



## **A NEW KIND OF RELATIONSHIP: SUPPLIER AND PUBLIC PROCURER RESPONSE TO A CIRCULAR ECONOMY**

Insights from Philips Lighting's deal with Washington Metropolitan Area Transit Authority

Master Thesis, Sustainable Development, Utrecht University  
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# A NEW KIND OF RELATIONSHIP: SUPPLIER AND PUBLIC PROCURER RESPONSE TO A CIRCULAR ECONOMY

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Cover photo

The Bosphorus Bridge – only bridge in the world that connects two continents, Europe and Asia. Since 2007, a full LED lighting system, developed by Philips, illuminates the bridge at night. To me this photo represents a symbol of success. I imagine suppliers and public procurers on opposite sides, just like two continents. What brings them together is the common interest driven by communication and collaboration. In this photo sailing boats represent the transition to a circular economy. Despite of their diversities, both suppliers and public procurers need to facilitate the success of this transition.

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# ABSTRACT

**Background:** As a consequence of a linear economy characterized by mass production, consumption, and waste, we are facing depletion of resources, development disparities, and environmental degradation. Recent global trends such as increased global demand, resource price volatility, and increasing competitive challenges create incentives for suppliers and public procurers to internalize resource and financial risks. Such situation calls for the uptake of new business models that focus on the product's life cycle through deployment of a circular economy.

**Method:** A case study was used to explore and describe the main research question of this thesis: *How does a circular economy affect the relationship between supplier and public procurer, and how can these economic actors assess economic, environmental and social impacts of a circular economy value proposition?*

To this end, a Philips Lighting deal with Washington Metropolitan Area Transit Authority is chosen as a single explanatory case. This lighting deal is a proper example of a product service system business model and a front running case in circular economy deployment. The first aspect describes and explains how circular economy changes the relationship between supplier and public procurer, as a response to uptake of a product service system business model. The relationship change analysis is largely based on expert interviews and provides both supplier and public procurer perspectives.

The second aspect deals with sustainability assessment methodology as to reveal the actual environmental, social and economic impacts of circular economy. In that way, steps towards life cycle sustainability assessment are made by developing a sustainability assessment model. Sustainability claims of the chosen case study are challenged by using quantitative data and applying the designed model.

**Results:** The results of this thesis suggest that circular economy, as deployed in service business models, significantly affects the supplier – public procurer relationship, particularly in the shift of ownership, responsibilities and risk. Literature suggests that deployment of a circular economy is inhibited by procurement rules, regulatory pressures and lack of leadership. The analyzed case study uncovered the main issues in regard to a circular economy - risk management, financial model and behavior, i.e. the difficulty to change mindsets. Collaboration and communication were identified as important enablers for a circular economy both in literature as in the case study. For supplier – public procurer communication purposes, a circular economy value communication tool is proposed.

The designed sustainability assessment model, as a result of critical reflection on the life cycle sustainability assessment methodology, integrates product life cycle with people, planet and prosperity (PPP) framework. By applying the model on Philips Lighting case study, a comparison of service and product based business models is provided. Research reveals that the impacts of products service business model are greater in electricity use throughout the contract duration, while product based business model accounts for massive waste creation. Due to the lack of inventory flow data of the analyzed lighting product, a complete impact assessment could not be provided.

**Conclusions:** The most recent developments in circular economy, sustainable supply chain and public procurement theories were confronted with case study insights. This research exposes several disparities between literature and empirical findings in terms of relationship change.

However, there is a need to analyze relationship change elements in the long run in order to further develop this area of study. Certainly, more transparency and clarity are needed with respect to communication of the value a circular economy entails. To that end, this research suggests a three step approach that includes (1) value proposition elements, (2) cost & benefit results, and (3) impact assessment on people, planet, and prosperity. To validate the benefits of this communication approach suppliers should apply it on various public procurers in the initial contact phase.

The sustainability claims of circular economy are challenged by comparing impacts of circular and linear scenarios over the period of 20 years in the WMATA deal. This research recognizes circular scenario as marginally more sustainable. That means that sustainability impacts of a certain project depend to a greater extent on product specifications, rather than maintenance scenarios. The effect of a product's extended life time, i.e. circular economy, is most relevant in regard to waste generation and recycling rates (which means positive contribution to the use of virgin materials). However, partial and frequent technology upgrades (every 5 years) do not result in higher energy savings than a full technology upgrade after 10 years of product usage. Due to the lack of inventory flow data the designed sustainability assessment model could not be fully applied. That is why this research suggests re-assessing the WMATA deal by collecting and measuring social and prosperity impacts for a longer period of time and using a full inventory flow database for measuring environmental impacts. By taking these actions, a more accurate comparison between service and product based business models can be generated.

# ACKNOWLEDGMENTS

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Furthermore, I would like to thank my parents for supporting me financially over the last two years. Someday I hope to be in the situation to help you as well. Although you sometimes do not understand my choices, I appreciate the space you have given me to pursue my challenges.

Last but not least, I would like to thank my loving partner for all the support, patience, time and sacrifices over the last two years, in particular last nine months. It has not been easy for you but we have pulled it through! You bring the joy, happiness and sun in every day of my life. Let's never stop enjoying the little things and loving each other.



“

TO MOVE TOWARD GROWTH,  
WE MUST BREAK FREE FROM THE  
CONSTRAINTS OF THE PAST.

FRANS VAN HOUTEN, CEO - PHILIPS

# TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION	1
1.1. Problem definition	1
1.2. Research questions and objectives	1
1.3. Societal and scientific relevance	2
1.4. Thesis arrangement	3
CHAPTER 2 RESEARCH METHODOLOGY	5
2.1. General methodology	5
2.2. Literature review data collection	5
2.3. Case study	6
CHAPTER 3 LITERATURE REVIEW	11
3.1. Supplier – public procurer relationship change	11
3.1.1. Circular economy	11
3.1.2. Sustainable supply chain	19
3.1.3. Sustainable public procurement	25
3.1.4. Reflections on supplier – public procurer relationship	29
3.2. Product service system business model	30
3.2.1. Value proposition	31
3.2.2. Value creation and delivery	33
3.2.3. Value capture	35
3.3. Life cycle sustainability assessment	38
3.4. Literature review summary	44
CHAPTER 4 DESIGN OF SUSTAINABILITY ASSESSMENT MODEL	45
4.1. Introduction	45
4.2. Needs and requirements for communication about sustainability impacts	49
4.3. Choice of impact categories and sustainability indicators	50
4.4. Selection of impact assessment methodology	52
4.5. Implementation steps	54
4.6. Visualization of sustainability assessment model	58
CHAPTER 5 PHILIPS LIGHTING CASE STUDY	63
5.1. Supplier – public procurer relationship change	63

5.2. Application of sustainability assessment model on WMATA	75
CHAPTER 6 DISCUSSION	83
6.1. Discussion of main findings	83
6.2. Limitations	87
CHAPTER 7 CONCLUSION	89
7.1. Conclusion	89
7.1. Directions for future research	90
REFERENCES	92
APPENDICES	103
Appendix 1 Product service systems: Main and sub-categories	103
Appendix 2 UNEP/SETAC suggested S-LCA stakeholder impact categories and sub-categories	104
Appendix 3 Interview questions	104
Appendix 4 Atlas.ti coding report – Final list of code families and their members	106
Appendix 5 List of quotations	107
Appendix 6 Initial list of codes	107
Appendix 7 Sustania 100 – WMATA deal	108
Appendix 8 PGL075 32 LED product information	109
Appendix 9 Material and labor costs for WMATA owned and operated scenario	111
Appendix 10 Material and labor costs for Philips owned and operated scenario	112
Appendix 11 Energy cost for both scenarios	113
Appendix 12 Sensitivity analysis	114

## LIST OF FIGURES

Figure 1 Thesis arrangement (Source: Author)	3
Figure 2 Overview of research elements (Source: Author)	4
Figure 3 Linear versus circular economy (Philips, 2014)	12
Figure 4 The key principles of circular economy (Adapted from: EMF, 2013)	13
Figure 5 The CE Framework (Source: EMF, 2013)	13
Figure 6 Life's principles of biomimicry (Source: Biomimicry 3.8 website)	15
Figure 7 Potential costs savings from circular models for European economy (Source: EMF, 2013)	19
Figure 8 Triggers for sustainable supply chain management (Adapted from: Seuring & Müller, 2008)	21
Figure 9 The sustainable business models archetypes (Source: Bocken et al., 2014)	31
Figure 10 Areas of value creation in circular economy (Adapted from: Accenture, 2014)	34
Figure 11 Core competences needed to support circular business adoption (Adapted from: Accenture, 2014)	37
Figure 12 Focus areas of sustainability initiatives (Source: Author)	48



Figure 13 Purpose perspectives of choosing sustainability indicators (Adapted from: EPA, 2012)	49
Figure 14 An example of LCSA system boundaries (Source: UNEP/SETAC, 2011b)	55
Figure 15 Framework for sustainability assessment model (Source: Author)	57
Figure 16 Product life cycle phases of sustainability assessment model (Source: Author)	58
Figure 17 Illustration of sustainability assessment model (Source: Author)	60
Figure 18 Circular economy value communication tool (Source: Author)	61
Figure 19 Geographic liability areas of WMATA	63
Figure 20 Timeline of WMATA and Philips Lighting interactions (Source: Author)	64
Figure 21 Timeline of WMATA and Philips Lighting upon installation	66
Figure 22 Failure rate assumptions for all three fixtures of PGL075 32 LED (Source: Author)	78
Figure 23 Material and labor costs (Source: Author)	79
Figure 24 Separation of labor costs (Source: Author)	79
Figure 25 Lumen/watt projections until 2040	80
Figure 26 Energy costs for both scenarios (Source: Author)	80
Figure 27 Costs distribution of both scenarios (Source: Author)	80
Figure 28 Sensitivity analysis based on the price of electricity (Source: Author)	81
Figure 29 Waste management results (Source: Author)	82

## LIST OF TABLES

Table 1 Interviews list (Source: Author) P- Philips; W-WMATA; E-External	8
Table 2 Participant observations list (Source: Author)	9
Table 3 Documents list (Source: Author)	9
Table 4 Sustainable supply chain pressures (Source: Author)	20
Table 5 Elements that can support or hinder sustainable supply chain (Adapted from: Seuring & Müller, 2008)	22
Table 6 Major sustainable public procurement implementation barriers (Source: Author)	27
Table 7 Public procurer's needs (Source: Author)	28
Table 8 The five circular business models (Adapted from: Accenture, 2014)	30
Table 9 The supplier and public procurer arguments for product service system business model (Source: Author)	32
Table 10 Differences between traditional product sales and product service systems sales (Adapted from: Clark et al., 2009)	34
Table 11 Environmental performance impacts of product service system elements (Adapted from: Tukker, 2004)	36
Table 12 Critical areas to be addressed for LCSA developments (Source: Author)	43
Table 13 Current sustainability assessment practices (Source: author)	46
Table 14 Level of sustainability initiatives' integration in PPP (Source: GRI website, ITC website, ISO website)	47
Table 15 List of relevant indicator characteristics (Adapted from: Fiksel, 2009; Boër et al., 2013)	50
Table 16 The relevance of indicator characteristics for different indicator purposes (Source: Author)	50
Table 17 Sustainability assessment model indicators list and measuring units (Adapted from: Talberth et al., 2006, UNEP/SETAC, 2009, Boër, 2013, GRI 2014)	51

Table 18 Match between sustainability assessment indicators and life cycle impact assessment methodologies (Adapted from: Boër, 2013)	53
Table 19 Pros and cons of LCA software tools (Source: <a href="http://www.linkcycle.com">http://www.linkcycle.com</a> )	54
Table 20 Life cycle inventory and life cycle impact assessment databases (Source: Boër et al., 2013, PRé website)	56
Table 21 Addressed needs in integrated lighting solution for WMATA (Adapted from: Philips, 2013b)	68
Table 22 List of circular economy transition enablers and barriers (Source: Author)	68
Table 23 List of motivation elements to change business practices towards circular economy in WMATA deal (Source: Author)	69
Table 24 WMATA value proposition focal areas (Adapted from: Philips, 2013b)	70
Table 25 WMATA and Philips relationship change elements due to circular economy (Source: Author)	75
Table 26 The WMATA scenarios characteristics (Source: Author)	76
Table 27 The lighting fixtures present in WMATA value proposition (Adapted from: Philips, 2012)	76
Table 28 The life expectancy of different modules of PGL075 32 LED product (Adapted from: Philips, 2012)	77

## LIST OF ABBREVIATIONS

B2B	business to business
B2C	business to customer
B2G	business to government
BASF	Badische Anilin- & Sodafabrik
CAP	corrective action plan
CBA	cost and benefit analysis
CMLCA	Chain Management by Life Cycle Assessment
EICC	Electronic Industry Citizenship Coalition
ELCD	European reference lifecycle database
EMF	Ellen MacArthur Foundation
EoL	end-of-life
EPA	Environmental Protection Agency
ICLEI	Local Governments for sustainability
ISO	International Organization for Standardization
IT	information technology
LaaS	Light as a Service
LCA	Life cycle assessment
LCC	Life cycle cost
LCSA	Life cycle sustainability assessment
NGO	non-governmental organization
OECD	Organization for Economic Cooperation and Development
PPP	people, planet, prosperity
RFP	request for proposal

RFQ	request for questions
SA	Social Accountability
SETAC	Society of Environmental Toxicology and Chemistry
S-LCA	Social life cycle assessment
TBL	triple bottom line
UN	United Nations
UNEP	United Nations Environmental Programme
WEF	World Economic Forum
WMATA	Washington Metropolitan Area Transit Authority

# CHAPTER I INTRODUCTION

## 1.1. Problem definition

We live in a world that is dependent on the extraction of natural resources in order to maintain its current growth patterns. An unavoidable decay awaits us all if we continue to pursue our current production and consumption patterns. As a consequence of a linear economy characterized by mass production, consumption, and waste, we are facing depletion of resources, development disparities, and environmental degradation.

For decades scientific communities have been discussing the necessity for companies to take responsibility for their actions and reduce the damage they are causing to our planet. Numerous studies have illustrated the benefits of adopting sustainability strategies across the supply chain. However, such investments have been largely discarded due to cost and risk factors.

Recent global trends such as increased global demand, resource price volatility, and increasing competitive challenges create incentives for suppliers and public procurers to internalize risks and change business strategies. The only sustainable way forward is employing a 'life cycle approach' through the lens of a circular economy. A circular economy decouples growth from use of resources by relying on renewable energy, eliminating waste, and orchestrating services such as recycling, remanufacturing and refurbishment (EMF, 2013). A sound understanding how circular economy changes the relationship between suppliers and public procurers is needed as to understand the triggers and motivation of altering existing business practices.

Realizing the potential of a circular economy requires uptake of new business models, such as product service systems. Putting product service systems in the perspective of a circular economy has the potential to increase business resilience while uncovering commercial opportunities throughout the product's life cycle. Thus, a proper understanding of product life cycle phases is essential. As every business model has its economic, environmental and social impacts, it is important to take a step towards the methodology of sustainability measurement. On this wise, understanding how to prove life cycle value across people, planet, and prosperity (PPP) is vital.

Over the course of this research the empirical focus is set on Philips's Light as a Service (LaaS) deal with Washington Metropolitan Area Transit Authority (WMATA). To this extent research includes following elements: the description of a relationship change caused by a applying the concept of a circular economy ; the analysis of product service system opportunities; and the comparison of service and product based business models based on a sustainability assessment.

## 1.2. Research questions and objectives

This research is set to address the following knowledge gaps: permutations in supplier – procurer relationship caused by a circular economy and; consequences of business proposition for environmental, economic and social impacts. To that end, the following research question is proposed:

*How does a circular economy affect the relationship between supplier and public procurer, and how can these economic actors assess economic, environmental and social impacts of a circular economy value proposition?*

In order to support the steering function of the main research question, several sub-research questions are presented:

1. What are the elements of change in the supplier - public procurer relationship caused by circular economy?
2. What is the value proposition of a product service system business model in the context of a circular economy?
3. How to design a sustainability assessment model as to reveal economic, environmental and social impacts across product life cycle?
4. What is the added value of sustainability assessment model results for supplier and public procurer?

The overall aim of this exploratory and descriptive research is to answer research questions with support of research objectives. Research objectives should be useful, realistic, feasible, clear and informative (Verschuren & Doorewaard 2010). To achieve this aim four objectives have been identified:

1. Contribute to understanding of changes in a supplier - public procurer relationship in the context of a circular economy.
2. Understand the significance of circular economy elements embedded in a business deal and the creation of value in a circular economy.
3. Develop a sustainability assessment methodology of the product life cycle across PPP.
4. Contribute to understanding the benefits of sustainability impacts disclosure.

### **1.3. Societal and scientific relevance**

The Ellen MacArthur Foundation(2013) argues that “the circular approach offers developed economies an avenue to resilient growth, a systemic answer to reducing dependency on resource markets, and a means to reducing exposure to resource price shocks as well as societal and environmental ‘externality’ costs that are not picked up by companies”. A major incentive for suppliers to engage in circular economy approaches is the opportunity to co-create with procurers, as well as closer and direct relationships. Procurers create incentives because they want to be supplied with more reliable, durable and repairable goods (Preston, 2012). New ownership and service models, namely product service system, are beneficial to society in general because they offer opportunities that can be shaped based on ones needs and preferences. Major groundbreaking innovation of circular economy embedded business models is in incentives for the behavioral change. This change is featured by co-creation processes, engagement, durability, reparability and reuse as elements of business model and relationship alteration. Companies have a growing incentive to redesign products chains vertically, starting from the top, to eradicate costs of waste, and provide tailored services. Incentives like these endorse the transition from a linear to a circular economy and foster economic and societal resilience.

The case study analyzed in this thesis offers insights into characteristics of a complete service package, supplied by Philips Lighting. (An interesting aspect of research) The results entail reasons why public procurer from the case study (Washington Metropolitan Area Transit Authority) opted for a “Best value” proposal, instead of a traditional lowest-bid proposal. Scientific relevance is in linking project actions with environmental aspects as discussed by authors such as Palmujoki et al. (2010) Sanchez & Hacking (2002) and Uttam & Le Lann Roos (2014). There is existence of plurality in both the targets and sources of sustainability assessment methodology for service business models. Based on state of the art literature a sustainability assessment model is designed and applied

on an empirical case. Of scientific relevance is also a comparative analysis of product and service oriented business models, based on their sustainability assessment results. In addition, for supplier - public procurer communication purposes, a circular economy value communication tool is suggested, as a way to present the most relevant elements in a sales approach: value proposition details; cost & benefit analysis; and added value (economic, social and environmental impacts of a certain value proposition).

#### 1.4. Thesis arrangement

To reach objectives of this research, thesis is structured into seven units which are reflected in the figure below and in the individual chapters of this research (see Figure 1).

Chapter 1 discusses the problem that led to this research and presents the central research question and objectives. In addition, the relevance of this thesis is also discussed. Due to novelty of this research topic it was necessary to introduce the methodological foundation first. Thus, Chapter 2 specifies the research methodology that will help to answer research questions. Chapter 3 is the result of an extensive literature review on the main concepts used for this thesis, i.e. relationship change, a product service system business model and a sustainability assessment model. After presenting the literature review findings, In Chapter 4 sustainability assessment model is designed and visualized based on four phases (1. Goal and scope; 2. Life cycle sustainability inventory analysis; 3. Life cycle sustainability impact analysis and; 4. Life cycle sustainability assessment interpretation). The case study results are analyzed in Chapter 5 while research findings are discussed in Chapter 6. Finally, limitation and directions for future research are presented in Chapter 7. An overview of research elements, as presented in Figure 2, serves as an orientation tool of how elements are related and points towards new knowledge that is generated.



Figure 1 Thesis arrangement (Source: Author)

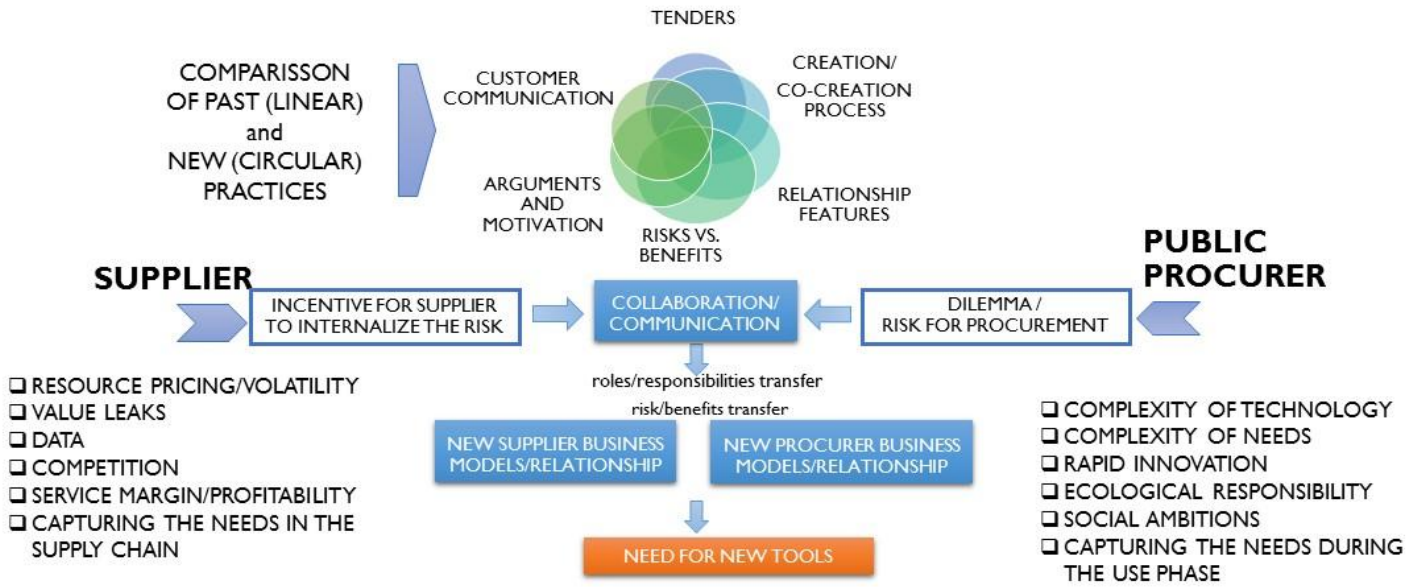


Figure 2 Overview of research elements (Source: Author)

# CHAPTER 2 RESEARCH METHODOLOGY

## 2.1. General methodology

This chapter elaborates the methodological approach chosen to answer the research questions and achieve the objectives of this research. The recentness and complexity of the studied area encourage engaging with both qualitative and quantitative research methods. Qualitative and quantitative methods should be viewed as complementary in order to combine methods effectively and overcome the weaknesses found in a single method design (Jick, 1979). This approach is called triangulation. In the social sciences, the use of triangulation can be traced back to Campbell and Fiske (1959) where they argued that more than one method should be used in the process of validating results. In addition to validity, triangulation of methods results in reliability, holistic and contextual portrayal of the phenomenon of interest (Denzin, 2009). This research has both qualitative and quantitative character. Therefore, the following methods of data collection were used: literature review, semi-constructed interviews, observations, documents and scenario modeling.

A qualitative research, based on interpretivism and constructivism, is suitable for answering 'how' questions as it allows more flexibility to explore new fields of interest (Denzin, 2009). "The emphasis of qualitative research is on process and meaning" (Sale, Lohfeld, & Brazil, 2002). Qualitative research explores a relatively new field of interest, the supplier and the public procurer interactions in the context of a circular economy. In addition, it explores the available methods for addressing life cycle sustainability assessment. However, quantitative research, based on positivism, is more applicable for case studies where sustainability assessment model is applied using quantitative data. The nature of this research is exploratory as it focuses on finding out how circular economy affects the supplier – public procurer relationship and how can sustainability claims of product service system be substantiated. Because of limited academic literature on circular economy and, in particular, relationship dynamics, the exploratory research is needed to get familiar with discourses and gain academic knowledge in this field of study.

By conducting a literature review and single in-depth case study, the research strategy aims to provide descriptions and thereby answer the main research questions. According to Verschuren and Doorewaard (2010) research strategy is a "coherent body of decisions concerning the way in which the researcher is going to carry out the research". The case study will provide an in-depth analysis of relationship interactions between Philips Lighting (supplier) and WMATA (public procurer) in the context of circular economy. As Philips claims to lead in sustainability practices these claims will be challenged by applying the sustainability assessment model on their product service system value proposition to WMATA.

## 2.2. Literature review data collection

The literature review includes individual reports, journal articles, books, working papers and other materials. Article databases such as Scopus and Google Scholar are consulted for the most relevant and cited articles. Furthermore, a snowball technique is employed to identify other relevant literature. Scientific articles and empirical studies on circular economy, product service system, sustainable supply chain and sustainable public procurement are selected on the basis of their



theoretical insights regarding the objectives of this research. Among others, the following journals were used: Journal of Cleaner Production, Journal of Interactive Marketing, Journal of Engineering manufacture, Harvard Business Review, Journal of Physical Distribution and Logistics Management and Journal of Product Innovation Management. In addition, literature review on available sustainability methods is done in order to design sustainability assessment model. The comprehensive review, as presented in this thesis, is mainly based on peer-reviewed journal articles; however, to some extent it also encompasses reports and insights from Philips experts on life cycle assessment (LCA). The life cycle cost (LCC), life cycle assessment (LCA), social life cycle assessment (S-LCA) methodologies and related case studies were critically reviewed. The relevant literature was selected based on the following methods:

- A) Journal articles. The majority of the scholarly articles were obtained through Scopus and Web of Science databases. The keywords “LCC”, “life cycle cost assessment”, “LCA”, “life cycle assessment”, “SLCA”, “social life cycle assessment”, “social LCA”, “societal life cycle assessment” and “life cycle sustainability assessment” were used in search field area. The selected articles were screen based on the information taken from abstract or article summary in order to select the articles relevant for identified key areas.
- B) Web-based search engines. Reports and books were searched via <http://scholar.google.com/> using the following keywords: “LCC”, “life cycle cost assessment”, “LCA”, “life cycle assessment”, “SLCA”, “social life cycle assessment”, “social LCA”, “societal life cycle assessment”, “principles of SLCA”, “life cycle sustainability assessment” and “guidelines for SLCA”.

