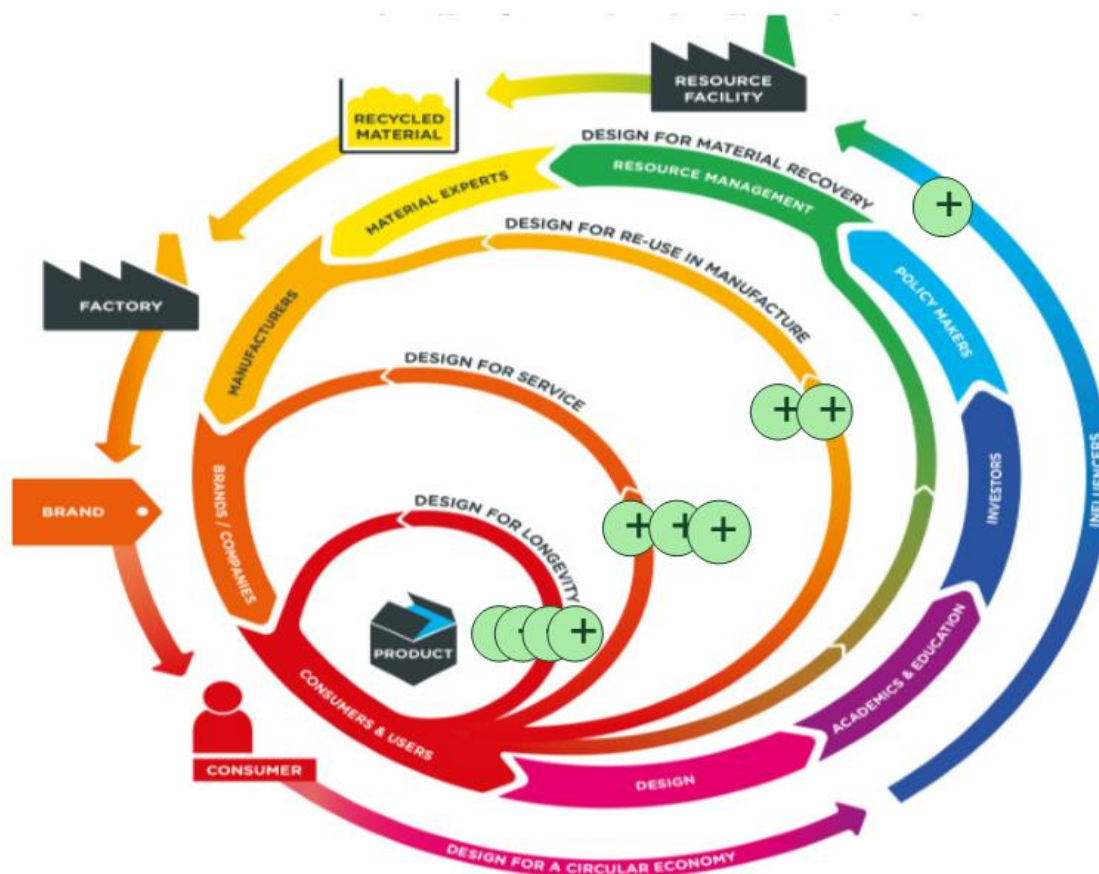
Investigate what business model could capture the economic and ecological values related to the product and the service, in both the distribution channel and in the minds of the customers. Key business concepts in line with the strategy are identified which allows maximum value creation, and relevant partnerships in the value chain are set-up.

**5. Explore product and service design**

Explore how to design products and services maximizing economic and ecological value capture aimed at identifying the key product and design attributes in line with the strategy. Partnerships in the value chain which support the strategic product and service design decision are set-up.

**6. Review and test**

This last step in the eco-innovation process is the set-up of a demonstration case in order to evaluate the degree of eco-innovation (economic and ecological) of the company or projects which could secure continuous improvements of the whole eco-innovation process (step 1 to 6). Review and test by setting up and measure eco-innovation through the demonstration case which allows to qualify and quantify the ecological and economic impact prior to and after the eco-innovation implementation.



