Future Scenarios of the Lighting Industry: Towards a More Sustainable and Innovative Market

The world is in the midst of a major transformative moment, and sustainability, among other aspects, has become one of the biggest challenges for society today. Some specific lighting features, such as new materials and efficiency, are already becoming very important. However, there are some other features that should be addressed. The question is not just whether and how sustainability will change the current products, but rather, what implications will be observed in the lighting value chain and what impact they will have on the current market.

As part of the European Commission's Horizon 2020 work programme, the aim of the Repro-light project is to start the transformation of existing luminaire solutions towards the next generation. The project takes into consideration sustainability, modularity, customization, intelligent systems and users comfort. Based on the technology that has been developed within this project, some future scenarios for the lighting industry have been identified. This article outlines six specific future scenarios. Three scenarios for Continuous Line Luminaire for industry context and another three scenarios for new desktop concept called Personal Table Light (PTL) for office context. The potential future scenarios have been developed according to type of luminaire, usage context, sustainable features, lighting features, lighting intelligent level, and personalization features. Using a storytelling tool and defining a specific Product-Service System (PSS) map for each scenario, the research work focuses on the implications that each potential scenario would have on the value chain of the industry. Moreover, it shows all the different stakeholders involved in service delivery and their mutual connections in a single frame. The obtained scenarios highlight the impact in the near future that the sustainable and innovative approaches will have on a luminaire company structure and the whole value chain perspective. Due to the creation of new advanced services in the near future, mainly related to sustainability and customer satisfaction, new stakeholders will join the PSS and some others will disappear.

Introduction

Scenarios are a "rich and detailed portrait of a plausible future word". Scenarios help to get a grip on the future by visualizing it and making it as realistic as possible [1]. Furthermore, they help focus thinking on the most important factors driving change in any product or service. By considering the interactions between these factors, it can improve the understanding of how change works, and what we can do to guide it. In the REPRO-LIGHT project scenarios have been used to help us to share the product vision and visualize the potential values and opportunities that the REPRO-LIGHT luminaire can bring to the user, client, company and environment. In addition, these scenarios have been used to identify the implications that each potential scenario might have on the current luminaire value chain. To this end, key scenario factors were identified and prioritized. Then, combining factors scenarios were defined. Afterwards, scenarios have been visualised base on storytelling technique and entirely described with a Product Services System (PSS) map [2]. The PSS is a synthetic graphical representation that shows in one single frame all the different actors involved in a product-service delivery, and their mutual links (e.g. flows of materials, energy, information, money, documents, etc.). Thus, a PSS clarifies how the different stakeholders and roles are connected one to the other, showing the values they exchange. The PSS is considered an excellent vehicle to enhance competitiveness and to foster sustainability simultaneously [3], so it perfectly fits in the general approach of Repro-light project and its objectives.

REPRO-LIGHT Luminaire Key Factors

The key lighting factors are light features that have been used to create scenarios. To define them, an exhaustive list of features that characterize the REPRO-LIGHT luminaires was developed. Next, features which referred to the same idea were removed, and the remaining features were grouped and discussed with luminaire experts from Bartenbach and Trilux companies. As a result, 7 groups of key factors and their corresponding sub-factors were defined and are described below.

Type of product

Two types of products were selected for scenario building. They are described below:

- CLL: Continuous Light Luminaire is a continuous line lighting system for industrial or office environments.
- PTL: Personalized table light is workplace lighting in the form of personal table light.

Level of luminaire

Two types of lighting levels were selected

for scenario building. They are described below:

- Standard: Luminaire that allows manual adjustment of light features to increase user comfort.
- Premium: Smart luminaire that adjust light features to user needs and environment in order to increase comfort and efficiency. The premium luminaire also allows the aesthetic personalization of the light housing.

Usage context

Three types of usage contexts were selected for scenario building. They are described below:

- Factory: Refers to an industrial site where workers manufacture goods or operate machines.
- Office: Refers to a room or other area where an organization's employees perform administrative work.
- Retail: Refers to the space where consumers buy goods and services.