### 2.3. Case study

Opting for an exploratory research is justified for three main reasons. Firstly, academic literature on the topic of circular economy is scarce. Developments on suitable circular economy business models and implications of circular economy deployment on business relationships are still in infancy. Secondly, according to Yin (2014) a case study is a preferred research method in situations when (1) the main research questions are “how” or “why” questions; (2) a researcher has little or no control over behavioral events; and (3) the focus of the study is a contemporary phenomenon. The phenomenon analyzed in this research is supplier – public procurer relationship change. The case study research method is chosen to get a deep understanding of the phenomenon within its real-life context (Yin 2014). In addition it provides a nuanced, empirically-rich and holistic account of the specific phenomena, as well as internal validity of delivered results. Finally, life cycle sustainability assessment literature across people – planet – prosperity is very limited. Therefore, exploratory case study contributes to existing knowledge on these topics.

#### Case selection and scope

The empirical sample in this single case study is the Philips Lighting’s deal with the Washington Metropolitan Area Transit Authority (WMATA). As a consequence of circular economy deployment and collaboration across the supply chain, a company like Philips is faced with relationship changes, both with their suppliers and procurers. The focus of this study is on public procurers as they have higher level of responsibility to purchase in a sustainable manner. Consequently, public procurers have the power to shift a supplier’s value proposition. There are several reasons why this empirical case is taken.

Firstly, Philips, as an international technology and manufacturing company has extensive upstream and downstream supply base and therefore more responsibilities and opportunities in the transition

to a circular economy. As a result, Philips is a front runner in sustainability practices and a partner of the Ellen MacArthur Foundation (EMF). As Philips aims “to make world healthier and more sustainable through meaningful innovation” it shares the same vision with Ellen MacArthur Foundation – “a resource efficient and, ultimately, a regenerative circular economy” (Philips, 2014). Secondly, Philips Lighting suits the purpose of this research as the chosen project for further analysis, WMATA, is a proper example of a product service system business model. This project is also recognized as one of the top 100 innovative and sustainable solutions around the world in 2014 by *SUSTAINIA 100*<sup>1</sup> (see Appendix 7).

In the WMATA deal, the value proposition is based on provision of services in a 10 year ownership-free performance contract. In addition, Philips came up with an innovative financial model that supports upgrades of 25 parking garages from outdated and inefficient lighting fixtures to state of the art LED technology through Light as a Service model. A Light as a service gives Philips and WMATA a vested interest in reducing the energy consumption and prolonging the lifetime of the lighting solution. Finally, this front running case of circular economy deployment serves as a single explanatory case on how supplier (Philips Lighting) and public procurer (WMATA) respond to circular economy. Access to both sides, as well as internal and external data proceeded from the internship position at Philips, Group Sustainability. Recentness of the case provides appropriate comparison foundation with the theory perspectives.

In regard to the case study scope, the first part of the analysis sets focus on the relationship changes between Philips, as supplier and WMATA, as public procurer. Second part of the analysis, applies the designed sustainability assessment model to product service system business model of Philips. The designed sustainability assessment model is based on critical analysis and integration of available LCC, LCA and S-LCA methods. Available methods are adjusted and upgraded as to ensure inclusiveness of all relevant indicators and impact areas. A comparison of impact results of a product service system business model and product based business model will reveal the added value of circular economy.

### Data collection methods for the case

The data collection for the case includes both qualitative and quantitative data. Qualitative techniques used include in-depth semi constructed interviews, observations, participation, and document analysis. Quantitative data collection comprises installation and maintenance details of WMATA deal, cost breakdown structure of all product, services specifications and financial model insights.

The framework for interviews is prepared from the literature review. The main structure of interviews includes relationship change due to circular economy, value creation in a product service business model, sustainability assessment methodology, and where applicable WMATA deal specifics (see Appendix 6). All 16 potential interviewees were contacted via e-mail to request an interview. The initial contact e-mail included outline of the master thesis and interview duration (30-60 minutes depending on availability of the interviewee). At the beginning of the interview, a guaranty of confidently was made and, once interviewee's permission has been granted, the interviews were recorded. In addition, permission for citation was also acquired and statement of anonymity guaranteed. In total, thirteen interviews were conducted, of which eight were face to face, four were via Lync (MS Office communicator)/Skype, and one was sent in written form. Both orally conducted and written interviews were in English, and include digital recording and literal transcription. As for

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<sup>1</sup> SUSTAINIA 100 is an annual guide to 100 innovative sustainability solutions from around the world. 2014 edition is available at: [http://www.sustainia.me/resources/publications/3rd\\_sustainia100\\_2014.pdf](http://www.sustainia.me/resources/publications/3rd_sustainia100_2014.pdf)

the gender structure of interviewees, nine out of thirteen are male, while four interviewees are female. On average, duration of interviews is 45,23 minutes. Interviewees were chosen based on two characteristics: (1) involvement in circular economy, and/or (2) insights in Philips Lighting case study. General interview questions are provided in Appendix 3, while WMATA specific questions were asked during the interview, based on depth of interviewee involvement in the case. The list of interviews conducted is presented in Table 1.

<b>Interviews list</b>					
#	Organization	Position	Duration	Date	Location
P1	Philips, Supplier development, quality and sustainability	Supplier sustainability manager	55:58	18/11/14	HTC, Eindhoven
P2	Philips, Global market European affairs office	EU regulatory affairs manager	39:49	21/11/14	Online
P3	Philips, Group Innovation/Innovation services	Hardware designer	41:30	19/11/14	HTC, Eindhoven
P4	Philips, Research North America	Principal member research staff	37:52	11/11/14	Online
P5	Philips Lighting, Global market governance and public affairs	Head of global public and government affairs	45:25	18/11/14	HTC, Eindhoven
P6	Philips, Group sustainability	Senior scientist	39:19	25/11/14	HTC, Eindhoven
P7	Philips, Governance	Head of procurement risk and market intelligence	54:34	19/11/14	HTC, Eindhoven
P8	Philips, Global markets European affairs	M2O Academy lead	36:23	05/12/14	HTC, Eindhoven
P9	Philips, Global markets governance and public affairs	Global head of government affairs B2G	60:00	14/11/14	HTC, Eindhoven
W1	WMATA, Sustainability department	Former assistant general manager	39:07	01/05/15	Online
W2	WMATA, Sustainability department	Principal sustainability advisor	42:03	18/05/15	Online
E1	Omgevingsdienst Zuidoost-Brabant (ODZOB)	Advisor sustainability and climate	52:08	05/11/14	ODZOB office, Eindhoven
E2	European Commission, Directorate General for Environment	Green Public Procurement Officer	written form	03/12/2014	Online

Table 1 Interviews list (Source: Author) P- Philips; W-WMATA; E-External

Along with interviews, data for this research is gathered in the form of participant observation. Observation methods are useful to researchers for many reasons, e.g. to determine who interacts with whom, check how much time is spent on various activities or observe situations informants have described in interviews (Kawulich, 2005). Various authors suggest using participant observation as a way to increase the validity of the study, as observations support researcher in better understanding of the context and phenomenon under study (Patton, 1999; Kawulich, 2005; DeWalt & DeWalt, 2010). During the events displayed in Table 2, researcher analyzed given material, took

notes and engaged in discussions. As the last element of data collection, this study is also based on internal and external documents analysis (see Table 3).

Participant observations list						
#	Event	Topic	Representatives	Duration	Date	Location
1	Circular economy expert panel debate	Enabling legislation for a circular economy	EU Commissioners, NGO's, Businesses, Philips employees	4 hours	07/10/14	Brussels
2	Accenture – Philips circular economy workshop	Implementing a circular economy, business models & enabling technologies	Accenture Strategy, Philips Lighting & Group employees	2 hours	22/10/14	HTC, Eindhoven
3	Circular economy score-card deployment session 1	Scoring lighting products on circularity	Philips Lighting employees	8 hours	22/10/14	Winterswijk
4	Circular economy score-card deployment session 2	Scoring lighting products on circularity	Philips Lighting employees	1.5 hours	03/12/14	HTC, Eindhoven
5	Circular economy project meeting x8	Developing the circular economy framework for Philips Lighting	CE project team Lighting	8x1.5 hours	Bi-monthly (June-October)	HTC, Eindhoven
6	Ellen MacArthur Foundation circular economy immersive course	Explore the possibility to enroll CE course within the organization and train Philips' employees on how to implement CE within projects	EMF, TU Delft, Bradford University, Philips employees	13 hours	19&20/01/15	HTC, Eindhoven

Table 2 Participant observations list (Source: Author)

Documents list	
Internal	External
1. Average useful life of lighting products installed in the WMATA deal	1. Circular economy brochure
2. WMATA LaaS case study	2. WMATA's request for proposal
3. Volume I – cost/price data for WMATA deal	3. LED inside news report
4. Volume – technical data for WMATA deal	4. WMATA news release
5. Conformed contract between Philips Lighting and WMATA	
6. Philips Excellence practices - WMATA	

Table 3 Documents list (Source: Author)

## Data analysis

Data analysis, as an iterative and ongoing process, aims to analytically reduce the data. Coding was needed to process and analyze the transcribed data, as to make it relevant for research questions. For this purpose, transcribed interviews were analyzed in *Atlas.ti* coding program. Firstly, based on open coding process, 27 codes were identified (Appendix 6). The open coding process marks quotations and assigns a suitable code (see Appendix 5). Secondly, after adjustment of initial codes, final coding categories were identified (Appendix 4).

# CHAPTER 3 LITERATURE REVIEW

**A** preliminary research in the form of literature review provides theoretical insights and an holistic overview of the key concepts, i.e. supplier – public procurer relationship change, product service system, and life cycle sustainability assessment (LCSA). A literature review will help to discover gaps in already published research, generate new ideas, show the originality and relevance of this research and rationalize choice of research methodology.

Circular economy is in the focus of this research. Combining theoretical findings on sustainable supply chain and sustainable public procurement is set to be the main platform for analyzing how circular economy affects manifold aspects of the relationship between key actors across the value chain – in the scope of this research that are supplier and public procurer. Secondary literature on product service systems is analyzed as to explain the concept of a value proposition, value capture and process of enabling the value in the context of circular economy. The literature review on LCSA gives an overview of key developments in science and current practices in measuring sustainability. Also, it serves as a foundation for design of sustainability assessment model in Chapter 4.

## 3.1. Supplier – public procurer relationship change

The concept of circular economy has emerged in the context in which supply chain actors need to secure long-term supply and improve the management of resources. Moving to a circular economy requires systemic change and it affects all stakeholders in the value chain (European Commission, 2014). Due to its characteristics, circular economy affects both suppliers' and public procurers' business models, as well as their relationship. However, since literature on supplier – public procurer relationship change induced by a circular economy is very scarce a broader perspective on circular economy is taken, associating it with general sustainability issues. Thus, in the context of this research, sustainable development and circular economy alter supplier – public procurer relationship in a resembling way.

### 3.1.1. Circular economy

Given the recent development, the global economy will face millions of new middle-class consumers entering the market and expecting the same level of satisfaction and needs fulfillment that already exists in developed countries. Over the next two decades, it is estimated that the middle class will expand by another three billion people, thus drive the waste problem beyond its current magnitude (EMF, 2014). The growing demand will reflect on resource availability and pricing. As we are at the end of the era of cheap oil and materials, we will face resource-related risks and challenges to manage commodities. Despite of movements in developed countries, the mindset in certain industries is still locked in a linear system way. As a consequence, more and more experts are urging the shift to a circular economy. A circular economy breaks the vicious circle of linear production, which is characterized by take-make-dispose principle, by decoupling economic growth from resources. Based on make-use-return principle (see Figure 3), a circular economy could potentially help to resolve the sustainability challenge and support organizations moving towards sustainability by reducing resource extraction and waste streams, leading to decreased environmental impact (Stahel, 2010).

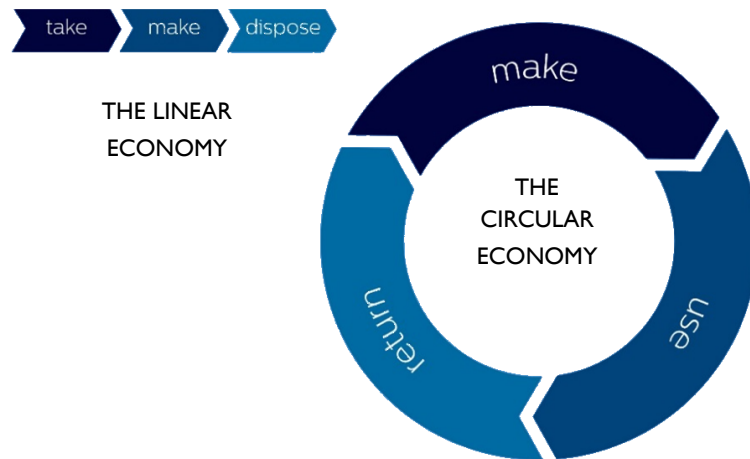


Figure 3 Linear versus circular economy (Philips, 2014)

A circular economy is an economy that enables producers to show value and quality of their product to customers and at the same time offer services and products that are designed for performance and re-use of all materials (Joustra et al., 2013). “The circular economy offers a strategy for value creation, growth and competitiveness that will become increasingly compelling against a backdrop of high and volatile resource prices” (Preson, 2012). For a successful deployment of a circular economy it must be linked to an organization’s overarching business strategy and not just remain a subset of its sustainability or resource efficiency strategy (Perella, 2013).

Although the concept of a circular economy is present in scientific circles for couple of decades there are still uncertainties about official definition and end-goal of circular economy. Moreover, ambiguous terminology is used in the past as a reference to circular economy. In order to clarify main underpinnings, the theoretical framework of circular economy is analyzed in turn. Based on principles and lessons from various schools of thought, guided choices in the transition to a circular economy are presented.

### Principles of circular economy

Although elements of circular economy can be traced back to couple of decades in the past, it is not until 1970s that academics contributed to circular economy framework. According to Stahel and Reday (1976) circular economy is about economics and it consists of the following 5 guidelines:

- The smaller the loop (activity-wise) the more profitable and resource efficient it is.
- Loops have no beginning and no end; value maintained replaces value added.
- The speed of the circular flows is crucial; the efficiency of managing stock in the circular economy increase with a decreasing flow speed.
- Continued ownership is cost efficient: reuse, repair and remanufacture without a change of ownership save double transaction costs.
- A circular economy needs functioning markets.

One of the most prominent advocates of circular economy practices and business transformation is the Ellen MacArthur Foundation. Taking up and adjusting existing terminology on circular economy resulted in key principles of a circular economy (see Figure 4).

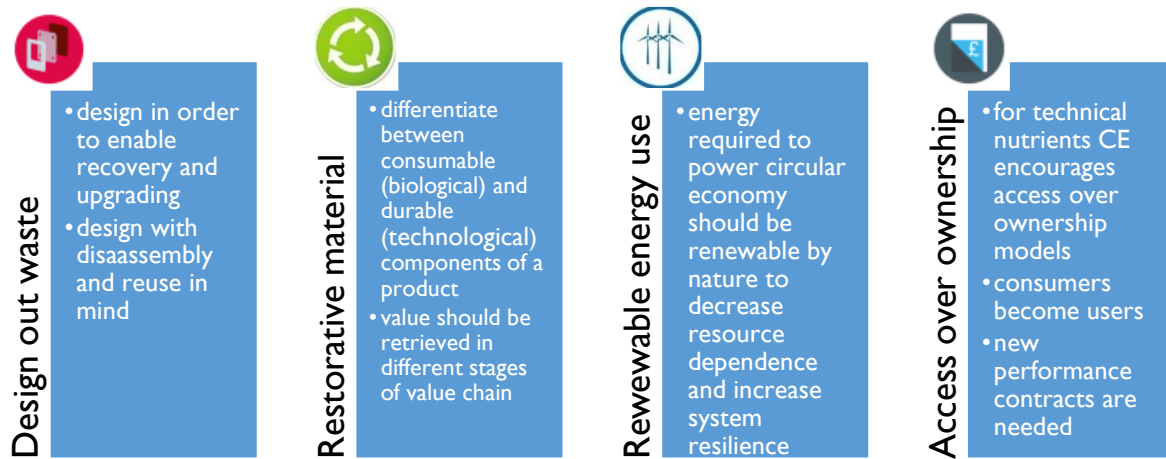


Figure 4 The key principles of circular economy (Adapted from: EMF, 2013)

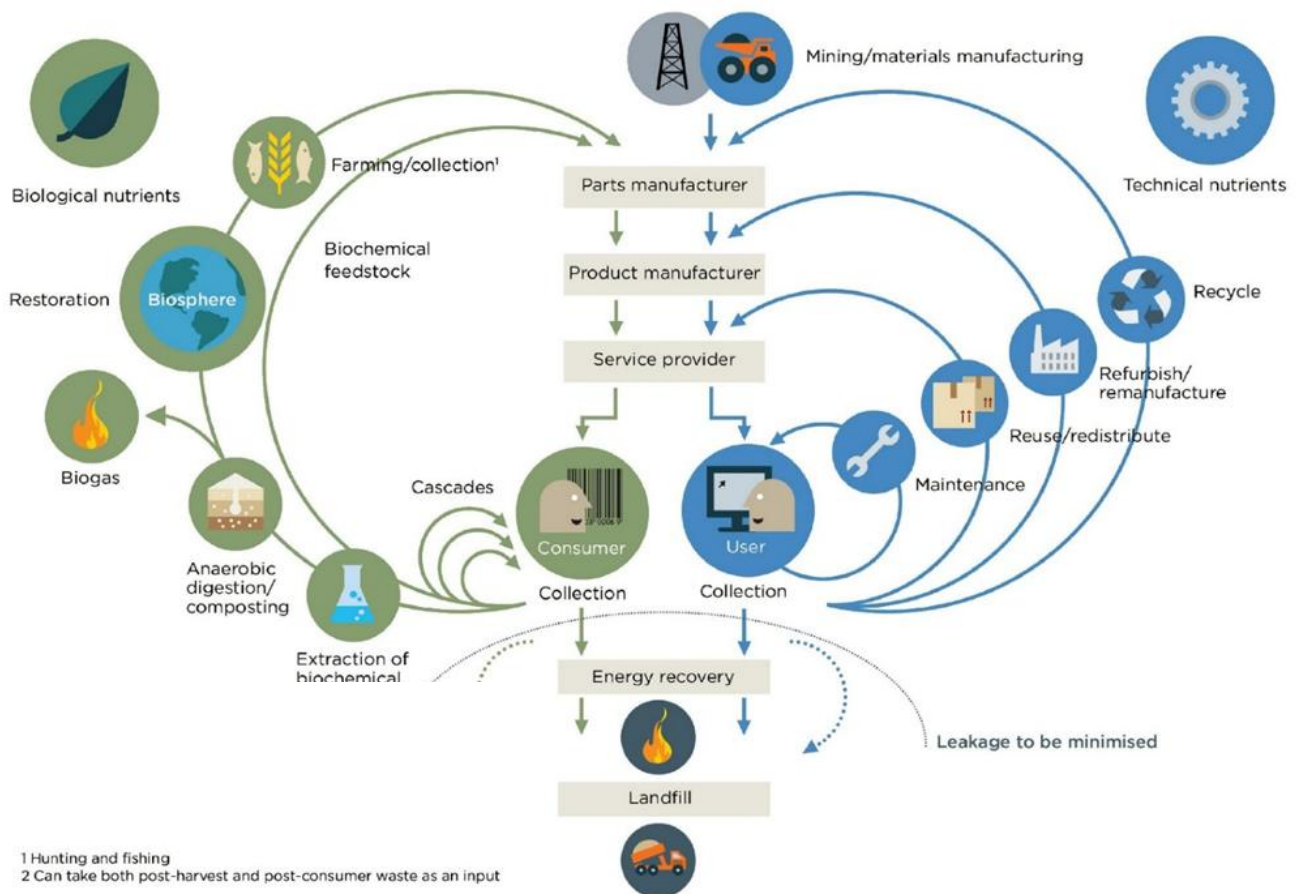


Figure 5 The CE Framework (Source: EMF, 2013)

Ellen MacArthur foundation took the principles of a circular economy and translated them into a circular economy framework that addresses both biological and technical materials (see Figure 5). The figure presents linear economy as a vertical process in the middle, from material extraction and manufacturing to landfill. The figure also presents two circular economy value loops, biological nutrients on the left and technical nutrients on the right side. Authors claim that value is created through closing loops. Unlike biological materials, technical materials are not cascaded to other applications but the functionality, integrity and the value of embedded energy are maintained through



remarketing, reuse, disassembly, refurbishment and remanufacture. The significant difference in the circular economy approach is that its starting point is economic value creation and that makes it interesting for businesses. In practice circular economy is deployed from three circles perspective: the first circle includes corporate level (micro level) initiatives such as cleaner production and environmental management systems; the second circle is inter-firm level (meso level) that focuses on eco-industrial parks and industrial symbioses to make profit out of waste products; the third level is the social (macro level) and includes activities such as development of eco-cities and eco-provinces (Lepak, Smith, & Taylor, 2007; Yuan, Bi, & Moriguchi, 2006). After covering principles of circular economy it is important to introduce the schools of thoughts that circular economy originates from.

### Lessons from various schools of thoughts

Since it was first developed in the 1970s, the circular economy approach has brought to the attention of science and business alike. Pinpointing the circular economy concept to one literature stream would be a challenge since it has its origin in several schools of thoughts. Multiple authors took different design approaches and tools when reflecting to living systems. Obviously, there is an element of overlap in already existing principles upon addressing circular economy and its origin.

#### 1 - Industrial Ecology and pollution prevention

Industrial ecology is a system view of the interactions between industrial and ecological systems (Garner & Keoleian, 1995). It aims at quantifying the material flows and accompanying impact on environment. Frosch & Hallopoulos (1989) propose a principle of using one industry's output for another industry's input, thus reducing the use of raw materials, waste and pollution. At the very core of industrial ecology is the redesign of society, originally inspired by ecosystem (Wermeulen, 2006). By far the largest part of industrial ecology literature deals with the development and application of various methods for measuring environmental impacts of human production and consumption; and describing practical cases of products, materials and eco-industrial regions (vermeulen, 2006). Compared to a system approach of industrial ecology, pollution prevention is more of a long-term strategy aimed at reducing the amount of residuals and toxicity released to nature. In addition pollution prevention advocates for elimination of waste, while industrial ecology favors use of waste as input in production process.

#### 2 – Zero emissions initiatives

As envisioned by Gunter Pauli, the future of sustainable development is in co-evolution with nature. There are three perspectives that are covered: (1) from an environmental perspective, the elimination of waste represents the ultimate solution to pollution problems that threaten ecosystems while shift towards renewable sources means utilization of earth's resources in a sustainable manner; (2) for industry, zero emissions can be viewed as a standard of efficiency – producing more with less; and (3) governments can prosper from use of renewable materials as that creates new industries and generates jobs<sup>2</sup>.

#### 3 - Ecodesign

To keep pace with the rapidly changing industrial setting, many environmental movements have included social and economic concerns in their scope (Webster & Johnson, 2008). Ecodesign is the most widespread notion of fusion between design and environment that tackles both social and profit elements of production. Other notions include 'design for sustainability', 'design for environment', 'environmentally conscious design', 'green product design' etc. Scientists and industrials have acknowledged the necessity to amalgamate product development and design

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<sup>2</sup> More information available at: [http://www.zeri.org/ZERI/ZERI\\_Perspectives.html](http://www.zeri.org/ZERI/ZERI_Perspectives.html)

together with environmental concerns. Crul & Diehl (2008) argue that ecodesign consists of 'product-profit-planet' elements, excluding 'people' dimension. Further developments of the concept include several improvements on social domain and new product concepts, such as offering product functions as services.

#### 4 - Biomimicry

Janine Benyus, as most influential author in the field of biomimicry, categorizes biomimicry as innovation inspired by nature that studies nature's best ideas, such as photosynthesis, brain power, and shells- and adapts them to human use. In addition, biomimicry revolutionizes how we invent, compute, harness energy, repair the environment and feed the world (Benyus, 1997). Modeling innovative strategies and measuring design against sustainable benchmarks are enabled by several life's principles as inspirational ideals (see Figure 6). Life's principles are a lesson from nature that can be used to learn from living organisms and systems (Poppelaar, 2014).

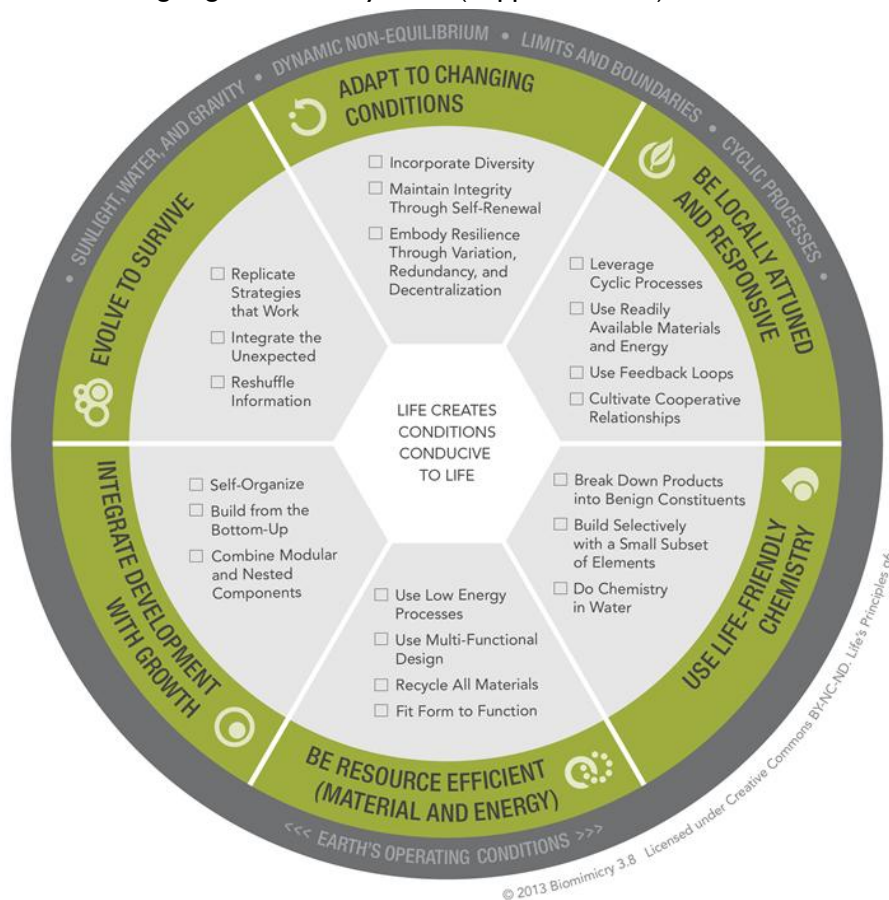


Figure 6 Life's principles of biomimicry (Source: Biomimicry 3.8 website)

#### 5 - Cradle to Cradle (C2C)

The Cradle to cradle concept is developed by chemist Michael Braungart and architect Bill McDonough by merging intentional design, chemistry, and products for industry. This concept is about improving product quality by moving from simply being 'less bad' to becoming 'more good' (McDonough & Braungart, 2002). Former approach is characterized as eco-efficient where the aim is to reduce or minimize damage. The latter is displayed as eco-effective approach where positively established goals are based on cradle to cradle values and principles toward a positive or beneficial footprint. The biological and technical cycle of the product should be stated and materials should be inventoried (Poppelaars, 2014). By using materials health assessment process, biological and chemical materials assessment are addressed and visualized according to cradle to cradle standards.