**Figure 17: Environmental value creation strategies**

## 6.2 Traditional Green Assessment Tools

Energy analyses and environmental Life Cycle Assessments of material flows can be used as tools for assessments of the business situation. Scarce materials are interesting, because most of the existing plants and animals are not adapted to those materials. Some of the materials in electronics, LED and light conversion phosphors are quite scarce, also from business point of view (see also D2.1). Assessments of recycling opportunities can also provide guidance for strategic planning and development of new business models.

However, the most direct business value of energy and LCA knowledge is that it can be a competitive advantage, e.g. when tendering for energy saving investments. It is also a possible branding advantage to show concern and knowledge about the underlying green priorities. In depth understanding of the possible synergies between user value priorities and green priorities is a possible competitive advantage for knowledgeable lighting companies.

### ***LCA (Life Cycle Assessment)***

An SSL company in the forefront needs to be able to relate their work to a positive societal development. SSL is energy efficient in itself, but the large savings potential lies in the ability to create just the light that we want and nothing else. An optimal solution for the user is also an optimal solution from energy efficiency point of view.

The standard for LCA (ISO14040, 1997) focuses on the quotient:

$$\frac{\text{Environmental load}}{\text{Functional unit}}$$

The functional unit shall be a useful measure that describes the major function. For lighting environments the most relevant side-effects that should be avoided are glare, disturbing and ugly lighting; in outdoor lighting the term 'light pollution' is often used for some of these adverse side effects. Those aspects are negative for numerator and denominator of the LCA quotient; they simultaneously reduce the functional value and waste energy. However, it should be noted that the mainstream understanding of the scope for LCA tends to neglect the problem of negative side effects. This shortcoming may be dangerous for the green image of SSL.

To be able to clarify the sustainable development advantage of SSL it is crucial to be able to show the added functionality value. This is important for the relevance of the functional unit that is used as a comparison basis in LCA. The knowledge about the added value aspects may be important in your branding as a knowledgeable green business actor, whenever you are confronted with LCA comparisons that only focus on irradiance levels ( $W/m^2$ ) and even more importantly when people only compare the energy consumption numbers (kWh).

The character, quality and functionality of the lighting is also important from Corporate Social Responsibility (CSR) and Societal Social Responsibility point of view. Now that we have come to understand that the dynamic character of the light is important for health and wellbeing it is hardly acceptable to ignore the quality of the light.

### ***Energy analysis***

A map of the energy flow, in the company or at the client building, is normally used to find the "energy hot spots", as a guideline for where it is possible to cut most of the energy. If we turn the perspective around those spots are also most likely the places where the lighting is most needed. The map of the energy flow is an opportunity to save energy and develop the ability to get a deeper understanding of the user value.

## 7 GBDM Dialogue tools

The new light qualities that SSL can provide raise the need for a language, a conceptual world to specify the new added values that Smart Lighting offers. There is also a need to nuance and challenge the meaning of Sustainable Development in relation to Human Centric SSL solutions which is so much more than solely energy savings.

### 7.1 Limitations in the current methods of light measurements

Lots of different instruments for on-site analysis of a light environment are being developed. It is possible to make complex measurements of the illuminated environment but the research to judge the effect of those different characters is not yet available. The human perception is very complex and some aspects, e.g. aesthetics, might not even be measurable in a physical sense. It is, for instance, possible to measure the spectral distribution in a room, but the combined effect of different wavelengths, light intensity, room furnishing (etc.) on humans is very complex.