Light features

Three types of light features were selected for scenario building. They are described below:

- Brightness: An attribute of visual perception in which a source appears to be radiating or reflecting light. In other words, brightness is the perception elicited by the luminance of a visual target. It is not necessarily proportional to luminance.
- Color: The characteristic of visual perception described through colour categories.
- Distribution: The way light is distributed throughout the workspace.

Light intelligence criteria

Four types of light intelligence criteria were selected for scenario building. They are described below:

- Person detection: Refers to the system that is able to detect the presence of people in a specific area and function accordingly.
- Ambient light detection: Refers to the system that is able to detect the features of the ambient light and function accordingly.
- Fatigue detection: Refers to the system that is able to detect worker fatigue level and function accordingly.
- Task detection: Refers to the system that can detect the type of task the worker is performing and function accordingly.

Sustainability aspects

Three types of sustainability aspects were selected for scenario building. They are described below:

- Maximum energy efficiency: Refers to the refurbishment of the luminaire for re-use in a similar application.
- Maximum material efficiency: Refers to the refurbishment of the luminaire for re-use in another application with lower light demands.
- Renewable energy grid: Refers to the refurbishment of the luminaire with an increase of the drive current.

Aesthetic criteria

Refers to the option to personalize the housing of the luminaire as well as the furniture or system where the luminaire is going to be installed.

Results

Combining the different factors and subfactors, six scenarios have been generated: three potential scenarios for the Continuous Line Luminaire (CLL) product, and another three future potential scenarios for the Personal Table Light (PTL) product. **Table 1** shows the selection of factors and subfactors that result in the construction of the six abovementioned scenarios. The first column of the table sets out the key factors and subfactors, the second column the first scenario, the third column the second scenario and so on until all scenarios are presented. The "×" in the table indicates which of the subfactors are considered in each of the scenarios.

Table 1: Factors and sub-factor of each scenario

	CLL			PTL		
	1	2	3	4	5	6
LEVEL OF LUMINAIRE						
Standard	×			×		
Premium		×	×		×	×
USAGE CONTEXT						
Factory	×	×				
Office			×	×	×	×
Retail						
LIGHT FEATURES						
Brightness		×	×	×	×	×
Colour			×	×	×	×
Distribution				×	×	×
INTELLENGE CRITERIA						
Person detection		×	×	×	×	×
Ambient light detection		×	×	×	×	×
Fatigue detection					×	×
Task detection					×	×
SUSTAINABILITY ASPECTS						
Maximum energy efficiency	×			×	×	×
Maximum material efficiency		×				
Renewable energy grid			×			
AESTHETIC CRITERIA						×

Scenario 1: This scenario represents REPRO-LIGHT standard Continuous Line Luminaire in a factory environment. The scenario presents how the installation and refurbishment of the luminaire in companies can achieve maximum energy efficiency.

Scenario 2: This scenario focuses on REPRO-LIGHT premium Continuous Line Luminaire in a factory environment. The scenario presents how intelligent luminaire adapts brightness based on person detection technology.

Scenario 3: This scenario is focused on REPRO-LIGHT premium Continuous Line Luminaire in an office environment. The scenario presents how intelligent luminaire adapts brightness and colour based on person and ambient light detection technology

Scenario 4: This scenario is focused on REPRO-LIGHT standard PTL luminaire in an office environment. The scenario presents how a worker can manage the luminaire features (brightness, color and distribution) according to their task and level of physical and mental fatigue.

Scenario 5: This scenario focuses on REPRO-LIGHT premium PTL luminaire in an office environment. The scenario presents how an intelligent luminaire system adapts features (brightness, colour and distribution) to the specific task of the worker and their level of physical and mental fatigue.

Scenario 6: This scenario focuses on REPRO-LIGHT premium PTL luminaire in an office environment. The scenario presents how a luminaire housing as well as the furniture systems can be personalized to fulfill the aesthetic requirements of the company.