## 6 - Blue Economy

As an advocate of blue economy, Pauli promotes it as “the best and the cheapest solution for health and the environment where necessities of life are free due to local system of production that works only with already existing resources” (2010). Innovative business model and competitiveness are two characteristics of blue economy that serve as a motivation trigger. In a blue economy, business models are capable of bringing competitive products and services to the market by responding to basic needs while building social capital and enhancing mindful living in harmony with nature’s evolutionary path.

.....

Key lessons learned from various schools of thought suggest that different focuses can be noticed. While circular economy and blue economy are mostly concentrating on the business model, others are looking more into environmental impact of systems and products (industrial ecology and pollution prevention, cradle to cradle, and zero emissions initiatives) or product design efforts (eco-design and biomimicry). To a certain point, circular economy, as a way of thinking, can relate to every mentioned school of thought.

### From linear to a circular economy: motives and implications

“

*We need fearless leadership that embraces and rewards the circular economy, a leadership that encourages not only customers to alter their consumption from owning to using, but also stakeholders to co-design, co-create and co-own.*

*Frans van Houten, CEO Philips*

Shift from linear to circular economy is made when connection between resource use and waste residuals is established (Bilitewski, 2012). Adopting a circular business model that aims to sustain the planet could present an appealing situation on multiple levels, from environment to governance. In the long-run this transformation could offer an essential competitive advantage as circular economy claims to create more value from resources, support companies in meeting demands of the market, lowering environmental costs, increasing consumer awareness and participation as well as securing supplies (Preston, 2012; EMF, 2013; Bechtel, Bojko, & Völkel, 2013).

Closing the loop on a global level poses a challenge to all circular economy stakeholders due to unsafe consumer and industrial products of unknown specifications that can readily enter the global market (Bilitewski, 2012). Fundamentals of circular economy contribute to finite resources independency of economies, resource price volatility and supply disruptions. “In terms of resource prices for energy and material we have witnessed two important trends: firstly, prices were constantly decreasing for the last 100 years and maintaining ownership of materials to assure access to future resources had no sense; secondly, at the beginning of the 21st century the prices were constantly increasing creating a big paradigm shift where actors maintaining resource ownership have guarantee of resource availability and price in the future” (Stahel, 2010). Wide observations on circular economy also suggest the following global trends as trigger of transition to circular economy (EMF, 2013):

- (1) **Low gains on manufacturing processes efficiency** – as gains are insufficient they fail to generate real competitive advantage or differentiation;
- (2) **Energy use and resource depletion** – due to improvements in energy and resource efficiency the real amounts of materials and energy used is increasing;
- (3) **Supply chain disruptions** - risk to supply security and safety associated with global supply chains is increasing; and
- (4) **Competition challenges** - competition for virgin resources is getting more sensitive, even on a local level. Supply chain actors respond to these global trends because they create disruptions and increase risks. As a consequence, the priority is on risk management, change of business strategies and introduction of new business models.

Among other things, circular economy implies that decision making on product and material level must address all three dimensions of sustainability by using life cycle thinking. “Applying life cycle thinking offers a way of incorporating sustainable development in decision-making process” (Valdivia et al., 2013). Techniques have to be life cycle based as to recognize and avoid trade-offs by including the whole life cycle (Klöpffer, 2008). Due to its systemic approach, life cycle thinking supports integration of sustainability into innovation, design and evaluation of products and services (Sala, Farioli, & Zamagni, 2013a). As a circular economy is restorative by intention it relies on renewable energy, eliminates the use of toxic chemicals and eradicates waste through careful design (EMF, 2013). The aim is to optimize the systems and change business model, rather than just focus on changing the system components. Compared to the linear manufacturing economy, circular economy builds on self-responsibility of economic actors and higher competitiveness through more efficient available market solutions, technical and commercial innovation (Stahel, 2010; Andersen, 2007). Given the characteristics of a circular economy, it is important to reflect on the main supporting and inhibiting factors for the transition to circular economy. EMF (2014) recognizes following supply chain drivers for transition from linear to circular economy:



#### Circular design.

Improvements in materials selection and product design are crucial for circular economy with an emphasis on modular design and use of renewable resources.



#### Innovative business models.

There is a shift from ownership to performance which creates incentives for suppliers to include design for reuse and longevity into attractive value propositions.



#### Core competencies along reverse cycles and cascades.

Since suppliers have the ownership over products, there is an urgency to develop waste management practices. On that wise, a high quality and cost-effective systems for reverse logistics and treatment have to be established.



#### Financing and risk management tools.

As important functions for every successful transformation, attractive financial models need to be supported with advanced risk management analysis.



#### Regulation and infrastructure development.

In order to deploy circular economy principles in businesses, regulation and infrastructure have to change. The legislative framework should provide motivation rather than inhibit supply chain actors from making the shift.



## Education.

It is important to increase the knowledge and information flow on circular economy, both within, and outside, of an organization. Internally, skills have to be created to drive circular innovation, while externally the general customer awareness has to increase.

In the transition to circular economy, supply chain actors need to be aware of the potential inhibiting factors. Whether obstacles are stemming from regulation, policy or are linked to cultural, social and technological context, there is factor present in the value chain. Rather, obstacles often influence each other. For example, reverse logistics, as an essential component for circular economy, can be heavily influenced by various levers: extended producer responsibility, new business models or policy instruments (European Commission, 2014). As outlined by Preston (2012), some of the most important barriers of transition to circular economy, found in industrial practices and consumption patterns, are set out below:

- Lock-in to resource-intensive infrastructure and development models.
- High up-front costs.
- Complex international supply chains.
- Lack of consumer enthusiasm.
- Legislative framework.
- Challenges for company-to company cooperation.
- Political obstacles to putting an appropriate price on resource use.

This is a non-exhaustive list but it covers the main barriers that supply chain actors are challenged with. These obstacles have to be addressed in a systematic way since they are relevant for any stage of a value chain. Having in mind drivers and obstacles for the transition to a circular economy, “actions towards a circular economy to date have been mainly driven by value maximization along the value chain and the interest in continually reintroducing assets to markets” (European Commission, 2014). But in the last couple of years, a circular economy is also in the focus of international organizations, such as the World Economic Forum (WEF). A WEF proposes circular economy as a key strategy to improve resource efficiency, waste related issues and support collaborative climate which could help businesses shift towards savings in material productivity. In addition, “adopting a circular business model that seeks to sustain the planet could present an attractive win-win-win situation for the society, the environment and the company itself” (Bechtel, Bojko, & Völkel, 2013). A circular economy offers both short – and long-term benefits. Benefits of circular economy transition are multiple and address concerns of industry and customers while sourcing for efficiency and innovation. For businesses it is not only about short term financial benefits but also an opportunity of creating a resilient market differentiation. As shown on Figure 7, the estimated potential costs savings for European economy range from 262 to 485 billion Euro until 2025 (EMF, 2013). Putting potential costs savings from circular economy into perspective of EU’s GDP reveals that estimated potential in 2025 is only 3.39% of 2014’s GDP<sup>3</sup>. A fact like this should initiate more in-depth discussion about the financial perspective. Next to direct financial savings, a circular economy offers indirect benefits as well: more efficient supply chain management, innovation developments, mitigation of volatility, drivers for job creation, long term resilience of the economy, and longer and better relationship with customers (EMF, 2013; IMSA Amsterdam, 2013).

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<sup>3</sup> <https://www.gfmag.com/global-data/country-data/the-european-union-gdp-economic-report>

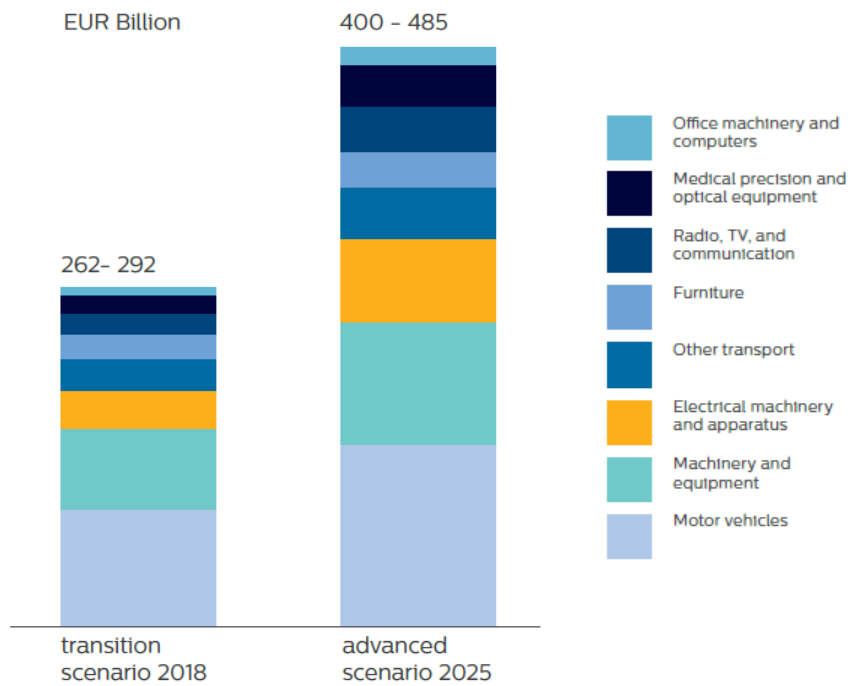


Figure 7 Potential costs savings from circular models for European economy (Source: EMF, 2013)

## Conclusion

Building and maintaining a company as to capitalize the circular economy opportunities is challenging. At theoretical and conceptual level explanations, drivers and obstacles can be described and analyzed. But translating theory into practice is not easy. Companies deal with existing strategies, structures and operations that are deeply rooted in the linear business approach. Business models that allow better access to products and services are needed to alter these institutional conditions. Companies seeking circular economy triple bottom line impacts need to develop new business models that are free of the linear mindset.

Only modifying current business models is insufficient since changes need to be applied across the whole value chain. Deploying circular economy affects existing behavior patterns and calls for greater engagement in terms of knowledge transfer and collaboration. Suppliers need to increase their knowledge of product impacts and associated risks to inform procurers and therefore influence their strategies. There is a growing need to understand and identify how these issues are undertaken in an actual case study. Therefore, in the empirical part of this research circular economy claims will be investigated. A Philips Lighting case study will investigate the drive for a joint approach towards a circular economy which demands partnerships and collaboration. Given the current conditions, the deployment of circular economy will greatly depend on: risk and performance management; environmental and social standards for monitoring and evaluation; and proactive strategy for sustainable products and services.

### 3.1.2. Sustainable supply chain

#### Contextual background

Sustainability as a concept has been broadly spread throughout the society (Carter & Easton, 2011). Accordingly, sustainability has gone beyond specific facility or organizational scopes to entire supply chains (Linton et al., 2007). Sustainable supply chain literature is found in environmental and sustainability related journals, as well as in traditional operations and supply chain management journals. Corporate and academic interest in sustainable supply chain has risen considerably in the last decade. This can be proven by the number of scientific papers and corporate reports. Although

research on sustainable supply chain has developed over the last decade, some fundamental issues still need to be addressed in order to offer prescriptive models of how to respond to supply chain triggers. The recent literature suggests that sustainable supply chain is facing several pressures which could point out towards possible relationship change elements (see Table 4).

### Sustainable supply chain pressures

Public responsibility for social and environmental performance (from employees to governments) – stakeholders have an important role in the supply chain which creates incentives for focal company to change.	Murphy & Poist, 2002; Carter & Jennings, 2002; Cramer 2006; Seuring & Müller, 2008; Walker, Sisto, & McBain, 2008; Carter & Easton, 2011, Müller, Vermeulen & Glasbergen, 2009
Public procurers – because of the high responsibility and accountability to citizens’ public procurers use their buying power as to alter suppliers’ practices.	Carter & Jennings, 2002; Linton et al., 2007; Pagell & Wu, 2009
Globalization – integrated global market place results in growing customer orientation, shorter product life cycles and increased competitiveness. As various functional activities have transcended companies’ boundaries, there is a need for more flexible, reliable and responsive business processes.	Cramer, 2006; Seuring & Müller, 2008; Seuring, Sarkis, Müller, & Rao, 2008; Walker, Sisto, & McBain, 2008, Hutchins & Sutherland, 2008
Outsourcing – customers start to value outsourcing of certain services such as maintenance, technology upgrades and insurance.	Seuring & Müller, 2008; Seuring, Sarkis, Müller, & Rao, 2008; Walker, Sisto, & McBain, 2008

Table 4 Sustainable supply chain pressures (Source: Author)

Supply chain is a complex field of continuously evolving markets and relationships. Since production processes are spread around the globe, customers, suppliers and focal companies are bonded by information, material and capital flows (Seuring & Müller, 2008). As a response to public responsibility for social and environmental performance, companies identify and address environmental and social outcomes across the supply chain. Social and environmental criteria compliance needs to be fulfilled if supply chain members want to remain within the supply chain, while supply chain competitiveness is maintained through meeting customer needs and related economic criterion (Seuring et al. 2008). Responding to pressures from public procurers leads to harvesting business benefits – reduced cost, improved quality and continuity of supply, increased revenue, innovative products and services, and managed reputation risk (APICS and PwC, 2014). Furthermore, by deploying sustainability in supply chains companies avoid laws and regulations related risks. As their roles and responsibilities are placed within public scope and have to be as transparent as possible, public procurers have become more aware of the fact that their actions have severe environmental and social consequences. That is why public procurers put pressure on suppliers to emphasize on environmental and social performance of products offered.

Companies can respond to these pressures and demands with proactive or reactive sustainable supply chain management approaches. For example, companies start introducing green and socially responsible products, and demand the same from processes within their own supply chain. In turn, this research looks at sustainable supply chain management, which is by Seuring & Sarkis (2008)

defined as “the management of material and information flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e. economic, environmental and social, and stakeholder requirements into account”.

### Sustainable supply chain management

In the scope of this research it is important to address sustainable supply chain management as to underline the business imperative behind responsible environmental and social stewardship. A systematic outlook of sustainable supply management strategies and practices demonstrates how companies respond to pressures and forge ahead, despite the manifold challenges across governance, processes and data management.

The concept of sustainable supply chain management emerged in the last 10-15 years with widespread of scientific and business related research. Although the first period of developing a concept of sustainable supply chain management reflected only on describing it, more solid foundation of frameworks and models emerged later on (Seuring & Müller, 2008; Seuring et al., 2008; Pagell & Wu, 2009). Seuring & Müller (2008), in turn, look at the sustainable supply chain management from three perspectives: (1) triggers for sustainable supply chain management, (2) supplier management risk and performance; and (3) supply chain management for sustainable products (see Figure 8). The latter two perspectives form two broadly accepted sustainable supply chain strategies, which should be mutually inclusive and complementary.

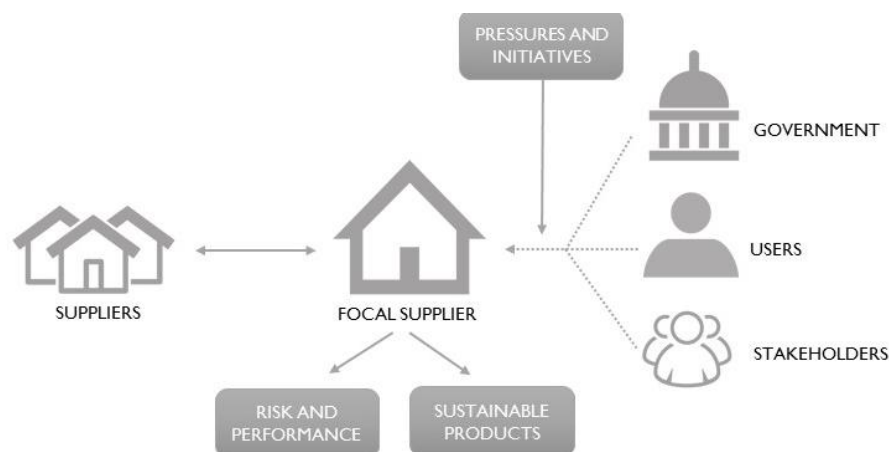


Figure 8 Triggers for sustainable supply chain management (Adapted from: Seuring & Müller, 2008)

In regard to triggers for sustainable supply chain management, the starting points are external pressures and initiatives set by different stakeholder groups on the focal company (see Figure 8). “Focal companies are those companies that usually (1) rule or govern the supply chain, (2) provide the direct contact to the customer, and (3) design the product or service offered” (Handfield & Nichols, 1999). In particular, governmental control and demands are relevant. In addition, users source for various pressures a since supply chain is justified only if products and services are accepted by customers. Other pressures can come from NGOs or other stakeholder groups that hold focal company responsible for environmental and social problems. Whether pressures on focal company come from customers, stakeholder or governments, they are usually passed on to suppliers (Seuring & Müller, 2008). By holding the most responsibility across the supply chain, the focal company operationalizes a wide range of strategies to deal with this responsibility. Two major strategies used are supplier management for risk and performance, and sustainable products supply. Based on the literature review of 191 papers, Seuring & Müller (2008) have identified main pressures and incentives for sustainability in supply chain, as well as main supporting factors for sustainable



supply chain management (elements are listed according to the number of papers that refer to them). In particular, legal demands and regulation score very high (see Table 5). Indeed, companies focus on environmental and social consequences of their operations in order to reduce related risks and comply with legal acts (Min & Gale, 1997; Cousins, Lamming, & Bowen, 2004; Koplin, Seuring, & Mesterharm, 2007).

Pressures and incentives	Supporting factors
Legal demands/regulation	Company-overlapping communication
Customer demands	Management systems (e.g. ISO 14001, SA 8000)
Response to stakeholders	Monitoring, evaluation, reporting, and sanctions
Competitive advantage	Training education of purchasing employees and suppliers
Environmental and pressure groups	Integration into the corporate policy
Reputation loss	

*Table 5 Elements that can support or hinder sustainable supply chain (Adapted from: Seuring & Müller, 2008)*

The second perspective on sustainable supply chain management reflects on supplier management for risk and performance (see Figure 8). This perspective provides an internal outlook on set of goals that are important for sustainability developments. Seuring and Müller (2008), for instance, state that barriers for implementing sustainable supply chains are (1) higher costs, (2) coordination effort and complexity, and (3) insufficient or missing communication in the supply chain. To hamper these barriers, companies deploy different management systems, from ISO standards that focus on environmental performance, to SA (Social accountability). Hence, combining environmental and social performance can result in mitigation of risk and better performance. These management systems require information on life cycle information of products that can be supported or hindered by supply chain actors (Norman & Jansson, 2004; Hervani, Helms, & Sarkis, 2005; Müller, Dos Santos, & Seuring, 2009).

The third perspective of supply chain management focuses on sustainable products (see Figure 8). It is highlighted that the overall goal of sustainable products is to satisfy customers and gain competitive market advantage, by improving environmental and social equity (Gold, Seuring, & Beske, 2010; Kolk & Van Tulder, 2010). So to meet this aim, product and service impacts need to be analyzed for all life cycle phases. Using life cycle assessments to assess product and service characteristics led to development of life cycle management (Seuring, 2004; Sudarsan et al., 2005; Stark, 2011). Although joint initiatives in addressing life cycle assessments result in more reliable and comprehensive outcomes, a focal company holds the responsibility and most important role strings in its value chain. Therefore, in mapping their supply chain, focal companies need to expand the assessment scope from first-tier suppliers to second- and third-tier suppliers and establish partnerships throughout operational process (Preus, 2005; Meyer & Hohman, 2000; UN Global Compact Office & BSR, 2010). This implies that focal supplier needs to incentivize better transparency across the supply chain as to analyze stages of the product life cycle phases and communicate why are improvements required (Seuring & Müller, 2008). In addition, companies are evaluating their production chains to discover any points at which waste and value leaks could be mitigated with the result that more circular business and revenue streams are created (JWT, 2014).

## Sustainable supply chain developments



*We can create innovations for this circular economy. If I do it alone, it will need much more time to scale up, which is why I am convinced of the need for business alliances, where companies can co-create new solutions, new technologies and new business models”*

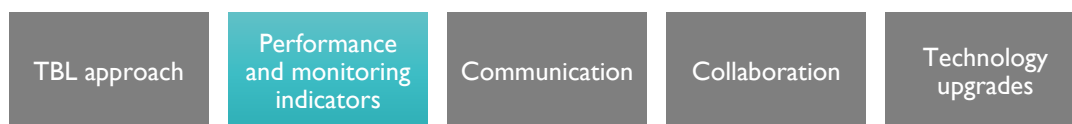
*Antoine Frerot, CEO Veolia*

This research acknowledges the existence of significant supply chain advancements that are probably sign of a broader shift toward integrating sustainability in supply chain relations, processes and strategies. Still, there are some areas that embody opportunities for further development of sustainable supply chain, as discussed in turn. These areas form internal and external needs that have to be facilitated across the supply chain in order to face challenges.



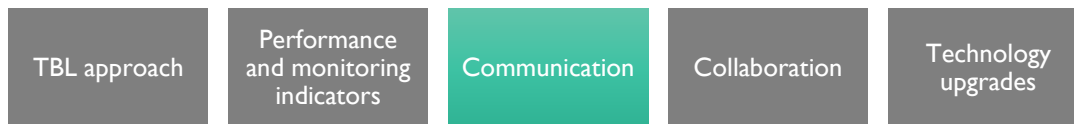
Developed by John Elkington, the ‘triple-bottom-line’ (TBL) concept revolutionized the approach toward measuring sustainability and performance of businesses, governments and nonprofit organizations. By focusing on people, planet and profit, TBL is an important tool that supports sustainability goals. It is considered that sustainability can be implemented on different scales and levels, ranging from short- to long-term dimensions, as well as local and global scales (UN Global Compact Office & BSR, 2014). In the scope of deploying TBL approach in supply chain, identified fields that require maturing research include:

- Empirical developments regarding the stakeholder influence on the choice of sustainable supply chain management strategies.
- Contributions on the relation change elements between suppliers and public as a response to internal and external influences.
- Empirical research, through case studies, on how supply chain actors improve their products and services through collaboration and partnerships.
- Developments on the relation between three dimensions of sustainability, sustainability assessment frameworks and tools from a product/service level.

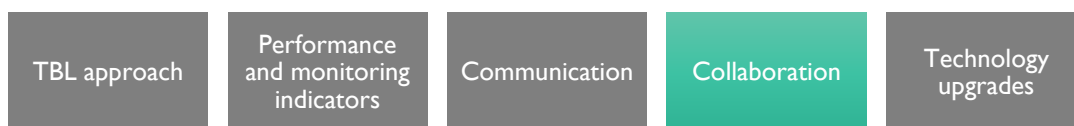


Performance and monitoring indicators outline environmentally responsible manufacturing practices and suggest alignment of product, process, and systems across the supply chain that result in greater financial benefits. Further, Schmidt & Schwegler (2008) seek to expand discussion on internal and external monitoring, control and reporting practices important for development of appropriate performance indicators that would support a set of organizational, management, and motivational dimensions. They propose development of top-level aggregate indicators that would allow individual companies vertical comparisons along the value-adding chain and horizontal comparison among companies or production locations. Outcome of these indicators could be used to guide general

decision making and suggest material flows changes in the supply chain. Although current available literature mostly covers economic and environmental performance indicators, the issues of social dimension need broadening (Seuring & Sarkis, 2008). Seuring & Müller (2008), Gupta (2011) and Gold, Seuring, & Beske (2010) provide some evaluation on impacts and requirements along the product life cycle phases by including all important actors, from raw materials supplier to end-user. In this perspective additional research is needed on inclusive indicators and assessment for all product life cycle phases (Graafland, 2002; Hagelaar & Vorst, 2001; Davies & Crane, 2003; Danse & Wolters, 2003; Matos & Hall, 2007; Diabat & Govindan, 2011).



Analyzed literature also outlines the need for communication on general supplier developments. Provided that companies are deploying sustainability practices, their relationship with stakeholders should change accordingly (Müller, Vermeulen & Glasbergen, 2009; Carter & Easton, 2011). Seuring and Müller (2008) emphasize the urgency of dramatic and systematic improvements in multi-directorial communication among all stakeholders across the supply chain. In such manner, internal stakeholders need to be provided with training, education and supporting incentive systems, while external stakeholders can benefit from personal relationship developments (Lindgreen et al., 2006; Greer & Lei, 2012). With focus on reuse and service, companies create extended relationship programs. These programs entice co-creation processes and make customers capture value. In all areas of supply chain effective communication and trust-based relationships are “critical to meeting sustainability objectives” while transparency and accountability are crucial in maintaining customer relationships (UN Global Compact Office & BSR, 2014).