Many people in the supply and delivery chain are not familiar with the range of measuring equipment available. The instruments that are being used in practice by almost all lighting professionals are very limited. They are based almost exclusively on point measurements of lux values (i.e. illuminance) which does not create any basis for meaningful characterization of a light environment. These lux-measuring instruments have a built-in function to correct for the luminosity curve (the so-called  $V(\lambda)$  curve; the curve of the phototrophic human eye wavelength sensitivity). However the built-in function might create a biased view of the amounts of light from different light sources. For a full assessment of a light environment the light sources as well as the surfaces that the light hits must be taken into consideration. The lux-value, that describes how much light incidents on a surface, often gives no good description of the light distribution that one sees in the room.

A major limitation of the current methods of light measurements is that there is a tendency to put light first and the people second. The most obvious proof of this is the choice of independent variables in different experiments, such as illuminance and colour properties of lamps. These variables are chosen because they are important for lighting equipment manufacturers, or because they are used in various calculations in lighting design and not necessarily because they are important to the people who are using the light. It is important that we move from expressing how well lit the objects are to the development of metrics how good they are to see.

Another limitation is the focus on generalization and this at the expense of context and overall descriptions. A large part of the lighting research has been focused on the establishment of general rules. The Swedish lighting industry handbook "Light and Space" consists of examples of such general rules. In the future, we need to focus on whether these general rules can be better adapted to different contexts. As long as the significance of context is neglected, it is unlikely that we will achieve a better understanding of the effect of light, in all its complexity.

To give a fair description of the many benefits with the dynamic light, it is important that we build up an understanding of the limitations of current methods and find a new way to describe the user value to customers.

## 7.2 Ability to clarify the added user values

It is important to be able to describe to customers why the new solutions contribute to a higher added user value. To tell the customer about the huge potential to affect our health and wellbeing with light or about the limitations imposed by the traditional lighting that has become normative can be a good start.

*The latest hundred years we have become accustomed to static, somewhat reddish, slightly flickering light environments where we essentially have been aiming for more lumens and the same light everywhere, all the time. However, the human sensory system is adapted to the varying light in nature, where the colour composition, the proportion of directional light and the intensity vary quite a lot. We know that sometimes we want functional light and sometimes we want cosy light, and also darkness. We know that the glittering light from moving water and in the forest feels good, many appreciate the play of light at sunrise and sunset, and we appreciate candlelight dinners.*

To a light researcher and perhaps to a lighting designer it is obvious that the aesthetical and health related aspects of light are very important for our health and wellbeing. Dynamics is a vital part of a well-functioning light environment. Our sensory systems evolved in nature and we get 80 % of the information about our living environments by light. The visual environment is important to the emotional state; for us to detect what we need to discover and to perceive each other's facial expressions.

It is strange that even though we know that the sense of sight essentially responds to contrasts and changes, we have accepted over a century to live in static lighting environments. On a fundamental level, most people know that light has the possibility to affect our mood in a powerful way but we do not connect this to our everyday artificial lighting.

A company being able to explain the potential inherent in everyday lighting has a huge possibility to become a forerunner in the SSL-business of the future.

When sales of individual light sources turns into provision of diverse lighting atmospheres, it becomes important to be able to put into words what each specific environment can provide in terms of experience. The traditional way to illuminate different types of facilities has been to provide a certain static standardized illumination level, typically 500 lux, in combination with requirements for lighting uniformity and the limitation of glare.

The combination of SSL and ICT enable dynamic lighting with the option to choose between several different lighting characters in one room. Such possibilities create high demands on the ability to clarify the user needs, for visual tasks, regarding non-visual lighting, and to provide a solution that is aesthetically attractive. It is evident that when an area is divided into smaller user/application zones that especially the demands for generic lighting levels and uniformity will become a constraint against improvement and innovation, see for instance the pre-school yard of Figure 18.



**Figure 18:** An example of what a characterization of a pre-school yard could look like.

The design of the user interface is crucial. The challenge is to create a control that as far as possible is self-adjusting, but at the same time gives a lot of freedom for the user to choose between different settings.

Lighting design specific knowledge is important in order to be able to transform from a lighting product focus to a focus on the creation of lighting atmospheres. The requirements for the illumination of e.g. a work place are dependent on several factors e.g. social climate, design and furniture, and activities.