As mentioned before, for each specific scenario a storytelling and a PSS have been describe. Storytelling is a narrative of the complete path followed by a character in the chosen context and it shows the value-in-use by a sequence of realistic service moments. It presents the experiences of the customers and helps to better understand what the experience of the intended user is like [4]. To build the storytelling firs it has be considered what the beginning of the story is and how it will develop and end. Later, key moments of the experience have been defined and finally, visuals to illustrate the story were design. **Figure 1** shows part of the storytelling of scenario 2. The storytelling of scenario 2 describes the actions of Ana, a factory worker, throughout a working day. The storytelling describes how an intelligent Continuous Line luminaire system interacts with Ana from the moment she arrives at the factory until she leaves.

In parallel, a Product Service System (PSS) was build for each scenario. As mentioned

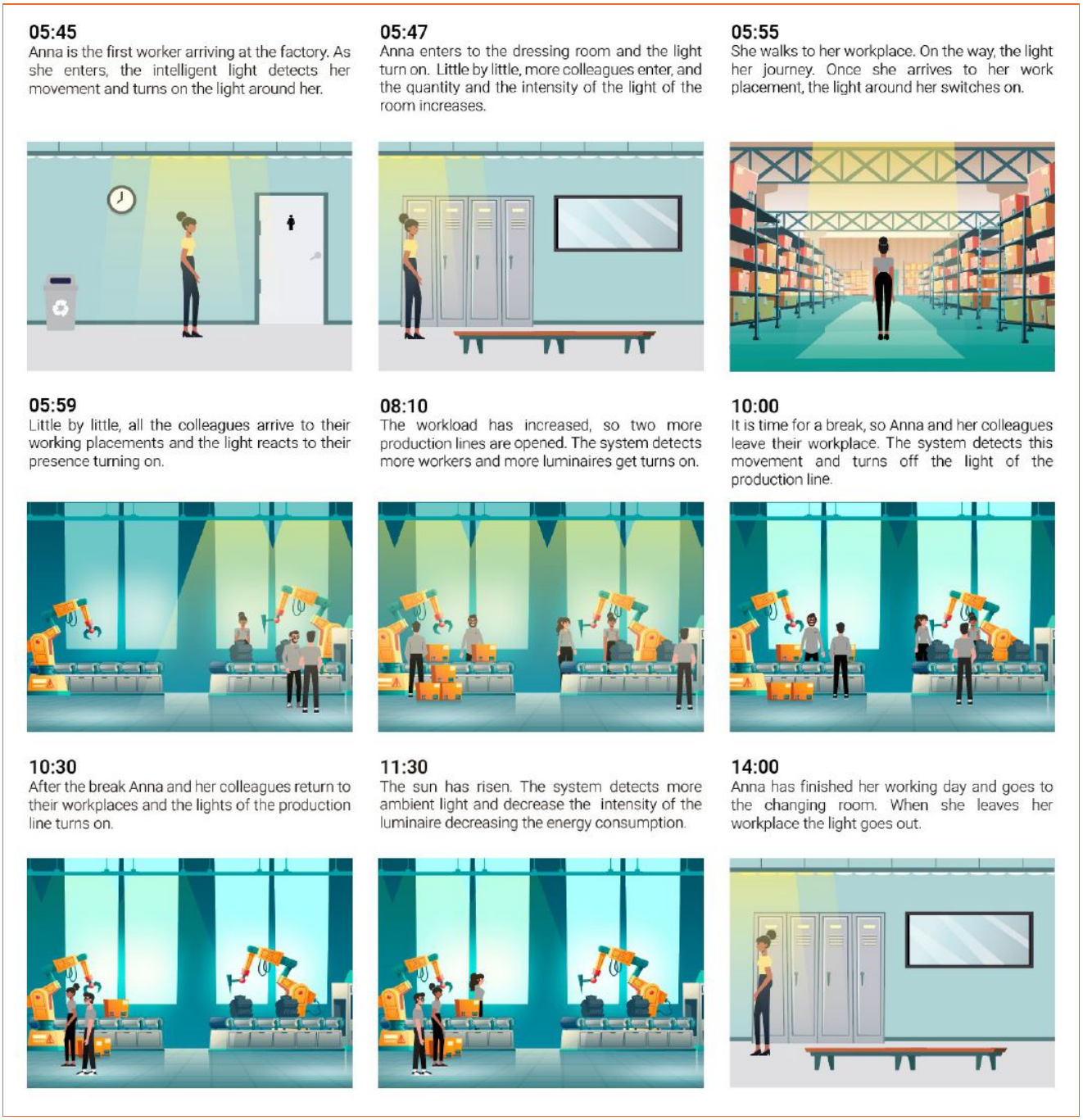

Figure 1: Storytelling of Continues Line Luminaire - Scenario 2

before, the PSS resumed in a synthetic representation of the whole product-service delivery and the links between all stakeholders. In this specific case, the PSS map illustrates how the different participants are connected to each other, highlighting the values they exchange. It also helps to understand the dynamics of the services, identify gaps and opportunities [5]. To build the Repro-light PSS maps (i) first the boundaries of the whole system were defined, (ii) later every stakeholder involve in the services was identify and, finally, (iii) the mutual links were described.

The set up process starts with suppliers who provide luminaire parts to the manufacturer. In this scenario in addition to luminaire parts, the suppliers also provide software solutions to manufacturers. Manufactures are the stakeholders who manage the development and manufacturing of the luminaire products and software's and are those who provides services and materials directly to their customer or through sales agents (wholesaler). In addition, these processes may also involve other stakeholders such as installers. Finally, the users are the stakeholders that interact, direct or indirectly, with luminaires through customers.

Closing the system general flow, customers are those who contact installers, wholesalers or the manufacturer to request maintenance or end of life. These processes are managed by installers, which means that they are in charge of deinstallation and