Deploying sustainability practices and communicating them in a transparent way can yield better economic benefits in collaborative supply chain climate. Several authors highlight that individual actions on performance improvements are negligible when compared to collaborative actions within supply (Côté et al., 2008; Seuring & Müller, 2008; Vermeulen & Seuring, 2009; Wiengarten et al., 2010; Cao & Zhang, 2011; Hazelzet, 2015). Economic, social and environmental benefits can be achieved with collaboration and strategic partnerships across the value chain through transition to a closed-loop supply chain and reverse logistics operations (Papageorgiou, 2009; Müller, Vermeulen & Glasbergen, 2009). Sustainable supply chain theory continues to investigate how to meet customer needs and sustain competitiveness. Pagell & Wu (2009) for instance, inquire about partnership and collaboration aspects of the supply chain and establish a wide range of opportunities. Therefore, it is not surprising that there is a need for collaboration across the value chain. In particular, circular economy motivates different companies to embrace cross-category collaboration and “help break down the supply chain and materials barriers that prevent the circular economy from fully taking shape” (JWT, 2014). Also, benefits from new technologies can provide impetus for collaboration across the supply chain.



Supply chain actors have to undertake initiatives to promote greater responsibility by encouraging the development and diffusion of environmentally friendly technologies (UN Global Compact Office & BSR, 2010). Many of the changes in the supply chain would not be possible without support of innovative new technologies – especially the digital ones, such as *Internet of things* and *Big Data Analytics*. “The emergence of *Big Data* has shifted the manner and scale in which problems can be solved, providing deeper market knowledge and increasing customer-focused solutions” while offering better asset tracking (Philips, 2014). When reflecting on circular economy it is suggested that designing value chains to embed circular business models is a major frontier for digital revolution allowing products to flow between users, markets, and lifecycles at very low transaction cost (Accenture, 2014). Furthermore, emerging *Internet of things* and new communication technologies can provide a critical set of business capabilities that are essential for uptake of circular economy-inspired business models (EMF, 2014). The *Internet of things* has the potential to expose flow of materials and provide timely information of state in which products are, allowing automated reintegration of materials back to economics systems and addressing concerns around transparency, ownership, quality and value (EMF, 2014).

### Conclusion

As a result of the literature review on sustainable supply chain, a conclusion can be drawn – the sustainable supply chain management field is dominated by an environmental focus. Integration of social sustainability is in infancy, and needs to be further investigated. In addition, relations between value chain actors need to be described and analyzed so their responses to pressures and challenges can be mapped in the decision making process. There are different delivery modes within supply chains: (1) business to business – B2B; (2) business to customer – B2C; and (3) business to government – B2G. Customer demands and purchasing power gives public procurement leverage to influence suppliers towards innovation and sustainability. Therefore, the empirical part of this research will reflect on the B2G sector (Philips Lighting to WMATA).

In particular, analysis is on how data is unlocked within the supply chain which allows a focal company (Philips Lighting) to inform public procurer (WMATA) about service pricing, end-of-life strategies, and resource sourcing. Equally important is to analyze circular economy compliance across the supply chain and presence of collaboration – as crucial element to make a circular economy work (Perella, 2014).

To subvert possible liabilities, supply chain communication needs to be addressed. A dramatic and systemic improvement in the supply chain communication among all stakeholders is an essential and urgent ingredient for responding to challenges and making improvements (Seuring & Sarkis, 2008). In regard to communication, the case study will highlight the type of constituents that were communicated between Philips and WMATA and to what extent communication improved their relationship.

### 3.1.3. Sustainable public procurement

#### Contextual background

The global economic downturn greatly tempered the linear mindset, including public procurers. Still, public sector remains responsible for helping to achieve public goals. In this way, public procurement is described as processes used by governments and public sector organizations to purchase goods,

services and commission infrastructure developments (McCrudden, 2004). As public sectors aim to develop safer, prosperous and equitable society with reduced environmental and social risk, sustainability practices are being deployed and integrated. Next to this, public entities' interest in sustainable public procurement includes cost effectiveness, importance of promoting sustainable public image and leadership by example (Walker & Brammer, 2009; Perera et al., 2007).

Being aware of immense responsibilities of public actors, it is crucial to explain the methodology behind sustainable public procurement. Public procurement articles seek to emphasize both on 'green' procurement and sustainable public procurement. Although there is no widely accepted definition of sustainable public procurement, there are clear distinctions between the two above mentioned concepts. Several papers (McCrudden, 2004; Parikka-Alhola, 2008; Palmujoki et al., 2010; Tarantini, Loprieno, & Porta, 2011) characterize 'green' procurement as a selection of products and services that decrease environmental impacts and require a company to set the scope of environmental impact assessment to all product life cycle phases. However, when it comes to sustainable public procurement, next to environmental concerns there are also social considerations that are taken into account (Walker & Brammer, 2009; Preus, 2009). In such manner, UK Sustainable Procurement Task Force (2006) characterizes sustainable public procurement as a process "whereby organizations meet their needs for goods, services, works and utilities in a way that achieves value for money on a life cycle basis in terms of generating benefits not only to organization, but also to society and economy, whilst minimizing damage to the environment". UNEP (2012) investigated a range of environmental and social considerations and suggested that environmental considerations include: reduction of greenhouse gas emissions and oil pollutants; improved energy and water efficiency; reduced waste and support for reuse and recycling; use of renewable resources; reduced hazardous waste; and reduced toxic and hazardous substances. Further, social consideration should include: gender and ethnic equity; poverty eradication; and respect for core labor standards (UNEP, 2012).

Environmentally compliant purchasing of goods and services, being aim of public procurement, affects environmental overload and contributes to sustainable consumption and production patterns (EPA, 2011). So by adjusting purchasing needs, sustainable public procurement has the opportunity to influence suppliers to shift toward sustainable practices (Claro et al., 2013). Public procurers became more mindful of consequences of their actions as a response to media attention about change in existing buying patterns. Given the character of policy environment and need to abide by procurement legislative directives, sustainable public procurement arises primary from external pressures to undertake it (Walker & Brammer, 2009) where transparency and competitiveness of public tenders are very important elements (McCrudden, 2004; Uttam & Roos, 2014). The main drivers and barriers of sustainable public procurement are highlighted and described in turn.

### **Drivers and barriers of sustainable public procurement**

Because of its market and societal power, sustainable public procurement is identified by several international initiatives (e.g. OECD Council, World Summit on Sustainable Development, UNEP International sustainable public procurement initiative) as an important instrument for stimulating more environmentally and socially sound product and service solutions. UN Department of Economic and Social Affairs (2008) identified that sustainable public procurement enjoys a significant push force from international and regional organizations and networks, e.g. European Commission, International Green Purchasing Network and Local Governments for Sustainability. Furthermore, local and governmental entities around the world identified the magnitude of social effects of sustainable public procurement, which could include lower unemployment rates and better gender,

race and ethnic quality. In Europe for instance, a large number of countries conformed their tendering processes so they would include environmental considerations when purchasing IT equipment, electricity, lighting and transport. Although deploying sustainable public procurement initiatives implies manifold benefits, major implementation barriers still exist (see Table 6).

#### Major sustainable public procurement implementation barriers

Outdated legal frameworks of public procurement	McCrudden, 2004; Hunja, 2003	Procurement officers in many countries are discouraged to choose more sustainable option since tendering processes are focused on the lowest cost offer. This way the full life cycle cost is out of sight, while environmental and social criteria are not adopted.
Budget systems and accounting perspectives	Hunja, 2003; UN Department of Economic and Social Affairs, 2008	This is partly sourced from orientation on lowest cost offer which then limits incentives to make different investment decisions.
Political will	Hunja, 2003; Elder & Georghiou, 2007, Vermeulen & Seuring, 2009	Generally, there is lack of governmental interest to restructure lengthy procurement procedures. But in order for actions to take place, a stable and strong governmental leadership is needed.
Lack of educational and training guidelines towards procurement officials	McCrudden, 2004; OECD, 2007	As a consequence, this results in poor monitoring and evaluation processes and sources for a vicious circle of sustainable public procurement.
Supply constraints	McCrudden, 2004; Walker, Sisto, & McBain, 2008	If there are insufficient sustainable suppliers there are consequences for public procurement decision making.

*Table 6 Major sustainable public procurement implementation barriers (Source: Author)*

Other potential barriers include: lack of leadership from senior managers and policy-makers, sustainability priorities agreements, sustainable public procurement decision-making tools, practical tools for procurement officers, awareness raising activities, proof-points and private sector engagement (Erridge & Greer, 2002; Hunja, 2003; McCrudden, 2004; Walker, Sisto, & McBain, 2008; UN Department of Economic and Social Affairs, 2008).

#### Sustainable public procurement developments

In the analysis of 106 public organizations, Walker and Brammer (2009) discovered that further development and implementation of sustainable public procurement practices can be hampered by financial constraints, while the most important facilitator of sustainable public procurement is senior management support. Further, they suggest that “four aspects of a particular organization’s environment may be important influences upon the implementation of sustainable procurement practices: familiarity with policies; perceived inefficiencies/cost of policies, supplier availability/resistance; and organizational incentives/pressures” (Walker & Brammer, 2009).

Although there are several phases identified in the process of incorporating sustainability in the procurement processes, academia emphasizes the need for development of tools and assessment guidelines (Arrowsmith, 2004; Li & Geiser, 2005; Elder & Georghiou, 2007; Aschhoff & Sofka, 2009). These developments would prioritize environmental, social and economic risks and assessment of

needs. But before assessments take place it is essential to investigate and identify the current state of affairs, in terms of existing policies and frameworks. Since every public procurer has its own needs and responsibilities that require to be rendered, so the priorities need to be customized. Needs assessment is essential in understanding external and internal development challenges. Public procurer need have to be met by their suppliers in order to establish and maintain a relationship. Literature review results (Walton, Handfield & Melnyk, 1998; Handfield et al., 2002; Sánchez & Hacking, 2002; Mouzas & Blois, 2008; Brammer & Walker, 2011; Walton, Oruezabala & Rico, 2012) in identification of multiple needs which are classified into 4 key areas (see Table 7).

Environmental, social and economic requirements	Better financial models	Continuous improvements	Legitimate purchasing
<ul style="list-style-type: none"> <li>• Avoid short term political focus</li> <li>• Focus on overall performance</li> <li>• Support new forms of collaboration and interactions with suppliers</li> <li>• Upgrade knowledge and evaluation criteria of LCSA</li> </ul>	<ul style="list-style-type: none"> <li>• Focus on fewer key suppliers</li> <li>• Use agile information systems and possibility to negotiate financial conditions</li> <li>• Emphasize on performance based contracts of products and services</li> </ul>	<ul style="list-style-type: none"> <li>• Comply with new sustainability standards and regulations</li> <li>• Innovate and propose new solutions</li> <li>• Focus on first rang global suppliers that can meet technical requirements</li> </ul>	<ul style="list-style-type: none"> <li>• Look for closer partnerships with top suppliers to enforce internal and external legitimacy</li> <li>• Require strong support from suppliers for knowledge and competences</li> </ul>

Table 7 Public procurer's needs (Source: Author)

When analysis of the current state is made and priorities are well set, the assessment phase can take place. An assessment often comes in the form of total cost of ownership (TCO). But public procurers have neither time nor knowledge to evaluate the total cost of ownership of purchased products and services. Thus, proving and communicating that sustainability underpinned solutions are more profitable is crucial when engaging with stakeholders. However, evaluation of new and innovative solutions is challenging since there is a lack of guidelines and tools to compare it with existing solutions. After every assessment recommendations for change should be provided for various procurement stages. Finally, whether changes took place and to what extend are they implemented is to be revealed through a monitoring and evaluation phase.

## Conclusion

There is a clear consensus across analyzed literature that sustainable public procurement is not only an important public objective but also a tool for achieving sustainable development. Without any doubt, sustainable public procurement has the potential to disrupt current market settings. Calling for increased environmental and social supplier responsibility through regulation and information are critical for successful deployment of sustainable public procurement. With respect to suppliers, sustainable public procurement can provide incentives to shift towards sustainable supply chain and thus support sustainable production and consumption patterns. The empirical part of this research will reveal to what extend did WMATA needs and requirements influence Philips and shape the value proposition.

For the successful and full-scale implementation of circular economy it is iconic to agree on capacity building, education and sustainability measurement tools. Further, the internal elements of change, i.e. culture and linear mindset, are similar in supply chain as in public procurement and need to be

properly addressed. Among presented findings, sustainable public procurement literature suggests that budget constraints and tendering procedures need to be altered for full implementation of sustainability. Various sustainability strategies play a crucial role in shaping the degree to which 'lowest bid' and tendering constraints can bottleneck further developments. The analysis of Philips Lighting and WMATA deal will highlight the changes in the tendering process, motivation to change, benefits of circular economy; and critically reflect on disclosed sustainability performance.

Finally, an important driver of sustainable public procurement deployment remains sustainable supply availability of products and services. In this challenging context, it is identified that sustainable supply chain and sustainable public procurement are interlinked and interdependent. With respect to interdependence, the case study will reveal the outcome of long-term focus and intensified collaboration between parties.

### **3.1.4. Reflections on supplier – public procurer relationship**

The business journey towards a circular economy is still full of uncertainties and greater understanding is needed of manifold conditions and circumstances that change in supplier – public procurer relationship as the transition from a linear to circular economy takes place. Working towards a circular economy requires time and resources, while employee engagement and more effective procurement strategies are pivotal. A circular economy calls for a behavior change, aiming at linear mindsets and established methodology. In order to benefit from circular economy, procurement procedures must be adjusted, leadership engagements must be encouraged and access to supply chain data must be provided.

A circular economy puts pressure on altering traditional procurement procedures that cause adversarial relationships. But, it is still unclear to what extent procurement practices change in regard to circular economy. However, integrating circular economy in public procurement calls for co-ordination and establishment of long-term partnership relations with suppliers (Steane & Walker, 2000; Erridge & Greer, 2002). With respect to a relationship's contextual background, a short-term competitive procedures need to be replaced with long-term and transparent approaches. Steane and Walker (2000) discovered that long-term relationships can create greater interdependence and help build social capital, which is important because it reduces transaction costs and encourages value sharing. Clearly, circular economy promotes coordinated relationships, which can only function well in a good collaborative climate. Trust and commitment between supplier and public procurer are essential for a good collaborative climate (Black, Akintoye, & Fitzgerald, 2000; Eriksson & Westerberg, 2011). In particular, circular economy affects the initial phase of supplier – public procurer relationship, where collaboration and co-creation processes need to be established as well as performance criteria. A clear value proposition and performance criteria on circular economy reduce risk management issues by making upfront costs known and timely adjusting services to meet a public procurer's needs. However, it is the supplier's role to provide an in-depth and detailed environmental, social and economic outlook of the value proposition. So far, social concerns are less established than environmental and economic ones in relation to value proposition offered to public procurers. Although this is a very important element of the supplier – public procurer relationship, it is often neglected or partially addressed. In order to communicate the real value capture and meet public procurer's requirements, suppliers need to focus on a whole life cost of their products and/or services. In that line, a clear and insightful communication of sustainability assessment contributes to transparency and trust-based relationships (Uttam & Roos, 2015).



The effect of circular economy on supplier's and public procurer's behavior depends on circumstances and nature of service delivery, and more research needs to be conducted on the conditions under which circular economy affects this relationship. Albeit regulatory pressures exist on both sides of the relationship and restrict the development of closer supply relations, bureaucratic procedures and public sector risk averseness need to be overcome (Erridge & Greer, 2002). A solution for this is to change existing procurement rules and develop new public risk management plans as to allow public suppliers and public procurers to enter performance based contracting. Further, education and training programs need to be established on both sides of the relationship so employees understand the benefits of circular economy and accordingly gain expertise and knowledge for long-term relationships.

### 3.2. Product service system business model

“The essence of every business model is in defining the manner by which the enterprise delivers the value to customers, entices customers to pay for value, and converts those payment to profit [...] thus, reflecting on [...] what customers want and how they want it” (Teece, 2010). As a business model combines core components of business strategies and operations that create and deliver value to the company and customers, it is important to discuss these components (OECD, 2012). Based on a wide range of literature (Oserwalder & Pigneur, 2010, 2010; Morelli, 2006; Durugbo et al., 2010; Bocken et al., 2014), a consolidated view on components of a business model is taken: the value proposition (product/service offering, customer relationships and segments), the value creation and delivery (resources, partners, distribution channels and activities) and the value capture (cost structure and revenue model).

As a result of 120 case studies of companies that are generating resource productivity improvements in an innovative way, Accenture (2014) identified five business models that are driving the circular economy, and product service system is one of them (see Table 8). Other business models include circular supplies, resource recovery, product life extension and sharing platforms.

Circular supplies	Provide renewable energy, bio based – or fully recyclable input material to replace single-lifecycle inputs.
Resource recovery	Recover useful resources/energy out of disposed products or by-products.
Product life extension	Extend working lifecycles of products and components by repairing, upgrading and reselling.
Sharing platforms	Enable increased utilization rate of products by making possible shared use/access/ownership.
Products as a service	Offer products access and retain ownership to internalize benefits of circular resource productivity.

Table 8 The five circular business models (Adapted from: Accenture, 2014)

Bocken et al. (2014) also identified sustainable business models, where ‘create value from waste’ and ‘deliver functionality rather than ownership’ business models have elements of a product service system (see Figure 9). Baines et al. (2007), for instance, state that “product service system is a special case in servitization, which values asset performance or utilization rather than ownership, and achieves differentiation through the integration of product and services that provide value in use to the customer”. Clearly, product service system business model is identified as a model that has the

potential to generate resource productivity improvements by integrating products and services in one offering (Baines et al., 2007; Tukker, 2004). Different types of PSSs are presented in Appendix I.

Groupings	Technological			Social			Organisational	
	Archetypes	Archetypes	Archetypes	Archetypes	Archetypes	Archetypes	Archetypes	Archetypes
	Maximise material and energy efficiency	Create value from waste	Substitute with renewables and natural processes	Deliver functionality rather than ownership	Adopt a stewardship role	Encourage sufficiency	Repurpose for society/environment	Develop scale up solutions
Examples	Low carbon manufacturing/ solutions	Circular economy, closed loop	Move from non-renewable to renewable energy sources	Product-oriented PSS - maintenance, extended warranty	Biodiversity protection	Consumer Education (models); communication and awareness	Not for profit	Collaborative approaches (sourcing, production, lobbying)
	Lean manufacturing	Cradle-2-Cradle	Solar and wind-power based energy innovations	Use oriented PSS- Rental, lease, shared	Consumer care - promote consumer health and well-being	Demand management (including cap & trade)	Hybrid businesses, Social enterprise (for profit)	Incubators and Entrepreneur support models
	Additive manufacturing	Industrial symbiosis	Zero emissions initiative	Result-oriented PSS- Pay per use	Ethical trade (fair trade)	Slow fashion	Alternative ownership: cooperative, mutual, (farmers) collectives	Licensing, Franchising
	De-materialisation (of products/ packaging)	Reuse, recycle, re-manufacture	Blue Economy	Private Finance Initiative (PFI)	Choice editing by retailers	Product longevity	Social and biodiversity regeneration initiatives ('net positive')	Open innovation (platforms)
	Increased functionality (to reduce total number of products required)	Take back management	Biomimicry	Design, Build, Finance, Operate (DBFO)	Radical transparency about environmental/ societal impacts	Premium branding/ limited availability	Base of pyramid solutions	Crowd sourcing/ funding
		Use excess capacity	The Natural Step	Chemical Management Services (CMS)	Resource stewardship	Frugal business	Localisation	"Patient / slow capital" collaborations
		Sharing assets (shared ownership and collaborative consumption)	Slow manufacturing			Responsible product distribution/ promotion	Home based, flexible working	
		Extended producer responsibility	Green chemistry					

Figure 9 The sustainable business models archetypes (Source: Bocken et al., 2014)

### 3.2.1. Value proposition

“Equilibrium and perfect competition are a caricature of the real world...customers don't just want products; they want solutions to their perceived needs”

David Teece

A successful business model contains a value proposition that is compelling to customers, achieves attractive cost and risk structures, enables value capture by the business that generates, and delivers products and/or services (Teece, 2010). A value proposition is about identifying a customer's problem and proposing a solution for it (Lindic & Silva, 2011). As the value proposition is a bundle of different elements (Osterwalder & Pigneur, 2010), its valorization depends on the value perception of each customer. A value proposition is often a combination of products and services, or a complete substitution of product by a service (OECD, 2012). A product service system “offers a generic approach to production that delivers value propositions based on providing functionality, availability or results to customers” (Durugbo, 2010). As Bocken et al., (2014) put it, in a product service systems business models, a product is less relevant compared to customer experience in regard to the value proposition offering. To meet customers' needs and demands for products and services, this generic approach is applied across a range of industry sectors and it aims at solving

customer's problems. After a deep understanding of customer's expectations and needs, a description of value proposition can be made with expected elements, allowing supplier to focus on those that provide the most value (Teece, 2010). Analyzed literature suggests both supplier's and public procurer's arguments for taking up a product service system business model (see Table 9).

Economic benefits	Procurers manage to avoid investment costs and associated investment risks, while the operation costs are transparent and known in advance (OECD, 2012; EPA, 2009; Tukker, 2004). Suppliers reduce internal costs of consumption of materials and supply products that have a longer lifetime or that are more energy efficient (OECD, 2012; Baines et al., 2007; Clark et al., 2009).
Functionality	The traditional functionality of a product is extended by incorporating additional services, while there is emphasis on the 'sale of use' rather than the 'sale of product' (Baines et al., 2007).
Comfort and flexibility	Customization and the flexible service component are delivered to suit customer needs (Cook, Bhamra, & Lemon 2006).
Increased trust and reliability	"Some business models [...] contribute to improved relationship between the provider and the customer and increased loyalty as the relationship becomes closer and lasts longer" (OECD, 2012). Trust and loyalty benefits mutual benefits in this relationship.
Brand value and reputation	A company that adopts product service system business model gains a reputation as environmentally and socially responsible company, thus reflecting on higher brand value which is transferred to the customer (OECD, 2012; Goedkoop et al., 1999).

Table 9 The supplier and public procurer arguments for product service system business model (Source: Author)

Putting the product service system into perspective of a circular economy couples it with opportunities in the field of service provision, life-time extension, re-use, repair and recycling. Product service systems unfold the potential of a circular economy as it aims at reducing environmental impact by adopting environmental sustainability in the core of value proposition, company's strategy, and operations (Brezet et al., 2001; OECD, 2012). Boons and Lüdeke-Freund (2013) claim that "the value proposition is typically concerned with the product and service offering that generate economic return" while for companies that are focused on sustainability, "the value proposition would provide measurable ecological and/or social value in concert with economic value". A circular economy acknowledges the importance of business model innovation, as it elicits the potential of circular economy and value creation (Bohnsack et al., 2014). However, business models change only if current business practices are altered, which would require a new assessment of the value proposition (Giesebrecht, 2014). Hence, in order to support circular economy, a product service system has to be designed to create a win-win solution for supply chains, environment, customers, local communities and business (Clark, Kosoris, Hong, & Crul, 2009; Bocken et al., 2014).

After all, a product service system has the capacity to challenge current consumption and production patterns by completely re-thinking products in the light of customer needs (Crul & Diehl, 2006). Thus, it is about "changing 'the way you do business'", rather than 'what you do' (Bocken et al., 2014).

## VALUE PROPOSITION

*“Provide services that satisfy user needs without having to own physical products. Business focus shifts from manufacturing ‘stuff’ to maximizing consumer use of products, so reducing production throughput of materials, and better aligning manufacturers’ and consumer’s interests. Product service systems business model generates environmental and/or social benefits – that is, change the value proposition to the environment and society through changes in the way the organization and its value-network create, deliver and capture value”*

*Bocken et al., 2014*

### 3.2.2. Value creation and delivery

“Value creation, both for the firm and the customer, is at the heart of any business model, as it can be one of the most important factors behind the viability of a new product, service or technology introduced in the market” (OECD, 2012). A sound understanding of how values are created and delivered is necessary in a business relationship. Tukker (2004) argues that a product service system business models allows companies to create new sources of added value and competitiveness since they:

- Fulfill client needs in an integrated and customized way allowing clients to concentrate on their core activities;
- Can build new relationships with clients, enhancing customer loyalty; and
- Can probably innovate faster since they follow their client needs better.

Durugbo et al. (2010) and Mont (2002) go even further as they claim that product service system upholds the co-creation of value between customers and companies. With performance based contracts companies really enter into a service relationship, i.e. a co-creation relationship with their customer. The value co-creation process sources for an important distinction between traditional and product service system business model. Another distinction lies in the orientation on services (Vargo et al. 2007, 2008), while products that are delivered are used by one or many customers through a lease or pay-per-use arrangement (Accenture 2014). Clark et al., (2009) analyzed and pointed out the main differences between traditional and alternative business models from the sales perspective (see Table 10). Osterwalder & Pigneur (2010) also elaborated on major distinctions and suggest that “the value created in product service system business model could include newness of product or service, better performance, customization, convenience, functionality, design, better price, potential cost reduction and savings, risk reduction, and higher accessibility”.

Traditional product sales	Product service systems sales	
Customer buys lighting system.	Customer rents lighting system.	Client buys a lighting system service from a company, while company determines best equipment and delivery methods based on client’s needs.
Client owns, uses and stores lighting system.	Company retains ownership of lighting system and responsibility for maintenance. Client is responsible for use and ‘quality of cleaning’.	Company owns, maintains and stores the lighting equipment. Company is responsible for ‘quality’ of cleaning.

Initial investment for customer could be considerable.	Customer costs are spread over time after paying a low initial deposit.	Customer costs are spread over time.
Customer disposes lighting system when failure rates reach saturation, and buys a replacement.	Company is responsible for disposal and has incentives to prolong use of product, reuse components and recycle materials.	Company is responsible for disposal and has incentives to prolong use of product, reuse components and recycle materials.