To be able to distinguish between different environments, it is important to be able to put into words what it is that is distinctive. An example of how to distinguish between different environments, that provide various forms of experiences, is Grahn's eight characters system<sup>23</sup>. An elaboration of generic lighting characters, analogous to Grahn's characters can enable a more advanced level of lighting design (see section 7.1.2).

### 7.3 SSL-erate lighting characteristics

This chapter deals with a proposal on how to work with lighting characteristics as a way to clarify the customer needs and wants. In environmental psychology and landscape architecture one assumes that humans are adapted to live in nature and that nature thus gives us the best possible conditions for recreation as well as more creative tasks. The basis for Grahn's eight character system is that we in the creation of better human environments have no better guidance to start from than the natural variation of light.

In an initial attempt to create a number of lighting characters, it seems reasonable to take a starting point in the natural light. In this way, section 4.2 ("SSL-erate lighting characteristics") also provides

<sup>23</sup> A planning tool for designing sustainable and healthy cities. The importance of experienced characteristics in urban green open spaces for people's health and well-being. Grahn, P. Stigsdotter, U. & Berggren-Barring, A-M. (2005)



another dimension of how to work with green as a competitive advantage in the marketing of SSL with new added values.

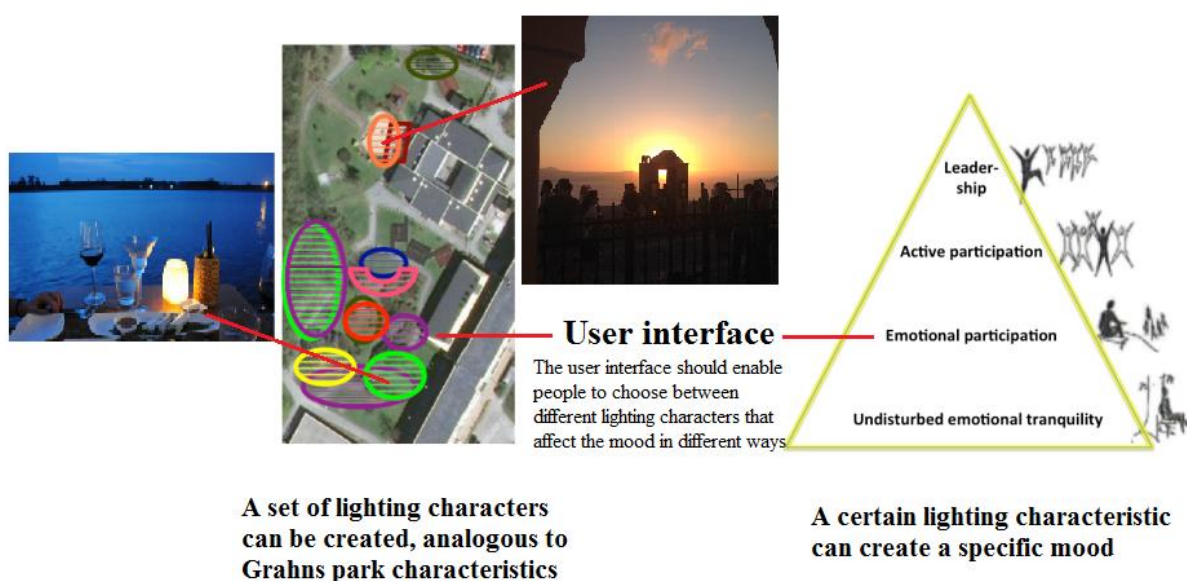
In order to start to build up a linguistic “tool-box” for SSL-erate lighting solutions we need to be able to talk about lighting in a way that highlights the added values. To give inspiration and think out of the box about how to create a vocabulary and linguistic “tool-box”, we turned towards the field of Landscape Architecture and Environmental Psychology. In Landscape Architecture and Environmental Psychology a set of eight characters (Serene, Wild, Rich in Species, Space, The common, The pleasure garden, Festive and Culture) are used to classify different areas in analyses of park environments, preschool-, school-, hospital yards etc.