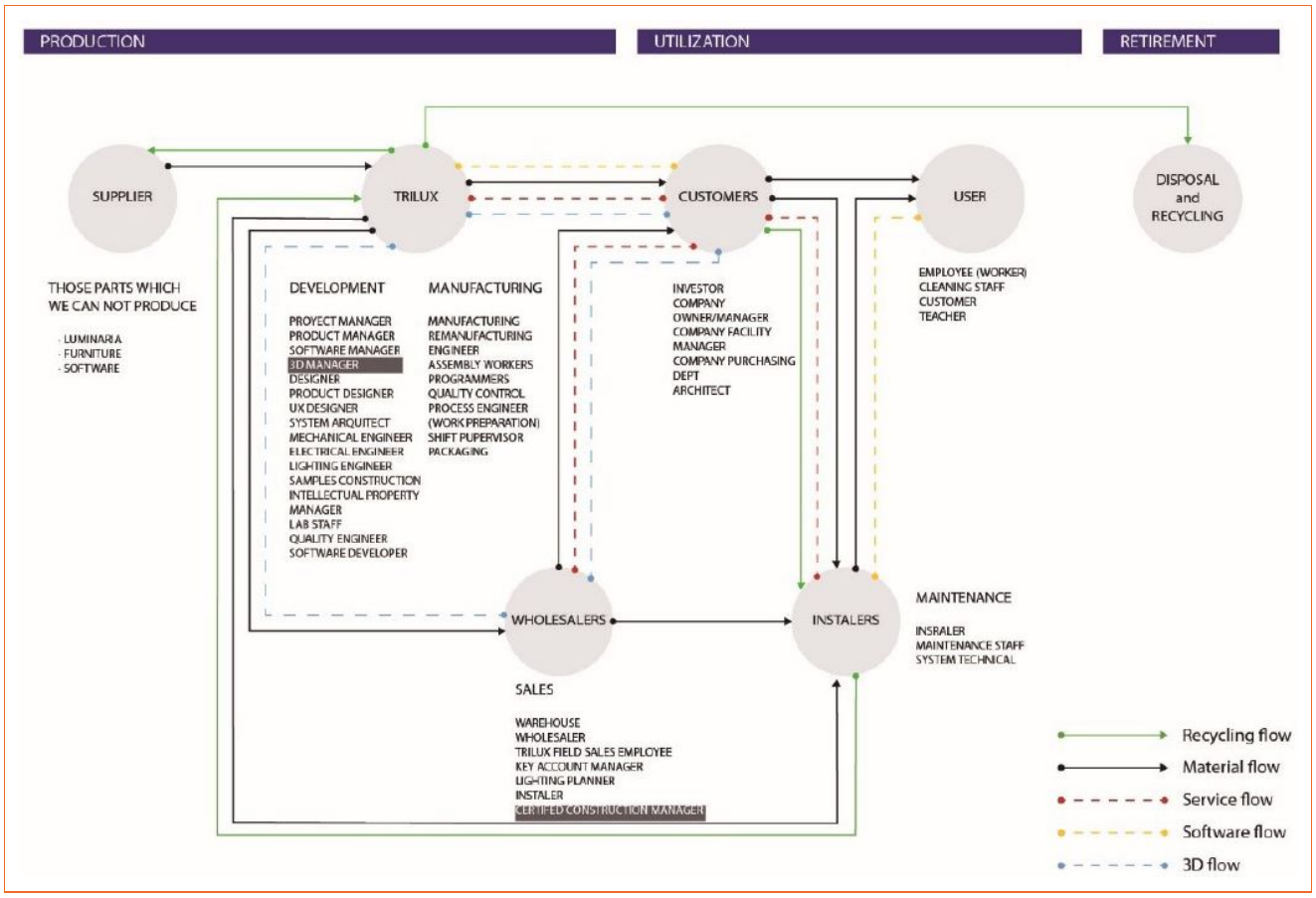

Figure 2: PSS of Continues Line Luminaire - Scenario 2

sending the luminaire back to the manufacturer. The manufacturer, will either reuse parts and components, send reusable parts and components to the supplier, or send parts to be recycled or disposed of.

Conclusions

The development of scenarios has begun with the analysis and identification of key factors that lead the future of intelligent and sustainable lighting. Combining factors, the REPRO-LIGHT project builds six potential future scenarios that visualize the future of intelligent and sustainable lighting. The future scenarios have been developed according to type of luminaire, usage context, sustainable features, lighting features, lighting intelligent level, and personalization features. Using a storytelling tool and defining a specific Product-Service System (PSS) map for each scenario, the research defines the implications that each potential scenario might have on the luminaire value chain.

The conclusions were obtained from the REPRO-LIGHT project. This analysis shows that the level of intelligence embedded in lighting systems is one of the most relevant axes that will drive innovation in the future of lighting. Intelligent lighting, besides providing comfortable environments for workers and users, encourages efficiency and environmentally friendly lighting. In this regard, systems that measure ambient light, identify the number and position of people and track their gestures and facial expressions need to be developed. The intelligent lighting systems require new stakeholders such as software suppliers, electronic engineers, software developers, UX designers and system technicians. In addition, new interaction flows ,such as software service flow is observed. The second predominant factor in the lighting sector is comfort. These systems seek to adapt the qualities and characteristics of the lighting to the needs of the environment. In this sense, research is moving towards the ability of lighting to adjust the color, distribution, brightness, and intensity of light.

The third predominant factor is sustainability. The lighting sector is not exempt from the understanding that nature and the environment are not endless sources, and that their protection and rational use is necessary. Therefore, understanding the life cycle of lighting systems and developing solutions that allow for a lower consumption of resources and a greater use of these will be a fundamental axis. Sustainable lighting requires stakeholders with knowledge in remanufacturing processes, techniques and technologies.

Finally, the customization of the lighting systems. Thanks to new technologies such as 3D printing, the manufacture of customizable lighting begins to be a reality. 3D printing enables the customization of products, being able to create products adapted to the needs of customers, technologically feasible and economically viable. Customizable lightning needs stakeholders such us product designers, 3D suppliers, 3D managers and certified construction manager. In addition, new interaction flows such as 3D flow appear in the PSS. ■

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REPRO-LIGHT

Initiating Transformation in the European Lighting Industry

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