Table 10 Differences between traditional product sales and product service systems sales (Adapted from: Clark et al., 2009)

Accenture (2014) adapted the technical materials loops of value creation, as presented by EMF – the power of the inner loop, the power of cycling longer, the power of cascade usage, and the power of pure cycles- and presented them as building blocks of value creation in a circular economy. Thus, according to Accenture (2014) value creation in circular economy is developed through lasting resources (better efficiency and effectiveness), liquid markets (products and assets are accessible and convertible between users), linked value chains (objective is zero waste through better resource efficiency and recycling) and longer life cycles (focus is on product longevity through services, upgrade and remanufacturing) (see Figure 10). In a circular economy, manufacturers create and deliver more value from each unit of resource, provided that products are designed with the goal of maximizing reuse (JWT, 2014). After covering how values are created and delivered it is important to analyze how to capture value in a product service system business model.

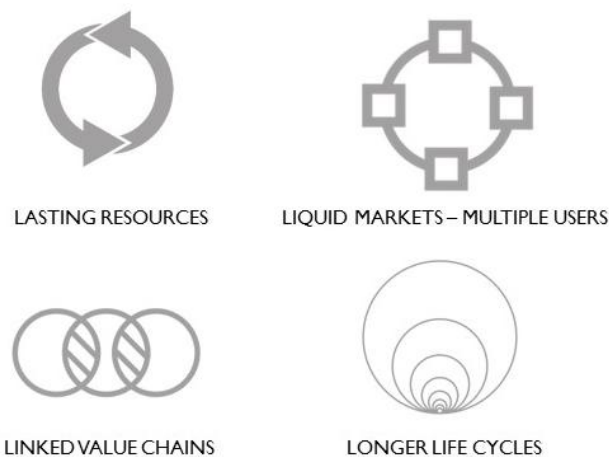


Figure 10 Areas of value creation in circular economy (Adapted from: Accenture, 2014)

## VALUE CREATION AND DELIVERY

*“Delivery through product/service offerings requires significant changes within the firm to deliver this and may incentivize redesign for durability, reparability and upgradability. Potentially, more direct consumer contact and consumer education to shift away from ownership. Supply chains become more integrated”*

Bocken et al., 2014

### 3.2.3. Value capture

“ My company is redesigning its products and considering how to capture their residual value. At the same time, it is shifting from a transactional – to a relationship-based business model-one that entails closer cooperation with customers and suppliers”

*Frans van Houten, CEO Philips*

Capturing customer needs is not easy because every customer differs in definition of value, buying criteria and priorities, but if value creation offers benefits that induce payment from customers, a value capture can be predicted (Priem, 2007). “Value capture is about considering how to earn revenues from the provision of goods, services and information to users and customers” (Bocken et al., 2014). Value capture relates to the costs in order to ensure the efficiency of current and future efforts (Walter, Ritter, & Gemünden, 2001). Tukker (2004) proposes to focus on the following aspects to capture the value:

- Strategic position in the value network - ability to capture value.
- Sustained low barriers for access to the service and a contribution to client loyalty.
- Contribution to a comparatively high speed of innovation.

As Porter (2008) suggests, the creation of value alone is not sufficient since the product service system provider should be powerful enough to capture this value. Tukker (2004) suggests covering three aspects as to ensure value capture in product service system. First, value is captured by covering the most important parts of the production system, i.e. the parts that are not easily outsourced to third parties because of unique relationship with customers. Due to its intangible nature, services are more difficult to replicate but also more challenging to price (Berry & Yadav, 1996). Second, payments are made per unit time/unit use which results in better client loyalty. Finally, by having low access barriers to services, a company has better insights into customer needs.

Sustainable business models, like product service system, capture economic, social and environmental value for a wide range of stakeholders (Grönroos, 2008; Lepak, Smith & Taylor, 2007; Bocken et al., 2014). Product service system can result in “lower impacts because of the inherent product design, or by stimulating behavior geared towards low material and energy use” (Tukker, 2004). As to achieve superior impact on system levels, product and service usage volume need to be mitigated (Bocken et al., 2014; Mizik & Jacobson, 2003; Kortge & Okonkwo, 1993). Tukker (2004) identified differences in environmental performance of products and product service system by evaluating each type of product service system model against a set of impact reduction mechanisms (see Table 11). Depending on the product service system elements, differences in environmental performance of products can be expected (Tukker, 2004).

10-20% impact reduction	Due to incremental efficiency improvements, such as better maintenance, there is less use of energy and consumables in the use phase and prolonged life of capital goods.
Up to 50% impact reduction	Manufactures have incentives to optimize the use of energy and consumables, and recycling of product parts and materials where possible. There is more intensive use or prolonged life of capital goods used in the system compared to traditional product system. Considerably less use of energy and other auxiliary materials in the use phase also reduce the environmental impact.
Up to 90% impact reduction	Application of a radically different technological system with radically lower impacts results in very high impact reduction.

*Table 11 Environmental performance impacts of product service system elements (Adapted from: Tukker, 2004)*

Albeit performance based contracts have manifold delivery models, they all depend on the level of service a customer wants to outsource and the level of risk a supplier can manage (Joustra, Jong, & Engelaer, 2013). Malleret (2006) argues that practices of costing and cost accounting methods play a major role in the creation and measure of value through service offers. In some companies services are priced according to standard unit costs, service features and the target margin (Berry & Yadav, 1996). For example, maintenance service charge can consist of the occupation rate of maintenance teams; the cost of materials; and equipment sold.

New set of competences are essential for capturing value from circular economy, and they have to be present throughout the value chain (see Figure 11). With respect to that, as a result of 120 case studies, Accenture (2014) points out core competences that are needed for circular economy. Firstly, company strategy needs to be altered and include engagement with suppliers, manufacturers, retailers, service suppliers and customers as to initiate circular economy deployment across the value chain. In regard to value chain cooperation, Clarke & Roome (1999) indicate openness and receptiveness, as a predisposition to shared learning and access to networks of other players to discuss strategy as key features of value capture in service based value propositions. Secondly, innovation and product development requires the focus on 'design for reuse' of products that have the potential to generate revenues during the use phase (e.g. maintenance, upgrading, sharing) and support reprocessing (e.g. modularity, traceability, and standardization). Thirdly, adjustments need to take place also in sourcing and manufacturing where product designs need to result in use of renewable or fully restorable material inputs with lowest possible environmental and social negative effects. A sustainable supply chain has to ensure that value leaks and production disruptions are avoided. Further, in circular economy, sales and product use involve understanding of the product's use phase and respond to preferences from the market by offering products and services for circular use. These functions are about actively participating in managing the lifecycle of the product and maximizing its retained value (EMF, 2013; Grönroos, 2008; Mont, 2002). Finally, what holds the entire circular business model loop together are return chains and reverse logistics. Operations related to the recovery and reuse of products and materials need to be established, thus resulting in "cost-effective collection, treatment and redeployment of products, components and materials on the market at high quality and high volume" (Philips, 2014).

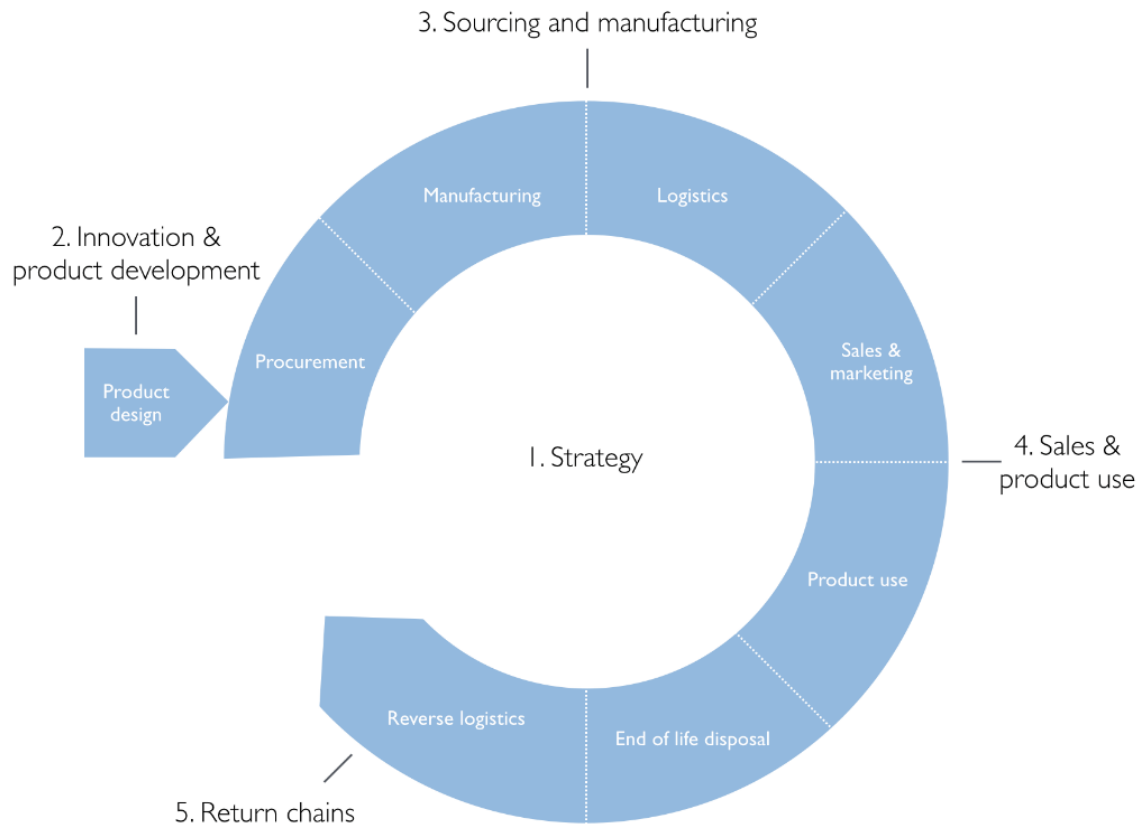


Figure 11 Core competences needed to support circular business adoption (Adapted from: Accenture, 2014)

## VALUE CAPTURE

“Consumers pay for the use of the service, not for ownership of products. Cost of ownership of physical products are borne by the company and/ or partners. This can enable consumers to access previously expensive products, so expanding the market potential of new innovations”

Bocken et al., 2014

## Conclusion and reflections on relationship change

A product service system generates great potential for a sustainable change for companies that have “a skill advantage relative to their customers in managing maintenance of products (giving them an edge in selling services and recapturing residual value at the end-of-life) and whose product’s cost of operation share is high” (Accenture, 2014). A product service system business model has the potential to change consumption patterns, in particular by reducing the need for product ownership. “Advancing access-over-ownership and take-back models will further accelerate the adoption of circular economy business models because they drive greater use of existing idle assets” (WEF, 2014). In regard to this, the risk management is relevant for product service system, since the service provider takes over all liabilities that in a product-based system were with the user. Further, since supplier/manufacturer remains the owner of product, it has an incentive to design for upgradability and reparability of a product so it could last longer. “By replacing old business practices, innovative business models also allow firms to restructure their value chain; generate new types of producer-customer relationships; and alter the consumption culture and use practices”



(OECD, 2012). But the effectiveness of a product service system will depend on the shared vision of possible and desirable proposition scenarios between supplier and procurer.

A circular economy context provides a trigger for customers to gain power in negotiating the value as they “will pay according to [their] utility rather than according to the company’s cost of production” (Prahalad & Ramaswamy, 2004). Supplier of services needs to know what creates a value for its customers, and to do so it is crucial to maintain a close trust-based relationship with frequent contacts (Grönroos, 2008). A supplier – procurer relationship, within product service system business model, is expected to radically change in the case of promising functional results (OECD, 2012). Albeit delivered results are functional, “the key challenge with product service system remains difficulty of agreeing with the customer and/or user on a set of good performance criteria” (Tukker, 2004). To uncover empirical implications of having a product service system an in-depth analysis of the case study will reveal elements of Light as a Service (LaaS) business model by reflecting on value proposition, value creation and delivery, and value capture between Philips Lighting and WMATA. The perspectives of both sides will be revealed during the case study analysis.

#### EXAMPLE

*Vodafone is one of the first companies in IT business that capture the benefits of the ‘access over ownership’ business model, which allow the company to strengthen their relationship with customers (WEF, 2014). Vodafone works with a business partner to take care of the reverse logistics, in which most devices are collected and transported to Hong Kong and China for sales in secondary markets (WEF, 2014).*

### 3.3. Life cycle sustainability assessment

“ Sustainable development is not a destination, but a dynamic process of adaptation, learning and actions. It is about recognizing, understanding and acting on interconnections, above all those between the economy, the society and the natural environment. We cannot make lasting progress in one pillar without progress on all”

*Ban Ki-moon (United Nations), 2012*

#### Introduction

Given the current consumption levels, moderate UN scenarios suggest we need nearly two planets by the end of 2030s<sup>4</sup>. Growing population and climate change put pressure on current natural resources to meet the basic human needs. Future scenarios are disturbing as they allude to unsustainable trends within our society. That is why international organizations call on governments and private sectors to address consequences of their actions on the three dimensions of sustainability: (1) environmental, (2) economic and (3) social, as proposed by the Brundtland commission (1987). To prevent shifting of industry burden, life cycle thinking has to be integrated into decision making processes.

In the last two decades, UNEP and SETAC provided significant contributions to life cycle thinking, namely with their publications: *Guidelines for social life cycle assessment of products* (2009); *Global guidance principles for LCA databases* (2011a); *Towards a life cycle sustainability assessment* (2011b); and

<sup>4</sup> For more information visit: [http://www.footprintnetwork.org/en/index.php/GFN/page/world\\_footprint/](http://www.footprintnetwork.org/en/index.php/GFN/page/world_footprint/)

*Methodological sheet of sub-categories for a social LCA* (2013). Aim of these publications is to enhance the global consensus and relevance of existing and emerging life cycle methodologies and data management (Valdivia et al., 2013). Still, there is no widely agreed methodology for how sustainability should be measured because all kind of impact factors, disciplines and technical requirements need to be taken into account (Schau et al., 2011). In particular, the last decade generated numerous sustainability assessment tools, approaches and frameworks presented by scientists and experts. Albeit these developments are a consequence of urgency to evaluate sustainability, most of them fail to implement a life cycle approach aiming to provide quantitative and qualitative results on sustainability (Valdivia et al., 2011). Exceptions to this situation include the following assessment tools: the BASF eco efficiency tool, the Product Sustainability Assessment tool, and the Sustainability Assessment model (Valdivia et al., 2011).

Although different assessment techniques allow companies and individuals to assess the impact of their production processes and purchasing decisions, most of them consider only economic objectives. But, there is a growing concern to assess all three pillars of sustainability (Epstein & Roy, 2003). In order to raise awareness of value chain actors and support decision-makers in prioritizing resources and investing them where there are more chances of positive impacts and less chance of negative ones, it is necessary to apply life cycle thinking in sustainability models. To that end, the life cycle sustainability assessment (LCSA) is suggested for measuring sustainability.

### About Life Cycle Sustainability Assessment (LCSA)

Combining three LCA techniques into a LCSA was first formulated by Klöpffer (2008), followed by Finkbeiner et al. (2010). Klöpffer (2008) underlines the importance of reading the results of each technique in combination with results of the other technique rather than summing them up. This will allow for integrated decision-making based on life cycle perspective and consideration of the three sustainability dimensions:

**LCSA = (environmental) LCA + LCC + S-LCA**

where

LCSA= Life Cycle Sustainability Assessment

LCA= Environmental Life Cycle Assessment;

LCC= Life Cycle Costing;

S-LCA= Social Life Cycle Assessment.

Albeit LCSA is conceptually rooted in sustainability science, it is still not fully integrated (Sala, Farioli, & Zamagni, 2013a). Methods for LCA, LCC and S-LCA have been developed as stand-alone tools, but only their combination in one tool allows for integrated decision-making on the triple bottom line of sustainable development: people, planet and profit (Finkbeiner et al., 2010; Jørgensen et al., 2008). There is a lot of ongoing general discussion around LCSA (Baxter et al., 2003; Weidema, 2006; Cavanagh et al., 2006; Guinée et al., 2010; Frinkbeiner et al., 2010; Swarr et al., 2011, Halog & Makin, 2011; Vinyes et al., 2011, Zamagni, 2012; Hauschild et al., 2013; Sala et al., 2013a; Valdivia et al., 2013). In addition to general discussion, some efforts are made in the direction of combining two LCA techniques (Oki & Sasaki, 2000; Itsubo & Inaba, 2003; Quariguasi Frota Neto et al., 2009; Valente, Spinelly, & Hillring, 2011). All authors are consistent in 3 things: acknowledgement of previous and emerging efforts in combining LCA techniques; lack of stakeholder involvement; and importance of international organizations that address sustainability from the value chain perspective (e.g. UN Global compact, OECD, Global Reporting Initiative and ISO 26000). There is a lot of scientific discussion on combining two or three LCA techniques. However, there is a lack of stakeholder participation and communication on strategic aspects with stakeholders. "Approaches to

stakeholders' involvement should be further developed" because stakeholders need to be involved in the decision making and mapped according to the level they are affected by TBL impacts of the proposed project (Sala, Farioly, & Zamagni, 2013b). In the top-down perspective, international organizations are important in addressing sustainability from the business and organizational level. The importance of addressing sustainability from the value chain perspective is highlighted through manifold guidelines on corporate social responsibility.

What is peculiar in LCSA approach is the same system boundary and functional unit used to address all three LCA techniques (LCC, environmental LCA and S-LCA). Sala, Farioli, and Zamagni (2013b) argue that a LCSA model should include following system levels in order to deal with complexity: ontological (comprehensiveness, holism and system-wide approach); epistemological (shift to inter- and transdisciplinary and participation of stakeholders) and; methodological (multi-scalability). Valdivia et al. (2013) argue that an LCSA can support businesses, decision makers and consumers in manifold ways, such as organizing complex environmental, economic and social data in a structured form; clarifying the trade-offs between the three dimensions, life cycle stages and impacts; providing guiding principles to achieve sustainable production while stimulating innovation (by identifying weaknesses and enabling further improvements over the product life cycle phases); helping to raise credibility by communicating useful quantitative and qualitative information about their products and process performances; showcasing how to become more responsible by taking into account the full spectrum of impacts associate with their products and services; and promoting awareness among value chain actors on sustainability issues.

The limitations of current LCSA include the interpretation of data that is limited by knowledge at scientific level, mechanisms and their modeling (Sala, Farioli, and Zamagni, 2013b). Therefore, more developments are needed on making interpretation of results more accessible. Further, there is no comprehensive life cycle inventory database that includes all inputs and outputs of the system (e.g materials, energy and waste flows) (Schau et al. 2011). This can be remedied by development of International reference Life Cycle Data system (ILCD) as a robust and fully documented life cycle inventory dataset. On the European level, European Commission, together with industries and national governments is making an effort toward this goal. The most challenging, if not impossible part, is the quantification of indicators and impacts. One example of this is biodiversity, as an important impact category in LCIA that has no suitable indicator(s). Klöpffer (2008) argues that formal weighting and any compensation between the three techniques must not be performed with respect to transparency. To contribute to the development of sustainability assessment methodology, by addressing environmental, social and economic impacts, this research will generate a comprehensive life cycle sustainability assessment model. The results of application of the model on a case study will reveal how far the model can be applied given the current limitations, namely data collection. In order to generate LCSA results, literature suggest taking up a framework proposed for LCA by ISO 14040 +44: (1) goal and scope, (2) inventory analysis, (3) impact assessment and (4) interpretation. How to combine and align the three life cycle techniques will be presented in 4.3 sub-chapter of this research.

## Overview of LCA, LCC and S-LCA

### Life Cycle Assessment (LCA)

The concept of environmental LCA is not a novelty, as it emerged already in the 1960s with studies that investigated material, waste and energy flows of a product life cycle (UNEP/SETAC, 2011a). So far, most significant contribution to development of LCA is ISO 14040 series that provides a technically rigorous framework for carrying out environmental LCA. Fiksel et al. (2008) refer to

LCA as “an assessment of all environmental costs associated with the life cycle of a product that are directly covered by any one or more of the actors in the product life cycle (e.g. suppliers, manufacturer, user or consumer, or EoL actor) with complementary inclusion of externalities that are anticipated to be internalized in the decision-relevant future”. Valdivia et al. (2011) take a similar route and emphasize that environmental LCA “aims to address the environmental dimension in a holistic manner by covering all relevant environmental impacts”.

Due to increased awareness in the general public, governments and industries have supported integration of environmental assessments into management systems. It is believed that these assessments can assist in communicating important environmental issues in a balanced way (UNEP/SETAC, 2011). In particular customers, as an important stakeholder segment, have recognized the benefits of communicating environmental results. Tools such as ecolabels, as a form of environmental product declarations, serve as an easy guide to identify environmental regulations compliant products. Environmental LCA is the only internationally standardized environmental assessment method. Still, as with all assessment methods, there are some limitations that hamper successful application of this method, but the most important one is the lack of considerations for qualitative environmental impacts (Valdivia et al., 2013). Maturity of LCA is expected in the following areas: uncertainty assessment methods and consistency, quality of LCA databases, valuation methods and methods for accessing impacts on ecosystem services (UNEP/SETAC, 2011a).

#### Life cycle cost (LCC)

In the LCSA equation, “environmental LCC refers to an economic assessment that is consistent with LCA, and social LCA” (Klöpffer & Ciroth, 2011). Valdivia et al. (2011) argue that “LCC summarizes all costs associated with the life cycle of a product that are directly covered by one or more of the actors in that life cycle but these costs must be related to real money flows in order to avoid overlap between environmental LCA and LCC”. These costs can include extraction cost, manufacturing costs, waste disposal costs, electricity costs, equipment costs, fuel costs, raw material costs and other costs (Traverso et al., 2012). An environmental LCC is useful because it can help customers to make a good decision by providing information beyond product price to point out the advantages of buying an environmentally preferable product (Klöpffer & Ciroth, 2011). The contrast between LCA and LCC is challenging to establish since both techniques share many similarities, in particular when it comes to functional unit and system boundaries. But what is specific for LCC is that it has no impact assessment component, rather “the aggregated result is calculated as cost per functional unit” (Valdivia et al., 2013). Usually, costs of use and end-of-life phases are not included in the LCC, but that should be altered because only by including costs of these phases importance of ‘green’ products and services can be demonstrated (Valdivia et al., 2013). So far, LCC did not include external costs in analysis as to avoid double counting and it can be applied on three scopes:

1. Conventional LCC – incorporate private costs and benefits;
2. Environmental LCC – includes conventional LCC + external relevant costs and benefits anticipated to be privatized;
3. Societal LCC – takes into account conventional and environmental LCC + private and external costs and benefits.

In life cycle sustainability assessments, when referring to LCC, the focus is on environmental LCC. A societal LCC is still not compatible with LCA as it does not allow assessing the costs of product systems from the social perspective (Klöpffer & Ciroth, 2011). As LCC is recognized as one of the three sustainability pillars it is essential to explore this technique further (Swarr et al., 2011). For example, this can be done by applying LCC on broad array of case studies and across different

industry sectors. In addition, LCC is particularly attractive for public procurement sector in regards to project cost monitoring (Carlsson, 2005).

### Social Life Cycle Assessment (S-LCA)

The concept of S-LCA emerged in 1980s when the SETAC group started combining social aspects with environmental assessment of products (UNEP/SETAC, 2011). Their efforts and results were published as *Guidelines for Social Life Cycle Assessment of Products initiative* (UNEP/SETAC, 2009). This publication contributed to stakeholder mapping in S-LCA perspective, and provided stakeholder tailored approaches towards assessment of social and socio-economic impacts of product life cycle. Although the concept of S-LCA is still in infancy, there is an increase of recent scientific developments. Dreyer et al. (2006) emphasizes the relevance of social impact assessment and conclude that “impacts on people are naturally related to the conduct of the companies engaged in the life cycle rather than to the individual industrial processes”. Brent and Labuschagne (2006) and Kruse et al. (2009) seek to expand the discussion on social indicators and highlight lack of readily available quantitative social impacts that can be applied for life cycle purposes. In regards to social impacts, scaling and qualitative nature of social impacts are two main hurdles hampering further development (Klöpffer, 2008). Weidema (2006) for instance, inquires about implementation of cost benefit analysis elements and suggests using Quality Adjusted Life Years as a main measure of human well-being and health. Norris (2006) takes a similar approach and considers harmful socio-economic impacts and proposes to use Life Cycle Attribute Assessment - a web based instrument that can complement other life cycle assessment approaches.

An element that hampers successful application of S-LCA is inventory data collection and classification. What is needed to remediate this, is information provided by national or international statistics and data from producers, e.g. spent labor hours per functional unit (UNEP/SETAC, 2009). As Klöpffer (2008) states, “no development can be stable at the long run without social justice”, S-LCA has to be further explored. Notable contributions are suggested on following areas (Brent & Labuschagne, 2006; Jørgensen, et al., 2008; UNEP/SETAC, 2009; Benoît, et al., 2010):

- **Scoring systems** (positive or negative impacts require to be scored in relation to stakeholder needs and context);
- **Communication formats** (different dimensions and properties of qualitative and quantitative data must be taken into account when communicating LCSA results);
- **Areas of protection** (as LCSA needs to recognize value for the society, the area of protection, i.e. ultimate goal, could be wellbeing but it is still arguable if this can be applied to all three LCSA techniques);
- **Impact assessment methods** (life cycle sustainability impact assessment should consider the perspective of stakeholders in regard to relevance of impacts);
- **Data availability and collection** (broader availability of reliable and suitable data can strengthen the LCSA methodology development).
- **Methodology for the inventory analysis needs** (there is a need for methodological sheets for the stakeholder subcategories as to support the inventory analysis needs);
- **Results evaluation** (quality of data, i.e. the characteristics and ability to satisfy stated requirements, should be taken into account when interpreting results); and
- **Relationship between the function and the product utility** (not all three LCSA techniques have equal ability to document the product utility and the function to inform decision makers whether or not a product should be produced

## Life cycle sustainability assessment (LCSA) developments

Although LCSA is deeply rooted into sustainability science, a gap remains between current methods and methodologies. “More research is necessary, both on methodological and practical level, addressing at least the following aspects: (1) analysis of relevant decision contexts for S-LCA, (2) development of databases, (3) definition of impact categories and (4) case studies” (Sala, Farioli, & Zamagni, 2013b). Table 12 presents an overview of literature findings in regard to necessary developments in application of LCSA.