Jonas Kjellander, who was awarded the 2010 lighting prize in Sweden for his dedicated work with the lights on Matildelunds preschool, followed that route. The facilities of a kindergarten are often used for many different types of activities that require different kinds of light. The lighting in the school environment has looked the same way for long. On Matildelunds preschool, Kjellander introduced different lighting for different situations or "scenography" in the daily operations.

There are many similarities between Jonas Kjellander’s work with Matildelunds preschool and environmental psychologists work with Patrik Grahn’s characters. Such a characterisation of the space can be used to create different kinds of lighting for different sub-spaces.

The characters may in turn be connected to the individual’s mental strength and type of involvement and can therefore be used to create rooms with different moods. In work with people with special needs “sensory rooms” are sometimes used to stimulate the senses in various degrees to achieve different degrees of activity or relaxation.

Grahn’s Environmental Psychology model (right part of Figure 19) shows that the type of involvement is dependent on the individual’s mental strength. The pyramid can be used as a conceptual model to describe the different mental levels of a human. The characters are a thinking tool to be used to achieve environments that allow for the different needs. Light can be used to activate (blue light) or to calm down (red light) and if we find the appropriate way light can be used to enhance different kinds of moods for people.

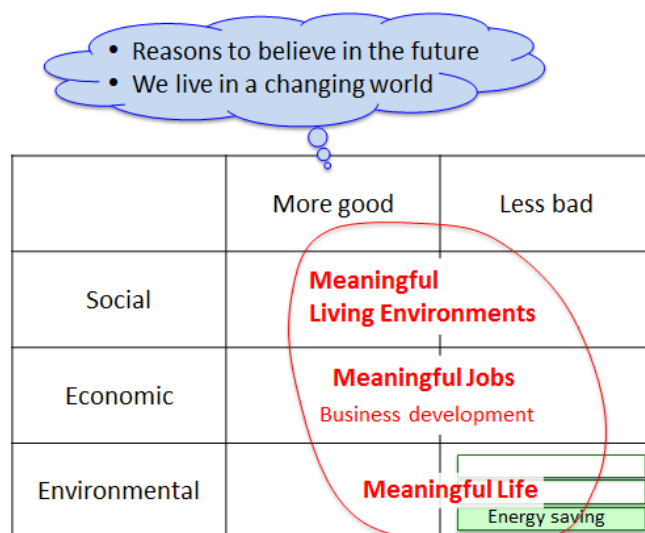


**Figure 19:** Interlinking lighting characters, user interface and mood

The lighting influences the atmosphere and thereby probably also the motivation to become involved in different ways. Patrik Grahn’s Environmental Psychology model and characters can be used to make analogies to understand the relation between lighting, health and wellbeing. Different characters of light can be created as a visual and linguistic “toolbox” to enable clarification and execution of the customer needs.

## 7.4 “Meaningful” as a tool to clarify the societal value

In the SSL-erate dialogue we have discussed that, in everyday language, “green business”, and “sustainable development” has become synonymous with reduction of environmental load. A new language is needed in order to enable companies to make positive connections between their ambitions to create higher added values and the politically driven energy saving discourse. We have chosen *Meaningful* as a key term for development-oriented dialogue to facilitate, clarify and expand the value enhancing advantages of SSL in research and green business experiments, as well as in the SMEs development and branding. “Meaningful” is a conceptual link between investments in meaningful living environments and meaningful green jobs, see figure 20.