Critical areas to be addressed for LCSA developments	
Combination of 3 techniques	The three life cycle techniques need to be better combined, whereas trade-off errors should be avoided. For example, certain company cannot claim that their product is more sustainable because it is more energy efficient, whereas negative social impacts are low or not even analyzed (Schau et al., 2011; Sala, Farioli, & Zamagni, 2012; Heijungs, Setanni, & Guinée, 2013)
Availability of data	Required data for LCSA needs to be available through a consistent and harmonized data management system (Klöpffer, 2008; Schau et al., 2011, UNEP/SETAC, 2011; Valdivia et al., 2013).
Choice of impact categories and indicators	A consensus has to be made on the impact categories and indicators (Schau et al., 2011; Traverso et al., 2012; Heijungs, Setanni, & Guinée, 2013).
Stakeholder consultation	Through stakeholder engagement and guidance in LCSAs, trust is generated. For that purpose, the following stakeholders should be consulted: employees, consumers, local community and value chain actors (UNEP/SETAC, 2011; Traverso et al., 2012; Valdivia et al., 2013)
User friendly LCSA software	Design and IT communities should be consulted as to facilitate more user friendly software to apply LCSA. A clear communication and publication format of LCSA results is needed in order to support better decision making (Sala, Farioli & Zamagni, 2012; Valdivia et al., 2011; UNEP/SETAC, 2011).

Table 12 Critical areas to be addressed for LCSA developments (Source: Author)

## Conclusion

Based on the literature review it can be inferred that an LCSA framework can support decision making by providing results on three dimensions of sustainable development through transparent, robust and comprehensive assessment. An LCSA should be a goal and solution-oriented decision support methodology rather than a single focus analysis. The current LCSA framework should be developed to be more holistic, transparent, and able to adjust the assessment for local/specific impact. In particular case studies are important for development of practices, methodology and knowledge as they generate a better understanding of interrelations between different impact categories.

Future developments on the field of LCSA include standardization and harmonization of the three techniques. Literature also highlights the importance of stakeholder inclusion that can promote social learning and generate knowledge. More developments are also needed on formats of LCSA communication, interpretation of results, as well as inclusion of impact categories. Literature review

insights on LCSA are used in Chapter 4 as a foundation to design of comprehensive sustainability assessment model with integrated PPP. The designed sustainability assessment model is to be applied on the Philips Lighting's value proposition in WMATA deal as to reveal actual impacts of circular economy deal.

### 3.4. Literature review summary



*Like all major transitions in human history, the shift from a linear to a circular economy will be a tumultuous one. It will feature pioneers and naysayers, victories and setbacks.*

*Frans van Houten, CEO Philips*

In addressing circular economy, this literature review took three perspectives: the supplier – public procurer relationship change; the product service system business model; and the life cycle sustainability assessment. Focus of the relationship change is set on public procurers because they respond to public pressures to act responsible in their procurement processes. Analyzed literature on circular economy, sustainable supply chain and sustainable public procurement suggests that it is still not clear to what extent circular economy alters their business relationship. Effect of circular economy on supplier's and public procurer's behavior depends on circumstances and nature of service delivery. However, it is clear that circular economy calls for long-term relationships, interdependence, collaboration and value co-creation. In order to share knowledge, best practices and skills, it is necessary to change the mindset and adjust legislative/regulatory framework, as both elements hinder the transition to circular economy. To overcome challenges and uncertainties related to transition it is essential to establish strategic partnerships, added value quantification methodology and communication tools. A contribution to knowledge about relationship change induced by circular economy is provided in the first part of Chapter 5 where this research analyses underlying elements of relationship change between Philips Lighting and WMATA.

From the business model perspective, suppliers need to clearly communicate value proposition elements and establish performance criteria as to reduce risk management issues. A value proposition has to meet public procurers needs by providing a set of products and services, making upfront costs known and ensuring technology adjustments. Value creation and capture in circular economy, by means of a product service system business model, is enabled through access-over-ownership and take-back models because they drive the greater use of existing idle assets (WEF, 2015).

As a result of ownership shift to supplier, two imperatives emerge: risk management and design for longevity. In a circular economy, current business practices are disrupted by adopting a product life cycle thinking which requires capacities to set the scope of sustainability impact assessment to PPP (people, planet, prosperity). Due to lack of consensus on the life cycle assessment methodology, an elaborated theoretical framework is presented which will be used in the following subset of this research – design of sustainability assessment model (Chapter 4). In the second part of Chapter 5, a comprehensive sustainability assessment model is applied on the WMATA deal by comparing PPP impacts of a product service system and a product based value proposition. It is important to know these differences and communicate them in the interest of contributing to transparency and trust-based relationships (Uttam & Roos, 2015).

# CHAPTER 4 DESIGN OF SUSTAINABILITY ASSESSMENT MODEL

As presented in the Brundtland report, sustainable development is the kind of development that “meets the needs of the present without compromising the ability of future generations to meet their needs” (1987). Since 1980s sustainability has gained popularity both in academic debates and business arenas. And despite of the contextual widespread of the concept, companies still find it difficult to perceive sustainability from the financial viability perspective.

To change this perception, there is a need for development of an integrated sustainability assessment methodology that addresses all three sustainability pillars (economic, social and environmental). “Defining sustainability is ultimately a social choice about what to develop, what to sustain, and for how long” (Parris & Kates, 2003a). Due to ambiguity of manifold sustainable development initiatives, there is no consensus on terminology, data and methods of measurement. The goal of this review is to assess the state of practice for characterizing and assessing sustainability.

## 4.1. Introduction

The sustainability assessment has largely evolved from environmental impact assessment. More recently, scientific contribution is provided from the strategic environmental assessment perspective. This perspective suggests extending the scope of sustainability by including social and economic considerations (Pope, Annandale, & Mirrison-Saunders, 2004). This reflects the triple bottom line concept of sustainability in an integrated assessment. For the analysis of current sustainability practices, the following initiatives are chosen: Global Reporting Initiative (GRI), International Trade Centre Standards Map, ISO 26000 and ISO 14040. Although all four initiatives contribute to sustainability practices, they differ in many aspects. Among other characteristics, they differ in established goals, unit and scope of analysis (see Table 13).

Current sustainability practices			
Initiative	Unit of analysis	Scope of analysis	Goal
Global Reporting Initiative	Corporate/non-governmental org. entities	Economic Environmental Social	Provide communities, investors, governments, and businesses timely, credible and consistent information on an organization’s economic, environmental, and social performance. <sup>5</sup>
International Trade Centre Standards Map	Corporate/non-governmental org. entities	Economic Environmental Social Quality Business ethics	Provide comprehensive, verified and transparent information on voluntary sustainability standards and other similar initiatives. The main objective is to strengthen the capacity of producers, exporters, policy makers and buyers, to participate in more sustainable production and trade. <sup>6</sup>

<sup>5</sup> More information available at: <https://www.globalreporting.org/information/about-gri/Pages/default.aspx>

<sup>6</sup> More information available at: <http://www.intracen.org/itc/market-info-tools/voluntary-standards/standardsmap/>



ISO 26000	Corporate/non-governmental org. entities	Social responsibility	Guidance on social responsibility, stakeholder identification and engagement to all types of organizations, regardless of their size or location. <sup>7</sup>
ISO 14040	Corporate/product level	Environmental	Describe the principles and framework for life cycle assessment. <sup>8</sup>

Table 13 Current sustainability assessment practices (Source: author)

A significant effort in measuring the companies' sustainability is represented by the Global Reporting Initiative as an array of globally applicable guidelines for reporting on the economic, environmental, and social performance (Parris & Kates, 2003b). GRI provides "guidance on what to report" for each of the subject areas of PPP and reflects on sources of impacts and company activities (GRI, 2014).

International Trade Centre Standards Map does not assess sustainability but enables users to identify sustainability standards, codes of conduct and audit protocols. Standards Map helps users to get information on compliance to voluntary sustainability standards and certification procedures across global supply chains (International Trade Centre website). This sustainability initiative is purely company activity oriented and provides only information for addressing sustainability hotspots in global supply chains.

As part of ISO organization, two initiatives are further analyzed: ISO 26000 (guidance on social responsibility) and ISO 14040 (principles and framework for environmental management and life cycle assessment). ISO 26000 provides guidance on socially responsible behavior and possible actions. "ISO 26000 does not provide guidance on specific indicators, nor on any other framework for comparing performance" (ISO, 2014). Due to these characteristics ISO 26000 is referred as source of impact oriented sustainability initiative.

The only sustainability initiative that is completely impact oriented (only environmental impact) is ISO 14040. This sustainability initiative provides steps for a life cycle assessment, as well as list of impact categories and indicators. Based on characteristics of four analyzed sustainability initiatives, this research prefers GRI and ISO 14040 methodology. An overview of PPP integration in all four initiatives is presented in Table 14).

Integration in PPP			
Initiative	PEOPLE	PLANET	(economic) PROSPERITY
Global Reporting Initiative	<ul style="list-style-type: none"> <li>Community</li> <li>[Corruption]</li> <li>[Public policy]</li> <li>Anti-competitive behavior</li> <li>[Compliance]</li> </ul>	<ul style="list-style-type: none"> <li>Materials</li> <li>Energy</li> <li>Water</li> <li>Biodiversity</li> <li>Emissions, effluents, and waste</li> <li>Products and services</li> <li>[Compliance]</li> <li>Transport</li> </ul>	<ul style="list-style-type: none"> <li>Economic performance</li> <li>Market presence</li> <li>Indirect economic impacts</li> </ul>

<sup>7</sup> More information available at: [http://www.iso.org/iso/sr\\_schematic-overview.pdf](http://www.iso.org/iso/sr_schematic-overview.pdf)

<sup>8</sup> More information available at: [http://www.iso.org/iso/catalogue\\_detail?csnumber=37456](http://www.iso.org/iso/catalogue_detail?csnumber=37456)

<i>International Trade Centre Standards Map</i>	<ul style="list-style-type: none"> <li>• Human rights</li> <li>• Labor rights</li> <li>• Gender</li> <li>• Health and safety</li> <li>• Employment conditions</li> <li>• Employment benefits</li> <li>• Community involvement]</li> <li>• Human treatment of animals</li> </ul>	<ul style="list-style-type: none"> <li>• Soil</li> <li>• Biodiversity</li> <li>• GMO prohibition</li> <li>• Waste</li> <li>• Water</li> <li>• Energy</li> <li>• Greenhouse gas</li> <li>• Synthetic inputs</li> </ul>	<ul style="list-style-type: none"> <li>• Direct economic impacts (minimum wage, living wage, premiums)</li> <li>• Written contracts between buyers and sellers</li> <li>• [Product quality requirements]</li> </ul>
<i>ISO 26000</i>	<ul style="list-style-type: none"> <li>• [Organizational governance]</li> <li>• Human rights</li> <li>• Labor practices</li> <li>• Consumer issues</li> <li>• Community involvement and development</li> </ul>	<ul style="list-style-type: none"> <li>• Environment (prevention of pollution, sustainable resource use, climate change mitigation and adaptation, protection of the environment, biodiversity and restoration of natural habitats)</li> </ul>	<ul style="list-style-type: none"> <li>• Fair operating practices (anti-corruption, responsible political involvement, fair competition, promoting social responsibility in the value chain and respect for property rights)</li> </ul>
<i>ISO 14040</i>	N/A	<ul style="list-style-type: none"> <li>• Global warming potential</li> <li>• Photochemical ozone creation potential</li> <li>• Eutrophication potential</li> <li>• Stratospheric ozone depletion potential</li> <li>• Acidification potential</li> <li>• Human toxicity potential</li> <li>• Depletion of natural resources</li> <li>• Land use</li> <li>• Water depletion</li> <li>• Energy depletion</li> <li>• Waste production</li> <li>• Product recycling potential</li> </ul>	N/A

Table 14 Level of sustainability initiatives' integration in PPP (Source: GRI website, ITC website, ISO website)

The sustainability initiatives analyzed in this study vary considerably in their organizational setup and categorization approach. Given the high degree of diversity associated with their integration in PPP, any interpretation of the various indicators displayed in this report has to be considered in the light of scope and ambitions of the initiative itself. Although these initiatives are organized in a different way, each of them has certain demarcations. Analysis of differences between four presented sustainability initiatives reveals a discrepancy in reasoning positions (see Figure 12). The reasoning positions towards sustainability range from **source of impact orientation** (GRI and ISO 14040 – provide input on source of impact), **company activity orientation** (ISO 26000, GRI and International Trade Centre Standards Map – contribute with output data on company activity by recording the degree of compliance specified by a standards with respect to categories shown in Table 2) and **impact orientation** (ISO 14040 – identify sustainability impacts of a product/company by choosing midpoint and/or endpoint categories). The source of impact and company activity orientation are suitable for reporting purposes but not for an impact assessment. Any sustainability assessment model should be about assessing impacts, i.e. measuring the problems and not solutions. As the aim of this study is to assess and compare sustainability impacts, a choice is made to pursue only sustainability initiatives with impact as focus area.

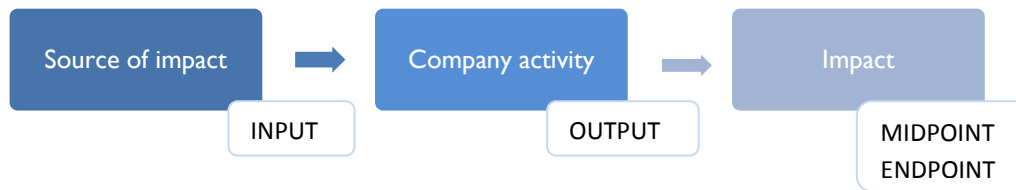


Figure 12 Focus areas of sustainability initiatives (Source: Author)

In addition to reasoning positions, these initiatives differ in categorizations of PPP elements (see Table 14). There is a certain level of ambiguity when it comes to categorization (indicators that are identified as ambiguous are marked with brackets [x]). It is not absolutely clear why sustainability initiatives lack to emphasize the gap between simplicity and validity behind chosen categorization approaches. For example, GRI places corruption and public policy to *people* dimension, whereas this research argues that these two elements reflect better (*economic*) *prosperity*. Further, there are elements that should be excluded when having sustainability assessment in scope (e.g. organizational governance in ISO 26000, and several compliance elements present in GRI, International Trade Centre Standards Map and ISO 26000). Due to diverse categorizations of sustainability initiatives, this research suggests that indicators should be placed based on where the identified impact is (people, planet or prosperity).

Without any doubt, existing sustainability initiatives are significant and relevant. As a result of critical reflections it is found that their relevance is greater in source of impact and company activity realms. However, impact orientation has serious limitations. Aiming to contribute to existing sustainability assessment methodology, this research suggests an integrated sustainability assessment model having following features in mind:

- Impact assessment orientation (problems are assessed by indicators of each impact category)
- Scalability from products to supply chain levels (impacts can be assessed on various levels of scope)
- Choice of social indicators is based on measurable and quantitative social impacts at organization level as presented in GRI, International Trade Centre Standards Map and ISO 26000).
- Environmental indicators are based on measurable and quantitative environmental impacts as presented in ISO 14040 methodology.
- Economic indicators are based on measurable and quantitative economic (prosperity) indicators resulting from company activity and direct economic prosperity as presented in GRI and International Trade Centre Standards Map.

The process of developing a sustainability assessment model encompasses several stages. The first stage deals with needs and requirements for communication about sustainability. In the next stage, impact categories and sustainability indicators are chosen. The third stage addresses the selection of most suitable life cycle impact assessment methodology, software tools and databases. Further, this research subset presents and describes four necessary steps for implementation of a sustainability assessment model. Finally, the sustainability assessment model is visualized as well as a circular economy communication tool.

## 4.2. Needs and requirements for communication about sustainability impacts

Upon measuring sustainability impacts, they should be communicated in a proper and understandable manner. Sustainability assessments are necessary to support decisions that have the potential to influence sustainability from a variety of perspectives, including industrial, regional, national, and global (Bare 2014). When choosing sustainability indicators it is important to consider the intended use of the indicators and generated results from impact assessment. From the stakeholder perspective, among others, sustainability impacts can be communicated to customers, non-experts, policy makers, experts and scientists. United States Environmental Protection Agency (EPA) (2012) outlines four different perspectives that can be considered when using sustainability indicators to communicate impacts: public reporting, decision making, research planning and program evaluation (see Figure 13). An additional perspective that this research suggests is the market exchange. The information used for market transactions and interactions is an additional purpose of sustainability indicators. Since EPA is a governmental agency their interpretation underlines the choice of sustainability indicators from a governance perspective. In that scope, relevant sustainability indicators for public reporting should be broad measures at a national scale. When it comes to decision making, indicators that (1) assess specific outcomes of the decision and (2) are meaningful to the concerned stakeholders should be selected. These indicators provide a “basis for identification of additional indicators to be incorporated into research projects that investigate the causal relationships” among sustainability conditions (EPA, 2012). In addition, indicators relevant for research planning should underlie drivers or unintended consequences of change (EPA, 2012). For the purpose of program evaluation, indicators that measure the outputs and direct outcomes of research activities relative to the time and resources invested should be selected.



Figure 13 Purpose perspectives of choosing sustainability indicators (Adapted from: EPA, 2012)

“Based on the three pillars of sustainability, as sustainability indicator can be defined as a measurable aspect of environmental, economic, or social systems that is useful for monitoring changes in system characteristics relevant to the continuation of human and environmental well-being” (EPA, 2012). Meadows (1998) argues that indicators arise from values and they create value, whether in the business or governance context. In addition, indicators are used to reveal current conditions, evaluate management decisions, track outcomes of actions, and assess progress towards stated goals (EPA, 2012). There are manifold sustainability indicators used by academic institutions and industries to evaluate sustainability performance. As proposed by Fiksel (2009) and Boër et al. (2013), in order to select the most suitable sustainability indicators for a sustainability assessment model the following set of criteria should be used (see Table 15). Not all sustainability indicators meet this criteria but a credible portfolio of sustainability indicators should have outlined characteristics.

Indicator characteristic	Explanation
Relevant	Indicator has to reflect interests of the intended audience.
Meaningful	Intended audience has to find indicator clear, comprehensive and transparent.
Effective	Indicator has to be able to support decision making and monitoring over time.
Comprehensive	Overall evaluation of progress with respect to sustainability goals needs to be provided.
Practical	Indicator has to build on existing data collection and ensure cost-effective implementation.
Established	An indicator and the way to calculate it should be accepted in the academic and industrial environments.

Table 15 List of relevant indicator characteristics (Adapted from: Fiksel, 2009; Boër et al., 2013)

The relevance of presented indicator characteristics for different purposes of sustainability indicators is presented in Table 16.

	Relevant	Meaningful	Effective	Comprehensive	Practical	Established
Public reporting	●	●				
Decision making	●	●	●			
Research planning		●			●	●
Program evaluation	●	●	●		●	
Market exchange				●	●	●

Table 16 The relevance of indicator characteristics for different indicator purposes (Source: Author)

### 4.3. Choice of impact categories and sustainability indicators

Based on the analysis of four sustainability initiatives (see 4.1), literature review (Goedkoop, 1995; Goedkoop & Spriensma, 1999; Goedkoop et al., 2009; Bar, 2002; Talberth et al., 2006, Frischknecht et al., 2007; Fiksel, 2009; UNEP/SETAC, 2011b; UNEP/SETAC, 2013; Boër et al., 2013) and relevant indicator characteristics (see Table 3), the following impact oriented indicators and corresponding metrics are proposed for the sustainability assessment model (see Table 17). There is no ratio assigned to three types of indicators since, in the scope of this research, they are equally significant for sustainability.

## Environmental indicators



- Global warming potential (kg eq. CO<sub>2</sub>)
- Photochemical ozone creation potential (kg eq. C<sub>2</sub>H<sub>4</sub>)
- Eutrophication potential (kg eq. Po<sub>4-3</sub>)
- Stratospheric ozone depletion potential (kg eq. CFC-11)
- Acidification potential (kg eq. SO<sub>2</sub>)
- Human toxicity potential (kg eq. I,4-DCB)
- Depletion of natural resources (kg eq. Sb)
- Land use (m<sup>2</sup>/year)
- Water depletion (m<sup>3</sup>)
- Energy depletion (MJ)
- Waste production (kg)
- Product recycling potential (%)

## Social indicators



- Injuries intensity (#)
- Safety expenditure intensity (€)
- Employment opportunity (%)
- Workforce turnover intensity (#)
- Multi skilled operators (%)
- Staff development investments intensity (€)
- Worked hours (h)
- Child labor (%)
- Charitable distributions intensity (€)

## Economic indicators



- Labor costs (€)
- Material costs (€)
- Corruption - Corruption perception index (#)
- Income distribution (#)
- Crime (replacement costs and legal fees €)
- Education - the value of the labor directed to higher education (€)

Table 17 Sustainability assessment model indicators list and measuring units (Adapted from: Talberth et al., 2006, UNEP/SETAC, 2009, Boër, 2013, GRI 2014)<sup>9</sup>

As environmental LCA methodology is well established and most developed it is rather easy to find sources for environmental indicators (Goedkoop, 1995; Goedkoop & Spriensma, 1999; Guinée, 2002; Frischknecht et al., 2007; Goedkoop et al., 2009). Guinée (2002) suggests that selection of sustainability indicators should be performed based on positioning of the focal point of indicators in the cause-effect chain – inventory results to endpoints. Life cycle inventory results have to be translated into environmental impacts, and for that purpose impact assessment methods are used. Impact assessment methodologies are systematic calculations that use life cycle inventory to get environmental, economic and social impacts. In LCA impact methodology there are two impact category approaches - midpoint<sup>10</sup> and endpoint<sup>11</sup>. Choice depends largely on the goal and scope of study and/or stakeholder interest. The midpoint approach is problem-oriented and it is meant to translate impacts into environmental intervention themes. The second approach, endpoint, is damage-oriented and it focuses on modeling the potential environmental damage and translating the

<sup>9</sup> Corruption Perceptions Index is developed by Transparency International and it ranks countries/territories based on how corrupt a country's public sector is perceived to be. "CPI is a combination of surveys and assessments of corruption, collected by a variety of reputable institutions. The CPI is the most widely used indicator of corruption worldwide" (Transparency International Website). More information available at: [http://www.transparency.org/cpi2013/in\\_detail#myAnchor1](http://www.transparency.org/cpi2013/in_detail#myAnchor1)

<sup>10</sup> The term expresses the point that is an intermediate point between the LCI results and the end of pathways (Julliet et al., 2003).

<sup>11</sup> Endpoint category is an attribute or aspect of natural environment, resources, or human health identifying an environmental issue.

environmental impacts into issues of concern within environmental areas for protection. Most environmental impact assessment methodologies use midpoint measurements. The reason behind it lies in the complexity, uncertainty and fractional effect of endpoint effects. For example, it is difficult to measure to what extent is human health degraded due to total releases to air, water, and soil caused by one company's activities. Due to complexity, uncertainty and fractional effect of endpoint approach, this research suggests using midpoint categories for all three sustainability assessment techniques (LCA, S-LCA and LCC).

Social indicators have received the least attention, especially compared to environmental ones. Consequently, social dimension assessment is still not established despite the existence of several methods and indicators proposals. Recent developments on social impact indicators are provided by UNEP/SETAC (based on ISO 26000 and GRI) and classified based on stakeholder groups (see Appendix 2). Stakeholder relevance can vary not only from one study to another, but also within each step of the supply chain (UNEP/SETAC, 2009). The choice of a stakeholder group depends on the particular context of the study, which affects the choice of appropriate indicators (UNEP/SETAC, 2009). As this study will analyze the sustainability impacts of different maintenance scenarios it is relevant to address workers, as a stakeholder group that is affected by economic activities which result in social impacts (for example injuries, safety, working hours, employment opportunities).

In the scope of this research, economic activity results in economic prosperity. The relevance of cost categories to sustainability is in practical aspect from the user point of view. "The environmentally friendly products, as identified and quantified by LCA, have often higher purchasing costs, but frequently turn out to be cheaper if the use phase/and or the end-of-life phase are taken into account" (Klöpffer & Ciroth, 2011). In addition, Klöpffer & Ciroth (2011) argue that "answers provided by LCC are related to the costs directly relevant for the decision maker or to another life cycle actor, over the full life cycle". Since the LCC does not address the global costs and thereby not live up to the global scope of sustainable development, it is important to include the economic prosperity dimension. Therefore, economic indicators embody 2 categories: organization's operating costs (labor and material costs) and direct economic prosperity (corruption, income distribution, crime, education). For operating costs, this research takes up UNEP/SETAC (2011) approach of cost categories. To address direct economic prosperity, the Genuine Progress Indicator's (GPI) approach to economic indicators is taken (Talberth et al., 2006) reflecting on corruption, income distribution, crime and education. The corruption index is on a country level and therefore very challenging to translate to a product level. Instead, the corruption index is used to establish contextual settings in which product's activity manifests. The income distribution measures the equity of the employee wage distribution within the solution space. In this case, the employees who engaged with the analyzed product are relevant. The education relates to the number of hours invested in training and education about product's maintenance.

After choosing sustainability indicators and identifying corresponding metrics, methods to acquire data for each metrics need to be employed as to analyze the product/system under study.

#### **4.4. Selection of impact assessment methodology**

The backbone of any sustainability impact assessment methodology is environmental LCA. The inclusion of LCC and S-LCA is marginal as they are still under development. That is why this study takes the environmental LCA perspective when making a selection of impact assessment methodology.

Several impact assessment methodologies are developed and applied for environmental LCA. The selection of the life cycle impact assessment (LCIA) methodology for this sustainability assessment model has been carried out analyzing which of the available LCIA methodologies addresses chosen environmental impacts. Only environmental indicators are considered as they are internationally standardized. Since sustainability assessment model's indicators are problem-oriented, the damage-oriented LCIA methodologies (IMPACT, Eco-Indicator 99, Ecological Scarcity and ecosystem damage potential) have been excluded in the selection process. The problem-oriented, i.e. midpoint impact assessment methodologies, supported by LCA software tools, include CML-IA<sup>12</sup>, Traci<sup>13</sup> and ReCiPe. CML-IA is a well-established LCIA methodology developed by the Institute of Environmental Sciences at the University of Leiden in the Netherlands. Traci is developed by U.S. Environmental Protection Agency (EPA) to assist in impact assessments for sustainability metrics, industrial ecology, pollution prevention, process design and life cycle assessment. ReCiPe is another Dutch developed methodology (National Institute for Public Health - RIVM, CML, Pré Consultants and Radboud University of Nijmegen) and a successor of CML-IA as it integrates the problem oriented approach (midpoint) and the damage oriented approach (endpoint). The methodologies are tested for the use of the same unit of measure expected by the sustainability indicator (see Table 18).

Sustainability indicator	CML-IA	Traci	ReCiPe
Global warming potential	x	x	x
Photochemical ozone creation potential	x		
Eutrophication potential	x		
Stratospheric ozone depletion potential	x	x	x
Acidification potential	x		x
Toxicity potential	x		x
Natural resources depletion	x		x
Land use	x		x
Water depletion			x
Energy depletion			
Waste production			
Product recycling potential			

Table 18 Match between sustainability assessment indicators and life cycle impact assessment methodologies (Adapted from: Boër, 2013)

The analysis performed on the LCIA methodologies shows that CML-IA is the best methodology fitting for chosen environmental indicators. CML-IA fulfills the selection criteria defined by the ISO relevant standard and the work of SETAC group on impact assessment (Boër, 2013). Another advantage of this method is free calculation of new or ad hoc potentials if the LCIA data are not directly available from databases (Boër, 2013). However, as CML-IA fails to cover all chosen environmental indicators, it is suggested to combine it with other impact assessment methodologies.

Since there are neither LCC, nor S-LCA software tools for sustainability assessment, only LCA tools are addressed. There are many LCA software tools available (e.g. CMLCA, SimaPro, GaBi and Umberto). Some of the advantages and disadvantages of 4 selected software tools are presented in Table 19.

<sup>12</sup> CML-IA - Center of Environmental Science of Leiden University Impact Assessment

<sup>13</sup> Traci - Tool for the Reduction and Assessment of Chemical and other environmental Impacts



## LCA software tool

## Pros

## Cons

LCA software tool	Pros	Cons
CMLCA	License is for free, flexible, used by scientists and non consultants, compatible with ISO 14040, can assess environmental, social and economic impacts	Contains no data (data has to be downloaded or bought), contains no impact assessment data, available for Windows, no graphical interface
SimaPro7	Easy sharing of findings, modeling a large number of variables, comes with inventory databases that can be edited and expanded without limitations	Only available for Windows, license has to be purchased. intended to be used only by professionals
GaBi5	Can be used to design products with more environmentally friendly components, easy sharing of findings, flexible, can evaluate social profiles of products	The original codebase is outdated, databases lacks transparency, license has to be purchased
Umberto	Modern graphical user interface, serves to visualize material and energy flow systems	Data are taken from external information systems, only available for Windows, intended to be used only by professionals, license and databases have to be purchased

Table 19 Pros and cons of LCA software tools (Source: <http://www.linkcycle.com>)

For the purpose of a comprehensive sustainability assessment model that takes into account all three pillars of sustainability, this research suggests to use the Chain Management by Life Cycle Assessment (CMLCA) software. There are several reasons why the CMLCA software tool is suitable for this sustainability assessment model. First of all, it supports the calculation of LCSA, instead of just environmental LCA. Second of all, CMLCA is intended to support the technical steps (goal & scope, inventory analysis, impact assessment and interpretation of results) of an assessment model, and excludes all procedural aspects (e.g. stakeholder involvement or peer review)<sup>14</sup>. By having no stakeholder involvement or peer review the process takes less time. Finally, as purpose of the designed sustainability assessment model is to communicate sustainability impacts to a wide scientific and business audience, it is important that its scope goes beyond the one of professional consultants. Thus, simplicity, transparency and flexibility are features that are widely appreciated amongst decision makers with respect to sustainability assessment models.

## 4.5. Implementation steps

### Goal and scope

The goal and scope of a sustainability assessment model include functional unit, system boundary and impact categories. As LCSA has one object of study, i.e. the product life cycle, it uses a functional unit in order to model the product system (Benoît et al., 2010). The functional unit of a sustainability assessment model describes both technical utility of the product (e.g. production of 1m<sup>2</sup> of carpet) and the products social utility (production of 1m<sup>2</sup> of carpet that is easy to maintain). To address social utility, one should first cover stakeholder analysis in order to identify the utility for each stakeholder. As presented in Figure 14, when it comes to system boundary, it has to be stated that each of the three techniques has different system boundaries based on their relevance to

<sup>14</sup> More information available at: <http://www.cmlca.eu/whatiscmlca.html>

sustainability (UNEP/SETAC, 2011b). The overall LCSA system boundary contains all unit processes relevant for at least one of the techniques, but in cases where one or more product life cycle phases are not included the reason for the exclusion should be justified (UNEP/SETAC, 2011b). If system boundary is identical for all three life cycle techniques, cut-offs are avoided. Else ways, a cut-off criterion, based on working hours, cost, prices, environmental or social relevance can be deployed (UNEP/SETAC, 2011b). The cut-off criterion allows conducting LCSA without having to model the whole product's system, allowing to omit a non-relevant life cycle stages or specific processes (omit energy use from LCSA). In regard to impact categories, for an integrative sustainability assessment model, it is recommended that all relevant impact categories across the life cycle of a product are selected. Both system boundaries and choice of impact categories depend on project characteristics and scope of intended results.

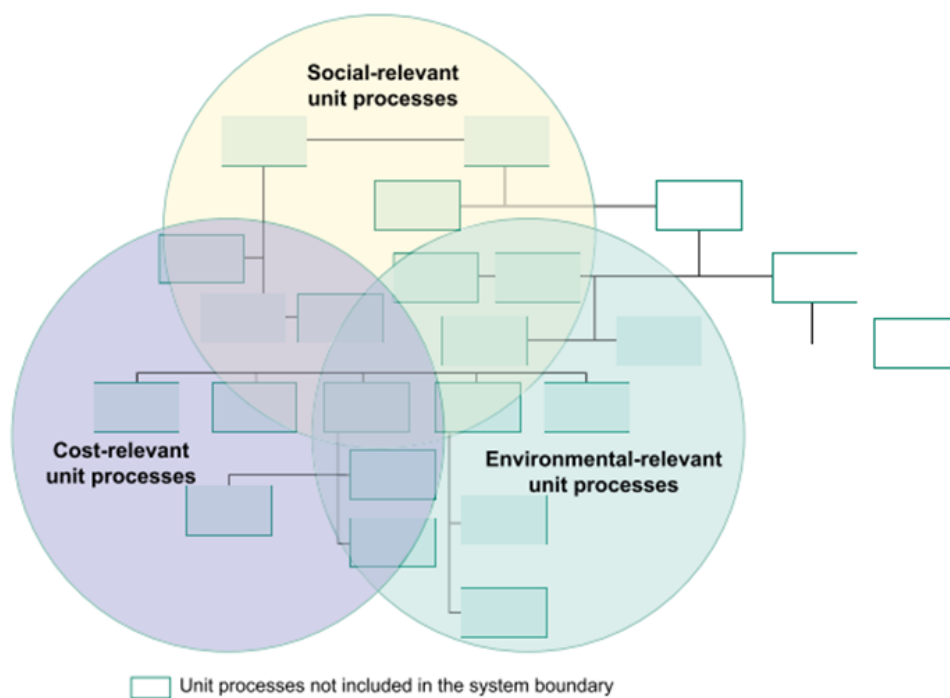


Figure 14 An example of LCSA system boundaries (Source: UNEP/SETAC, 2011b)

### Life cycle sustainability inventory analysis

In a sustainability assessment model, the life cycle inventory consists of “exchanges between unit processes and organizations of the product system and the external environment that leads to environmental, economic and social impacts” (UNEP/SETAC, 2011b). The input for inventory analysis is provided through “life cycle data collection on activity variables and used for prioritization, hotspots assessment, site-specific evaluation and impact assessment (UNEP/SETAC, 2009). A life cycle sustainability inventory analysis can be based on quantitative, semi-quantitative and qualitative results, which adds to the challenge of collecting different types of data along the life cycle (Valdivia et al., 2013). Results should be presented per output produced or as a description of results gathered for each product (see Table 18). For every process that is considered relevant, data is collected for LCA, LCC and S-LCA. The benefits of parallel data collection are more time- and cost-efficient process, better-informed data collection processes and reduced risk of double counting (Valdivia et al., 2013). Since this step in sustainability assessment model is rather costly, many databases are developed in order to “gather data about the most commonly used materials and processes that are relevant to the companies” (Boër et al., 2013). Some of the frequently used life

cycle inventory and life cycle impact assessment databases in business sector are: Ecoinvent, CPM (Common Provider Master) database, ELCD (European reference lifecycle database), GaBi (General information About Balance Interpretation) database and CML-IA (Center of Environmental Science of Leiden University Impact Assessment). Some of the main characteristics of abovementioned databases are presented in Table 20. It is recommended that both public databases and site specific data are used when implementing an LCSA (UNEP/SETAC, 2011b) as to generate more accurate and reliable results.

Database name	Authors	Content	Notes	Cost
Ecoinvent v3.1	Swiss centre for lifecycle inventories	Over 10,000 LCI and LCIA datasets in the areas of energy supply, agriculture, transport, biofuels, metals etc.	LCI and LCIA database. Data are available online, in XML, and Excel format.	With fee
CPM database	Chalmers University of Technology, Göteborg	Online database with access to over 500 datasets	LCI database. Data are available online in HTML format.	For free
ELCD	Joint Research Centre, European Commission	330 datasets with data from different industries; data on energy production, transport and end-of-life processes	LCI database. Data are available in XML format.	For free.
GaBi databases	PE International	Over 8,000 LCI and LCIA profiles	LCI and LCIA database.	With fee.
CML-IA database	Institute of Environmental Science, Leiden University	Contains characterization factors for life cycle impact assessment	CML-IA is easily read by the CMLCA software program.	For free.

Table 20 Life cycle inventory and life cycle impact assessment databases (Source: Boër et al., 2013, PRé website)

### Life cycle sustainability impact assessment

The LCSA is a technique to assess the potential social, environmental and economic impacts of a product or service during its life cycle. Since LCA, LCC and S-LCA have different time horizons, it is suggested to present LCC and S-LCA results in short- and mid-term time periods, while environmental LCA results in mid- to long-term period (Valdivia et al., 2011). On this way inclusive impacts can be captured.

Since environmental LCA is the only internationally standardized LCA technique, the environmental LCA impact assessment steps are taken when doing LCSA. According to ISO 14040 and 14044 standards there are two mandatory and three optional steps when performing an LCA impact assessment (UNEP/SETAC, 2011b). The classification and characterization steps are minimum and mandatory requirements for environmental LCA, while optimization, aggregation and weighting are optional. Environmental Protection Agency describes impact assessment steps as follows (2006):

**Classification** – assigning LCI results to the impact categories (e.g. classifying carbon dioxide emissions to global warming).

**Characterization** – modeling LCI impacts within impact categories using science-based conversion factors (e.g. modeling the potential impact of carbon dioxide and methane on global warming).

**Optimization** – expressing potential impacts in ways that can be compared (e.g. comparing the global warming impact of carbon dioxide and methane for the two options).

**Aggregation** – sorting or ranking the indicators (e.g. sorting the indicators by location: local, regional, and global).

**Weighting** – emphasizing the most important potential impacts.

Considering that LCSA consists of three techniques which have different characteristics and attributes, it is not always feasible to repeat all LCA steps. In this matter, the classification step is impossible to implement on LCC as inventory data provide a direct measure of impact. Further, the characterization is unavailable for LCC as it is impossible to convert economic results using science-based conversion factors. As for optional steps, UNEP/SETAC recommended not to address them because research and implementation of LCSA is still under development (2011b). Figure 15 highlights two things, (1) if feasible, a combined network for impact assessment based on the individual LCA, S-LCA and LCC frameworks should be used in this stage, and (2) the sustainability assessment model presented in this research suggests not to address damage effects (endpoint and categories). For more detailed information on life cycle sustainability impact assessment refer to 4.2. sub-chapter.

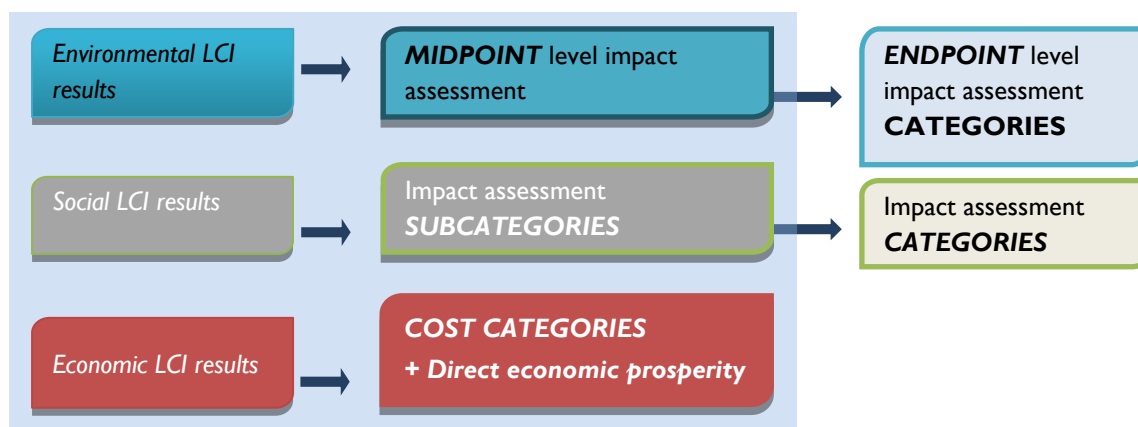


Figure 15 Framework for sustainability assessment model (Source: Author)

### LCSA interpretation

The results of the sustainability assessment model identify both negative and positive impacts. Evaluation of results in an integrated sustainability assessment model is twofold. First, an analysis of tradeoffs between economic benefits, social and environmental effects is done. Second, critical life cycle stages are identified by allocating source of impacts. By conducting these two approaches, a comprehensive understanding of social, environmental and economic impacts can be gained.

A comparison of two products or processes is enabled with interpretation of results. However, interpreting results in a combined fashion and presenting clear LCSA results to support decision-making processes is still a key challenge (Weidema, 2006; Traverso & Finkbeiner, 2009; UNEP/SETAC, 2011b). On the one hand, this is due to characteristics of data. On the other hand, the interpretation of results is left to the final user of the study which means that usefulness of the analysis is strongly limited (Sala et al., 2012). As the evaluation of results depends on the goal of the integrated study, so does the conclusion. In regard to findings, data needs to be checked for quality

and uncertainty. Valdivia et al. (2013) suggest using statistical methods for evaluation of quantitative data, while sensitivity analysis should be used for qualitative data.

#### 4.6. Visualization of sustainability assessment model

After highlighting important elements of the sustainability assessment model and describing implementation steps, it is important to illustrate the sustainability assessment model. As a result of literature review on LCSA and circular economy the following product life cycle phases are suggested: extraction of raw material, parts manufacture, product manufacture, distribution & packaging, use, maintenance, collection, prepare for reuse, remanufacture, recycling, energy recovery and landfill (see Figure 16). Important to mention is that every product life cycle phase includes waste generation and energy use. Out of displayed product life cycle phases, system boundaries are to be drawn when applying the model on an actual study. Based on the study characteristics, optional phases can be included, such as assembly, retail, product design and production of electricity and fuels.

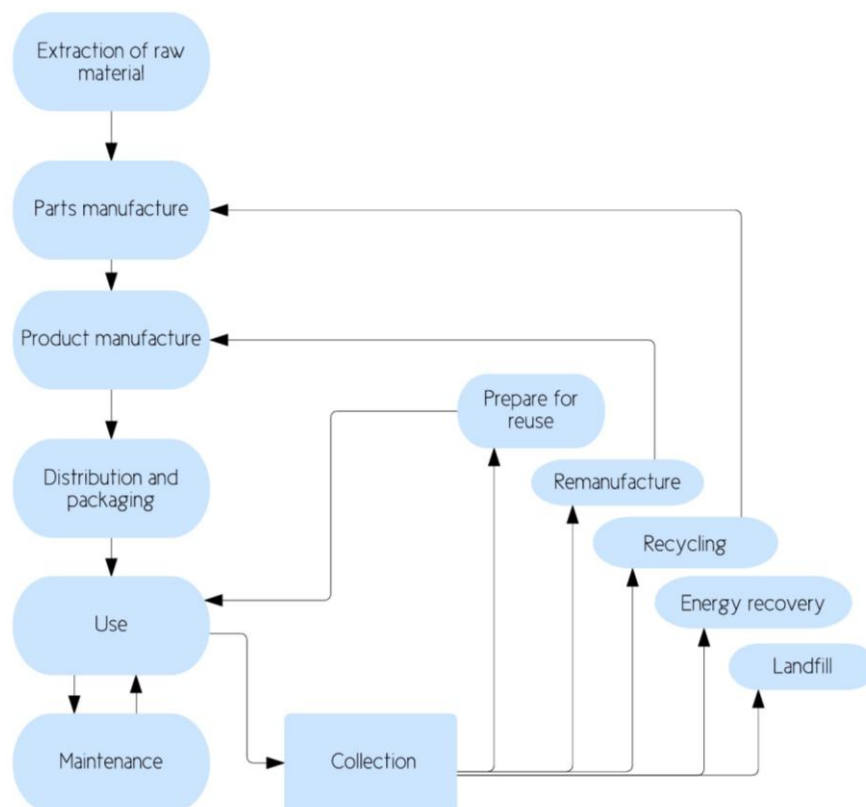


Figure 16 Product life cycle phases of sustainability assessment model (Source: Author)

Figure 17 is an illustration of necessary methodological steps towards LCSA of product life cycle. Addressing all three types of sustainability impact saves time and money. Companies could be interested in this approach for several reasons: quicker and cheaper than a full LCA; reveals hotspots over the complete life cycle of a product (hotspots are processes where negative impacts are identified); builds capacity and communication around product sustainability (capacity building refers to understanding of obstacles towards realization of development goals); helps to build a shared understanding of sustainability challenges across the company; useful for strategic decision-making when it comes to product innovation. Or putting it very simple, if you can't measure it – you can't manage it!

Understanding and communicating LCSA results is a challenging task. It depends greatly on the purpose of sustainability communication (see Figure 13). Based on type of reporting (public, decision making, research planning, and program evaluation) different levels of results integration are applied. The public reporting requires least detailed LCSA results and it should be communicated in a straightforward and illustrative manner. For research planning and program evaluation the LCSA results demand complex and all-encompassing results, usually in the form of tables and graphs. In regard to decision making type of reporting the literature review on circular economy and product service system call for development of communications tools that can 'translate' user's value proposition, benefits, investments and accompanying PPP effects. Combining value proposition and CBA elements with sustainability impacts is required in business discussions. To meet that end and accentuate added value from circular economy, this research proposes a *Circular economy value communication tool* (see Figure 18).

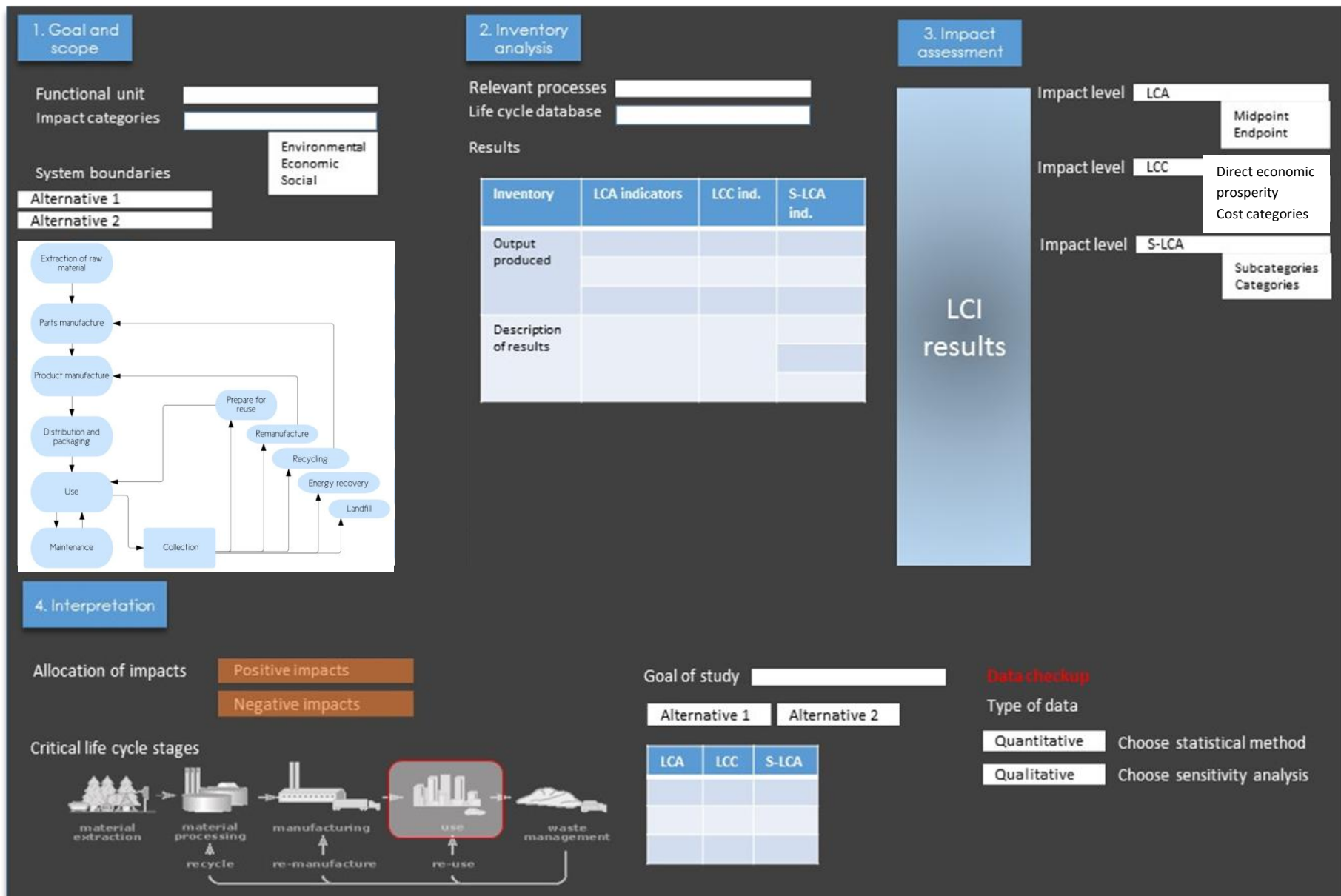


Figure 17 Illustration of sustainability assessment model (Source: Author)

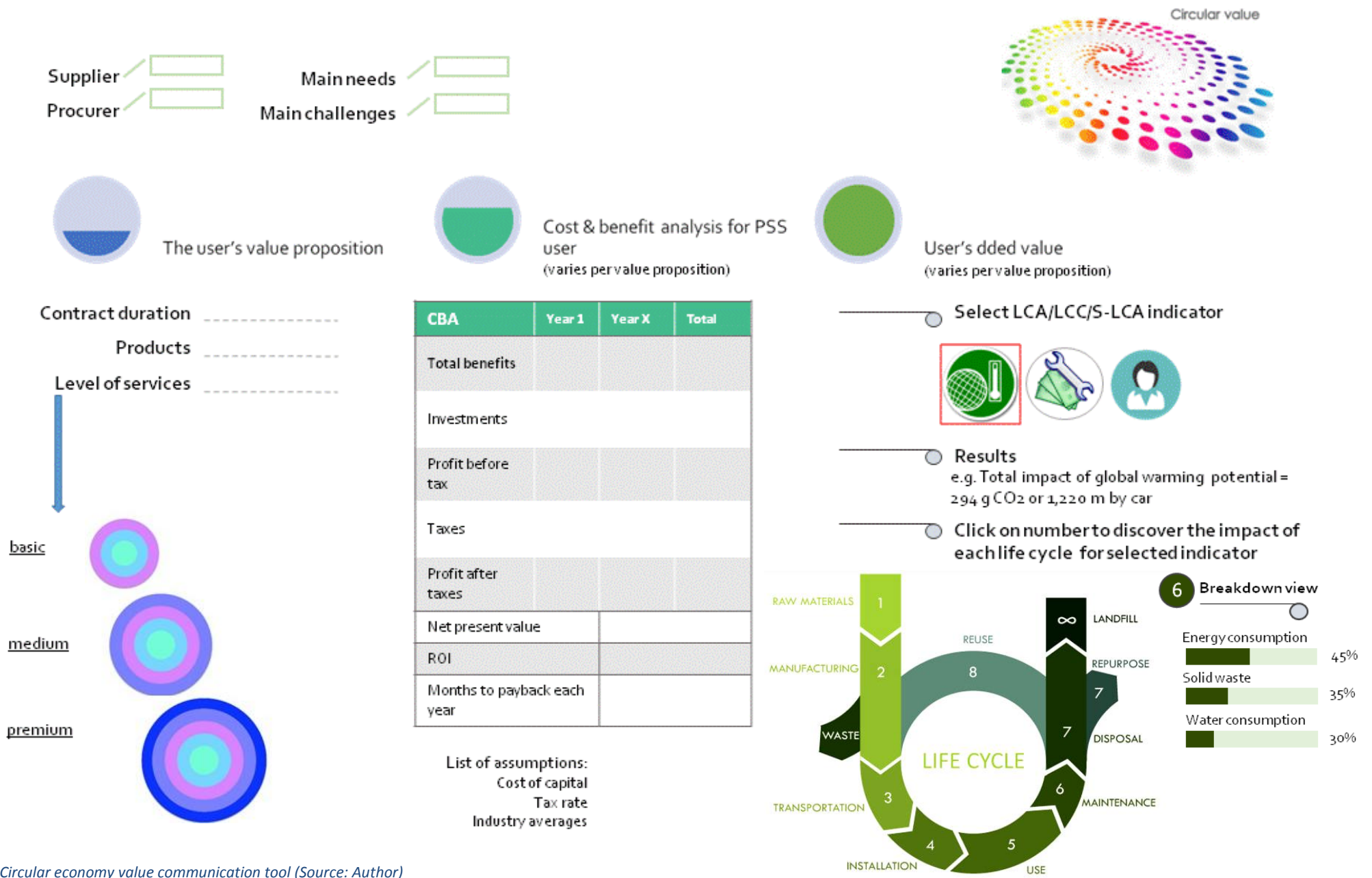


Figure 18 Circular economy value communication tool (Source: Author)



The presented communication tool has a PSS user orientation and decision making focus. That means that every element of this tool reflects user's perspective as it should support the decision making process. A supplier can initiate communication by establishing user's needs and identifying the main challenges which are based on the contextual settings and company's capabilities. Upon determining needs and challenges supplier reaches customer through a three step process.