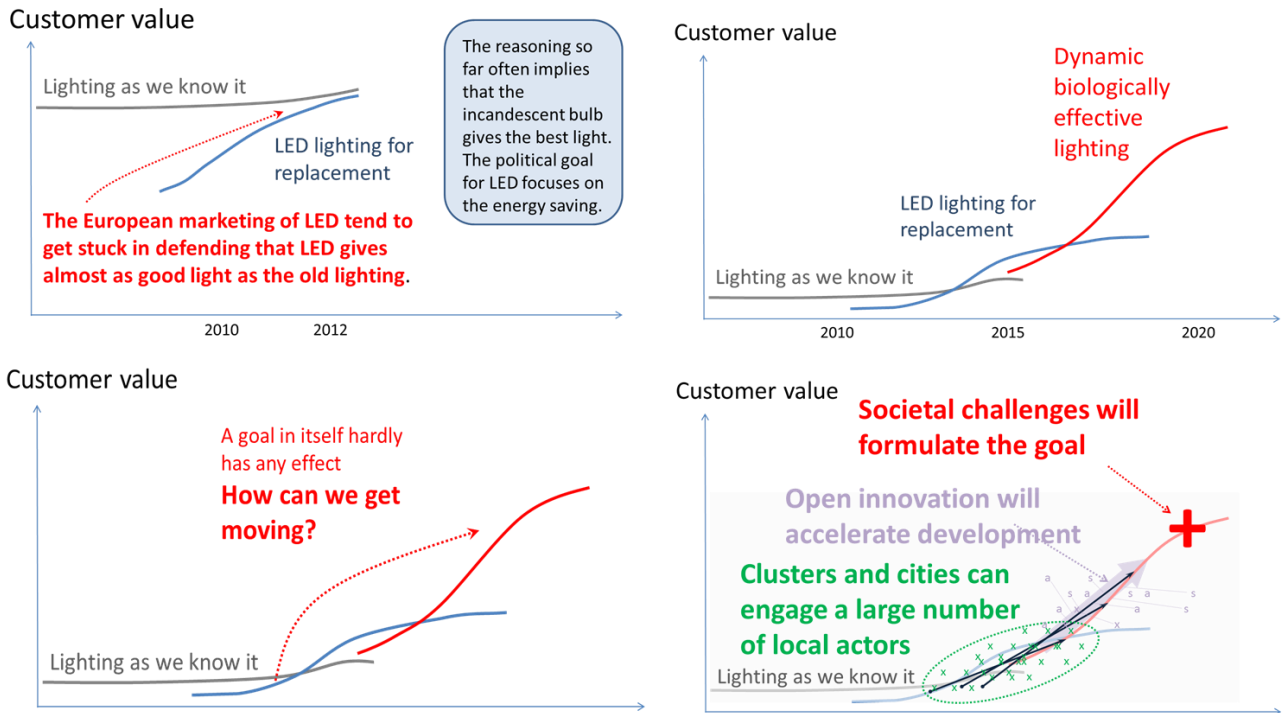
**Figure 20:** The concept of meaningful in the context of sustainable development

Early retirements and absenteeism due to stress and depression have increased for both men and women across Europe; and mental illness among the younger generation is also increasing. There is also an escalating use of sedative drugs. There is a tendency to alleviate various symptoms that are caused by distressing living environments and to neglect the underlying needs to invest in improvement of the living conditions. Smart adaptive lighting is a cost-effective way to significantly improve people's living environments.

The shift of focus from lighting products and energy saving to value enhancing light environments is one step towards the creation of better living environments and meaningful jobs; to invest in improvements rather than to alleviate the symptoms.

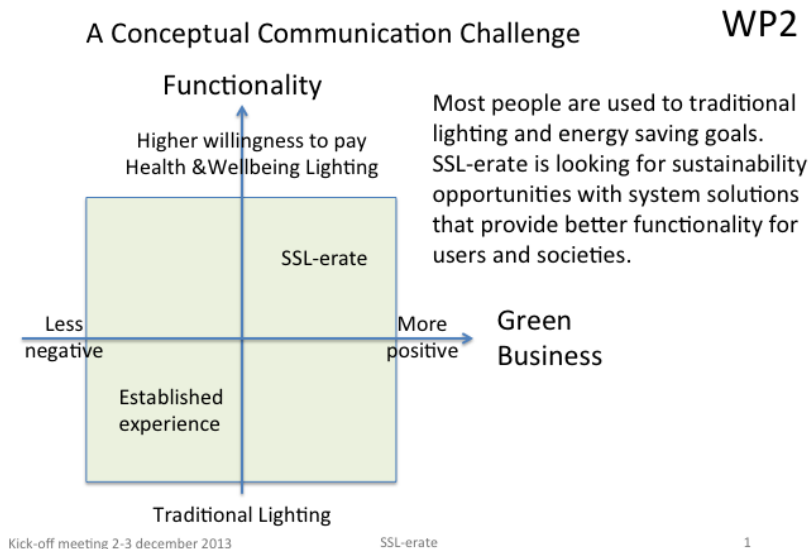
## 8 The SSL-erate transformative innovative perspective

In the SSL-erate project application we illustrated the ambition to support value enhancing business development by figure 21.



**Figure 21:** Value enhancing business development illustration for SSL in the SSL-erate project application

In the Kick-off meeting the value enhancing ambition was presented in a 4 fields chart, see figure 22:



**Figure 22:** Kick-off chart illustrating the value enhancing business development ambition of SSL-erate

In this perspective, D2.5 is aiming to enable business actors, both customers and suppliers, to find and develop new starting points in the SSL-erate quarter of the figure 22.

The structure and purpose of the well-acknowledged Innovation Ambition Matrix in chapter 2 is closely related to where the SSL-erate project is striving for. The Innovation Ambition Matrix can help SSL-erate clusters and companies to move towards more value enhancing Green Business. In relation to the GBDM it has the purpose to help the companies to decide their position and innovation level on the market.

### ***Innovation Management***

In the management of a company's innovation portfolio it is vital to assess various opportunities and risks in a structured and coherent way. An established tool to do this is the Innovation Portfolio Risk Matrix, see also [www.straligence.com](http://www.straligence.com).

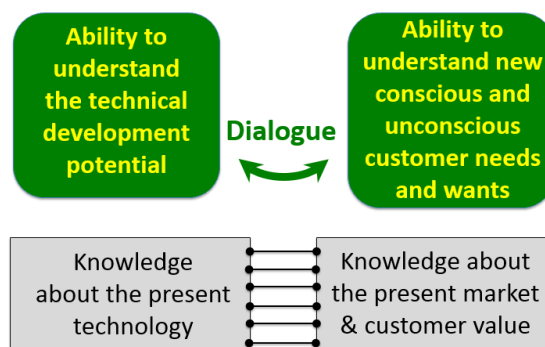
## 9 The GBDM support tools: Collaboration methods

The collaboration methods refer to the collaborative platforms particularly useful while developing SSL solutions, Open Innovation, inter-operability approach, as well as to build a common understanding that facilitate the “Meetings-of-Minds”, figure 23. This chapter takes its starting point in how business experiments and similar approaches can help companies to get out of the deadlock that prevents new SSL solutions to enter the market.

### 9.1 SSL-erate business experiments

A key to get moving with renewal is to demonstrate understandable examples of what it is that the new technology actually can provide. Furthermore, it is crucial to prove to different groups of investors that the SSL-erate lighting field of business ventures is viable, e.g. for venture capital actors. The most concrete SSL-erate activity to effectuate this is the WP4 Business. Experiments that are aiming to strengthen the motives and ability to get going with renewal oriented propositions for lighting with higher added value. The primary field is health and wellbeing and the aim is also to make use of the resources that have been allocated for Sustainable Development.

The SSL-erate business experiments resemble ENIGMA’s Pre Commercial Procurement (PCP). ENIGMA procurement of research and development is aiming for tools to enable the cities to become more vibrant and sustainable. The ENIGMA PCP and the SSL-erate business experiments are aiming to clarify the added value of the combined potential of SSL and ICT. A difference is that the ENIGMA provides EU funding for the winning R&D suggestions, whereas SSL-erate doesn’t. The ENIGMA PCP and the SSL-erate business experiments both make use of Open Innovation, i.e. border-crossing collaboration to enable a higher level of value creation.



**Figure 23:** *The Meeting of Minds*

To enable development of user tailored lighting systems it is important to involve the users as well as researchers in different fields. An open innovation process promotes a dialogue between actors with different competencies to solve integrated challenges with the help of cross-functional technology and solutions. A fundamental prerequisite to enable such a Meeting of Minds is to develop a common conceptual understanding.

## 10 Conclusion

The combination of SSL, sensors, hard- and software, user interfaces and the evolving new knowledge enables a new level of freedom of action for intelligent user adapted solutions. The presented Green Business Development Maps show the estimated development **opportunities** for various market segments.

To enable business actors and facility developers to make adequate advantage of the new opportunities this report provides tools for innovative open-minded dialogue about the features that today's smart lighting enables. To facilitate renewal oriented dialogue among multidisciplinary researchers, SSL and ICT experts as well as potential customers there is a need for new mental models, concepts and measures, as an addition to the traditional lighting concepts. This report includes a starting point for development of a unifying conceptual framing that enable mutual learning and build-up of awareness about individual and societal sustainability values of human-centric lighting.

The overarching ambition is to enable better synergy between Sustainable Development Investments, Enhanced User Value, Business Development Opportunities and more meaningful Green Jobs. The presented Green Business Development map, tools and examples aim to be useful to trigger enhanced awareness and customer interest.

## References

- *A planning tool for designing sustainable and healthy cities*. The importance of experienced characteristics in urban green open spaces for people's health and well-being. Grahn, P. Stigsdotter, U. & Berggren-Bärring, A-M. 2005
- *Competitive Advantage*. Porter, M. New York: The Free Press, 1985)
- *Digital agenda for Europe [COM (2010), 245]; [www.ec.europa.eu/digital-agenda/](http://www.ec.europa.eu/digital-agenda/)* Downloaded: 2014-10-15
- *European Lighting Equipment Market: Opportunities by Vertical Application Sector*, Frost and Sullivan, 2011
- *Factor Four – Doubling wealth, Halving resource use*. Von Weizsäcker et al. Earthscan, 1998
- *Facilitating Sustainable Innovation through Collaboration*, Djupenström et al. pp 17-39, Springer Netherlands, 2010
- *Flow: The Psychology of Optimal Experience*. M, Csikszentmihalyi. Harper Perennial Modern Classics; 1<sup>st</sup> ed., July 1, 2008
- *Green and Competitive: Ending the Stalemate*. M, Porter & C, van der Linde. Harvard Business Review, 1995
- *Green Paper - Lighting the Future: Accelerating the deployment of innovative lighting technologies*, [COM (2011) 889] Results of the Public Consultation, 2011
- *Human Centric Lighting: Going Beyond Energy Efficiency - An introduction to the LightingEurope*, ZVEI, and A.T. Kearney market study, 2013
- *Lighting the way: Perspectives on the global lighting market*, 2nd Edition, McKinsey, 2012
- *Managing your innovation portfolio*, Nagji & Tuff, Harvard Business Review (The Magazine), 2012
- *Organizing and the process of sensemaking and organizing*. Weick et al. Organization Science, 16(4), pp 409-421, 2005
- *Our Common Future* (the Brundtland Report). World Commission on Environment and Development, 1987
- *Sensemaking in organizations*. Weick, K. E. Thousand Oaks, CA: Sage, 1995
- *Strategic Opportunity Analysis of the Global Smart City Market*, Frost & Sullivan, 2013
- *The practice of adaptive leadership: Tools and tactics for changing your organization*. Heifetz, R. Boston: MA: Harvard Business Press, 2009