The first element that needs to be communicated depicts the user's value proposition. Supplier and customer agree on the contract duration, while supplier offers suitable products that meet customer's needs and desired service level. There are different service levels at customer's disposal, ranging from basic performance services to premium services. In the scope of a lighting product, the basic services could include functional light and continuous maintenance at a low service fee. The medium services could include functional light, continuous maintenance, single technology upgrade and energy usage report at a somewhat higher service fee than for basic services. The premium services are offered at the highest service fee and could include previously mentioned services in addition to software and fashion updates and advanced monitoring system. The provided description is merely an illustration of the concept of service levels rather than a blueprint.



The value proposition elements serve as an input for cost & benefit analysis that introduces customer with important financial elements from a user's perspective (e.g. total benefits, investments, net present value, and months to payback each contract year). The CBA should provide a detailed outlook for each year of the contract duration. An activity based taxing, that is linked to the value chain activities, could also create an input for impact assessment (include tax contributions of a company as an indicator of economic prosperity).



Finally, the 'added value' of circular economy is communicated. A supplier should have detailed assessments ready but involve customer by allowing him to calculate impacts by himself. Depending on the customer's preference, more elaborated insights on economic, environmental and social impacts of the chosen value proposition are disclosed. Discovering added value of circular economy is envisioned as a three level process. Initially, the customer chooses a LCA, LCC or S-LCA indicator that concerns him (e.g. global warming potential). On the second level, the total impact of chosen indicator is displayed and put into a non-expert perspective (e.g. the global warming potential equals 294 gCO<sub>2</sub> or 1,220 m by car). The third level allows customer to go a step further and discover the contribution of each life cycle phase in regard to chosen impact (e.g. life cycle phases that source for global warming potential are energy consumption – 45%; solid waste – 35%, and; water consumption – 30%). The provided example of global warming potential is merely an illustration of the sustainability impacts concept. Of course, there are many other environmental, economic or social indicators. It is important to mention that LCC indicators measure only user's value proposition, which is not the same as measuring the prosperity.

By covering value proposition, CBA, and sustainability impacts it is assumed that communication between supplier and customer will be more transparent and support decision making. Although the cost savings are a top priority for majority of customers, they are becoming more demanding in regard to sustainability as well. That is why suppliers need to take up the challenge by monetizing positive sustainability impacts and integrating them in the service fee.

# CHAPTER 5 PHILIPS LIGHTING CASE STUDY

This chapter is set out to challenge the literature review findings by answering the main research question:

*How does a circular economy affect the relationship between supplier and public procurer, and how can these economic actors assess economic, environmental and social impacts of a circular economy value proposition?*

Given the main research question, the Philips Lighting case study is analyzed from two angles. Firstly, the relationship change between Philips, as a supplier, and WMATA, as a public procurer, is explained and described in the context of a circular economy. The findings on the relationship change are derived from the analysis of interviews, as well as internal and external case study documents. The following aspects are covered: the enablers and barriers for transition to circular economy; the supplier's and public procurer's motivation to change existing business practices; the tendering process and WMATA needs; the value proposition and value creation; the value capture; and the relationship change elements. Secondly, the designed sustainability assessment model is applied on the Philips Lighting case study to reveal the sustainability impacts of the product service system business model, as integrated in the WMATA deal, and compare them with the product based business model's impacts. The results of difference in impacts are based on available qualitative and quantitative data on the product level.

## 5.1. Supplier – public procurer relationship change

### About the WMATA deal

The Washington Metropolitan Area Transit Authority (WMATA) serves a population of over 5 million commuters in the city's metropolitan area. The Authority was created in 1967 to plan, develop, build, finance and operate a balanced regional transportation system in the National Capital Area (LED inside, 2014). WMATA is responsible towards the federal government, Washington DC, Maryland and Virginia, as well as compliant with environmental laws, regulations, policies and procedures (WMATA website<sup>15</sup>). Researcher's observation is that WMATA's sustainability initiatives are energy efficiency driven while waste is in the focus of their supply chain activities.



Figure 19 Geographic liability areas of WMATA

The organization continually looks out for ways to improve the safety and experience of users and in 2013 decided to upgrade an outdated lighting garage system in 25 parking garages to an innovative

<sup>15</sup> More information available at: [http://www.wmata.com/about\\_metro/?forcedesktop=1](http://www.wmata.com/about_metro/?forcedesktop=1)

LED lighting technology. For this purpose, a 10 year performance contract was signed with Philips Lighting with no up-front costs as energy savings compensate services costs. How exactly this project evolved is discussed in turn.

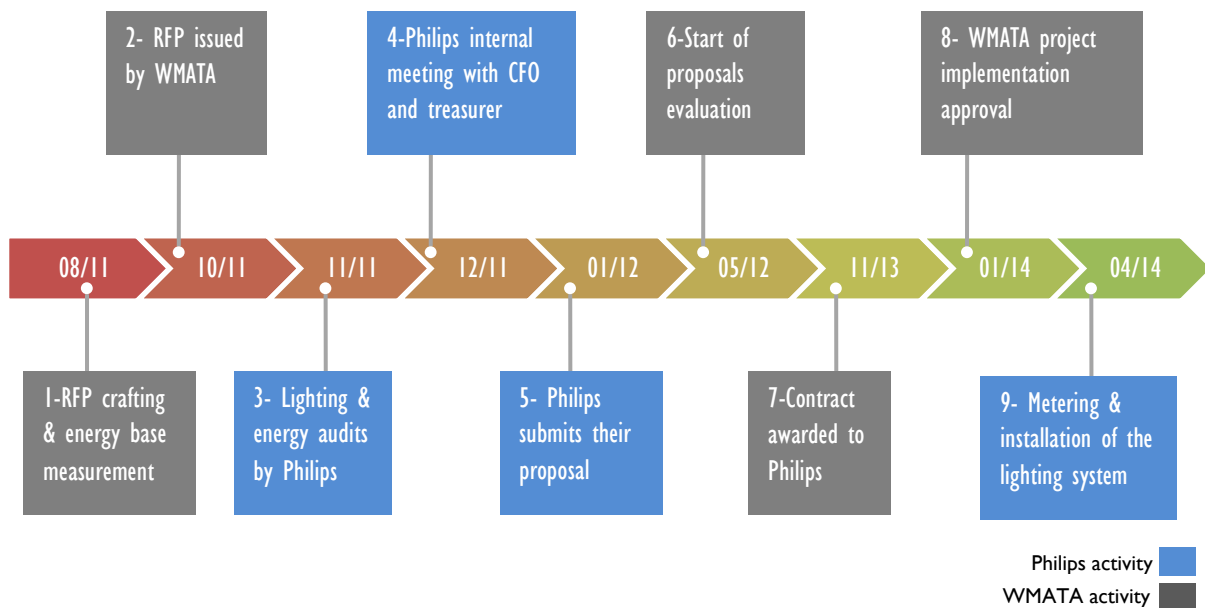


Figure 20 Timeline of WMATA and Philips Lighting interactions (Source: Author)

The whole process took nearly 4 years, from the RFP research to the installation of lighting system (see Figure 20). WMATA had a vision to show the public they are “using their money efficiently and developing new operating approaches that are modern, up-to-date, and people could relate to” (Interview W1<sup>16</sup>). At the time, WMATA was researching European transit agencies (Munich, Lyon, Brussels and Copenhagen) for their planning and operating activities (Interview W1<sup>17</sup>). After an inventory of possibilities that would generate the best result, WMATA choose the lighting initiative (Interview W1 & 2). During the consultations with a technical team it became clear they are risk averse and not interested in operating and maintaining a new lighting system, other than the one they are familiar with (Interview W1). That is why WMATA selected a performance contracting approach which “could give the responsibility to a vendor to provide lighting and use whatever technology they thought is best” (Interview W1). Because WMATA is a public entity the project had to be put to bid. This meant a request for proposal (RFP) needed to be created. A request for proposal is a solicitation, made as part of the bidding process, by a company or agency interested in procurement of products and/or services, to potential suppliers to submit proposals. The development of the RFP was based on the market research across many fields and conducted by WMATA (Interview W2). In addition, WMATA used the help of DC Sustainable Energy Utility’s lighting specialist for technical advises and Walker Parking Consultants for technical reviews support (Interview W2). Before issuing a RFP, WMATA conducted a measurement of their energy base as to predict energy savings. When formulating this RFP WMATA encountered numerous goals (WMATA, 2011). Foremost, the lighting criteria had to be met, regardless of the type of lighting technology (WMATA, 2011). Secondly, as WMATA is procuring light and not light sources (products), the project was not financed from capital investment funds (WMATA, 2011). The RFP was issued in October 2011 requesting the following: “[...] services of a qualified contractor to

<sup>16</sup> Refers to Interview list’s numbers at page 8.

<sup>17</sup> Refers to Interview list’s numbers at page 8.

design, install and maintain for a 10-year period, a lighting system at WMATA's parking garages that produces total cost and energy savings [...] It is expected that the contract costs will be financed through operating expense savings [...]'.

Philips was one of the interested suppliers that decided to provide a proposal to issued RFP. From the RFP it was clear to Philips that WMATA was not only looking to buy luminaires – they wanted a partner to implement a full solution. The challenge lay in the fact that Philips Lighting North America has never done a project of that type and magnitude. Although WMATA provided estimated energy savings, Philips Lighting had to conduct an extensive lighting and energy audit themselves (November 2011). The audits revealed detailed characteristics of current lighting system and energy consumption of each parking garage. Based on results and developed technical specifications Philips was able to calculate future energy savings they could offer. Based on characteristics of new lighting solution and controls, Philips estimated 68% annual reduction in kWh (WMATA, 2013b). The discrepancy between WMATA's and Philips Lighting's estimates could not be disclosed for confidentiality reasons. During the meeting with Chief Financial Officer (CFO) and treasurer Philips Lighting identified a financial model which was most suitable for the WMATA deal (December 2011). The financial model includes 20 semi-annuals payments generated from energy savings; and no up-front costs for WMATA. Having all of the technical content and financial information resulted in a final document that exceeded 1000 pages (January 2012). Several different suppliers submitted proposals, but the exact number is not revealed due to confidentiality reasons. The evaluation of proposals was extensive and lengthy (May 2012 – November 2013). This was due to lack of familiarity with performance contracting (Interview W1&2). Every proposal was scrutinized because the solution WMATA was looking for is very complicated and affects their customers. During the decision making process WMATA chose not to inform any of the possible suppliers of the decision making progress. As a supplier of the best solution, WMATA awarded Philips Lighting with a 10 year performance contract. According to former WMATA's assistant general manager "WMATA's taking a small step by using one [performance contract] to light its parking garages, but this could signal a new era of lower costs and higher performance for the agency, benefiting everyone who uses it" (Bottigheimer, 2014). WMATA deal implementation approval was issued in January 2014, giving Philips Lighting notice to proceed with project execution. Prior to issue of notice Philips Lighting delivered project specific scope and schedule details.

Figure 21 illustrates WMATA's and Philips Lighting's activities once the lighting system is in place. WMATA deal is currently in the implementation phase which consists of installation and metering of LED lighting system for 25 public garages (April 2014 – October 2015). Philips was also responsible for taking care of the previous lighting system and disposing it according to regulations (Interview W2). Initially, the duration of installation was estimated to one year (until April 2015) but the difficulties with metering resulted in delay. During the installation phase WMATA personnel will be provided with training and education. Once the installation is completed, WMATA will perform testing and verification of the lighting system.

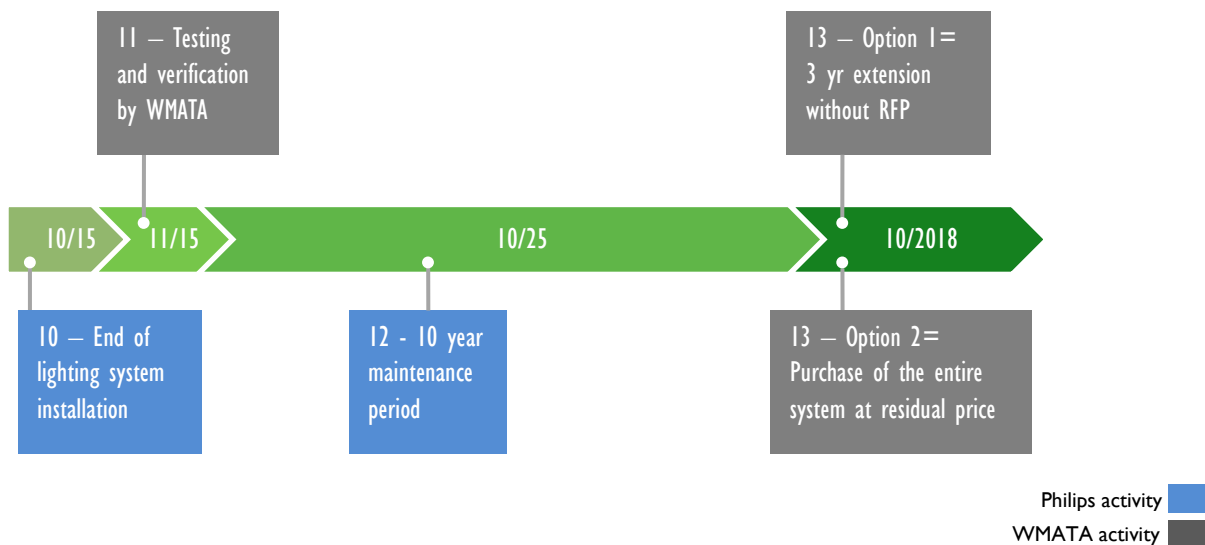


Figure 21 Timeline of WMATA and Philips Lighting upon installation

### Maintenance

The maintenance as a service starts upon the installation of lighting products (March 2015). During the 10-year maintenance period, Philips Lighting expects that primary components will fail with limited frequency in the early years but with increased frequency the primary components will surpass their average life (see Figure 20). For example, if the electrical driver of a LED light fixture fails after 10,000 hours, Philips Lighting will replace the failed electrical driver, rather than replace with a new light fixture. These fixtures, in collaboration with the contractors were designed for easy maintenance, including tool-free, click/snap solutions resulting in further cost savings. The fixtures are connected to the Philips LimeLite™ wireless controls system that will send an email alert identifying the fixture's location to the maintenance crew should there be failure in one of the fixtures. Philips will provide a 48-hour response time to all maintenance issues (Philips Professional Lighting Solutions, 2012). The control system was designed with the intention to be open and flexible, allowing it to be combined with other building automation systems.

### End of contract opportunities

After 10 years, WMATA has 2 options (see Figure 21):

- Contract extension for another 3 years (without RFP).
- Purchase of the lighting system at residual value

Philips will provide spare parts and extract material value from end-of-life components through centralized recycling (Philips Professional Lighting Solutions, 2012). The costs of parts harvesting and waste management will be fully financed by Philips Lighting. After covering elements of tendering process, maintenance and end of contract opportunities, it is important to address the contextual and legislative background of WMATA deal. To that end, private-public partnerships and WMATA needs are analyzed in turn.

## Private-public partnerships and WMATA's needs



Today's contract award advances our commitment to improving the system's infrastructure for our customers for years to come.

Richard Sarles, CEO WMATA

In the last decade Washington, D.C. officials have been pushing public-private partnerships forward. The incentive behind it lies in the need for new infrastructure and opportunity to leverage millions of dollars in private investment while creating new jobs and promoting economic development across the District<sup>18</sup>. One of the fierce advocates of public-private partnerships is former mayor of the District of Columbia – Anthony Williams (1999-2007). He suggested raising infrastructure investments in public transit, sewer systems and parks by means of private-public partnerships<sup>19</sup>. This is suggested as a way to supplement limited public sector capacities to meet the growing demand for infrastructure. In particular transportation is interesting, as it is highlighted as the most influential and implementable solution towards sustainability (UN Climate Summit, 2014)<sup>20</sup>. His successors took up the initiative further which resulted in *Public-private partnership for transportation: A toolkit for legislators*<sup>21</sup> (2010) and unanimously passed legislation of *Public-Private Partnership Act* (2014). This act is “an innovative piece of legislation that encourages investment in major public works projects and establishes a clear framework for securing public-private partnerships in the District of Columbia” (current D.C. Mayor, Muriel Elisabeth Bowser)<sup>22</sup>.

“The contract between Philips Lighting and WMATA reflects the new trend of public-private partnerships in USA. Public-private partnerships allow public agencies to use the private sector's knowledge and expertise to their advantage” (Nat Bottingeimer, assistant general manager WMATA). Among other things, the differences between traditional and Philips Lighting-WMATA contract are the following:

- Traditional contracts are not based on performance (quality of lighting, maintenance and monitoring of savings)
- Traditional contracts do not offer energy savings guarantee.
- Traditional contracts seek a specific product while WMATA's solicitation looked for the most cost-effective lighting.
- Traditional contracts do not offer value creation opportunities for procurers (obtain measurement and smart control reports), and inhibit suppliers from delivering the value (installing smart controls to meet operating needs).

Benefits of performance contracting and public-private partnerships are manifold. They provide better service and lower operating costs, infrastructure is modernized in order to ensure cost-

<sup>18</sup> More information available at: <http://mayor.dc.gov/release/mayor-elect-bowser%E2%80%99s-public-private-partnership-bill-unanimously-approved>

<sup>19</sup> More information available at: [http://www.washingtonpost.com/business/capitalbusiness/former-mayor-williams-pushes-for-public-private-partnerships-for-dc-infrastructure/2012/12/07/dbd69d64-3efb-11e2-bca3-aadc9b7e29c5\\_story.html](http://www.washingtonpost.com/business/capitalbusiness/former-mayor-williams-pushes-for-public-private-partnerships-for-dc-infrastructure/2012/12/07/dbd69d64-3efb-11e2-bca3-aadc9b7e29c5_story.html)

<sup>20</sup> More information available at: <http://www.un.org/climatechange/summit/2014/09/commitment-sustainable-transport-mobilized-un-climate-summit/>

<sup>21</sup> Full report available at: <http://www.ncsl.org/documents/transportation/PPPTOOLKIT.pdf>

<sup>22</sup> More information available at: <http://mayor.dc.gov/release/mayor-elect-bowser%E2%80%99s-public-private-partnership-bill-unanimously-approved>

savings, payment is dependent on meeting a certain performance standard, and the private-sector partner has a greater initiative to build lasting products. However, this performance contract required a different tendering process and carried certain pre-tender risks.

Philips engaged with WMATA to gain a deep understanding of their needs, and tailor the lighting in each garage to ensure that it delivers the optimum light levels for that structure. The key drivers for WMATA to engage in this project related to financial savings, no ownership over maintenance and chance to proof point a large scale performance contracting (WMATA, 2011). Philips was awarded with a contract due to its ability to provide a lower total cost of ownership, reputation as a market leader in innovations, credibility of providing LEDs and ability to develop possible future products to meet specific needs. In delivering an integrated lighting solution the following needs were addressed (see Table 21).

Improve lighting for customer comfort and safety.
Create operating cost savings.
Reduce energy consumption.
Transfer risk and performance to contractor through performance contracting.
Improve reporting of real time information for light fixture outages, power consumption, and asset management of parking garages

Table 21 Addressed needs in integrated lighting solution for WMATA (Adapted from: Philips, 2013b)

### Circular economy transition enablers and barriers

In the transition to circular economy various stakeholders are confronted with existing enablers and barriers. “Every stakeholder, from governments to end users ‘plays’ a different but equally important role in the transition to a circular economy: suppliers have to come up with innovative solutions; governments need to support it with laws and regulation; and end users have to recognize it as the best possible solution” (Interview P7). Both suppliers and public procurers change existing practices as part of necessary requirements towards a circular economy. Based on the analysis of interviews, the following transition enablers and barriers for Philips and WMATA (but also suppliers and public procurers in general) are derived (see Table 22).

Transition enablers		Transition barriers	
WMATA		WMATA	
Financial models		Lack of familiarity	
Performance guarantees		Tendering procedures	
Service level agreements		Lack of information	
Communication			
Philips		Philips	
Performance based contracting		Management practices	
Strategic partnerships and collaboration		Lack of experience	
Identify, quantify and compare added value		Lack of investment initiatives	
Increased visibility of circular economy		Legislative framework	
Mentality change		Linear mindset	
Leadership		Measurement challenges	

Table 22 List of circular economy transition enablers and barriers (Source: Author)

WMATA, as a public agency, is responsible for using public dollars which results in orientation on efficient use of financial resources. Appealing financial models and performance guarantees are found very important enablers in the transition to service based business models, i.e. circular economy. In addition, service level agreements need to be established and standardized. As public agencies are obliged to disclose their procurement processes, clear communication and transparency are necessary requirements. With respect to main inhibitors of circular economy transition for WMATA, it can be stated that the lack of technical familiarity and information are serious barriers. In addition, tendering procedures are something people complain about in WMATA (Interview W1).

For Philips, the opportunities that result from performance based procurement contracting are important as they result in a steady source of income and long term relationships with procurers. A circular economy, as still unexplored area of business development, motivates economic actors to form partnerships and collaborate. In this way each supplier can focus on its core competences and outsource other activities. An important enabler for Philips is the possibility to identify, quantify and compare added value of service based business models as to gain the better market position and unique value propositions. Although the transition to a circular economy is a challenging task, Philips has the incentive to further increase the visibility of circular economy by investing in communication and case studies, as well as to change internally by prompting a change in leadership and mentality. However, there are also certain inhibiting factors. They are identified in the current management practices that are driven by short term financial gains. Furthermore, internally Philips suffers from a lack of experience and investment initiatives regarding a circular economy. Although there are developments in this direction, they are less rooted in the organization itself and more dependent on the preferences of chief officers. In regard to practical matters, the benefits of a circular economy are difficult to measure because sustainability assessments are not internationally institutionalized.

### Motivation to change business practices towards circular economy

This case study highlighted a strong motivation to change existing business practices towards more circular ones. In particular, “Philips Lighting, with a clear strategic decision to go for further services in lighting, embraces circular economy approaches” (Interview P6). The Philips Lighting case study illustrates that motivation for change depends on the internal leadership and contextual settings. Based on analyses of interviews and WMATA documents it is argued that various motivational elements for circular economy prevail on both sides (see Table 23).

WMATA (public procurer)	Philips (supplier)
Cost reduction	Financial aspects
Lack of technology and service know-how	Resource efficiency
Hassle free solution	Competition
Interest in upgrades and replacements	Response to public procurers’ needs
Image and reputation	Short term focus <sup>23</sup>
Sustainability targets	Sustainability performance
Accountability to citizens	Added value of circular economy

Table 23 List of motivation elements to change business practices towards circular economy in WMATA deal (Source: Author)

<sup>23</sup> It is very difficult for suppliers that offer long-term products to be evaluated based on short-term benefits.



As previously mentioned, the main motivation trigger for WMATA to change existing business practices was the cost reduction. Philips was able to provide the energy reduction guarantee (in kWh) and the best solution to WMATA needs. WMATA sustainability team was neither able to persuade their technical team to accept the risks of switching on to a new lighting technology, nor to trigger them to perform maintenance themselves. In other words, lack of technology and service know-how led to the inquiry of a hassle free solution. As energy consumption sources for financial savings, WMATA showed interest in upgrades and replacements of existing lighting infrastructure. WMATA as a public agency complies with their sustainability targets and retrofit of lighting system is identified as a way to reach those targets. Lastly, WMATA is interested in changing because their job is to help the region to be more sustainable by providing efficient and effective transportation that ensures safety (Interview W2).

Philips is interested in circular economy mainly because of its financial aspects and resources related risk. A circular economy as a business model offers a better resource efficiency and market position. Companies that deploy circular practices (maintenance, reuse, refurbishment and recycling) have a better control over their supply chain and better sustainability performance. Public procurers with their accountability to citizens are becoming interested in a circular economy which results in immediate market response from suppliers. A circular economy solves the issue of short-term benefits by allowing companies like Philips to offer long-term products and be evaluated accordingly. Another reason why Philips is motivated to change business practices towards a circular economy is the added value of it: reduced waste, improved resource productivity, material cost savings, creation of new markets and products, security of supplies, reduced gas emissions and environmental impacts.

### Value proposition and value creation



*This high efficiency LED lighting overhaul not only means increased safety and visibility for riders, but also a 68% reduction in energy consumption at these facilities.*

*Richard Sarles, CEO WMATA*

Every stakeholder in circular economy looks at the value proposition from its own point of view. Suppliers want to keep the ownership because they want to keep on selling services. This is due to the character of services. “Service is something that is very flexible in terms of value, but both sides need to acknowledge it” (Interview P6). As certain elements of this deal beyond core competences of Philips, it was necessary to form strategic partnerships with installation and maintenance company (Weaver Cook), measurement and verification company (Green Generations Solutions) and smart controls company (LimeLight controls). For WMATA, energy savings are very important, so Philips responded by providing a flexible value proposition that can change according to technology developments. A value proposition that was delivered to WMATA addressed certain focal areas (see Table 24).

Unique lighting designs	Financial model
Product reliability and life expectancy	Maintenance and safety
Energy efficiency and sustainability	

Table 24 WMATA value proposition focal areas (Adapted from: Philips, 2013b)

Philips provided WMATA a unique lighting design based on characteristics of each garage (Philips, 2013a). These designs had a specific constraint. This implies that the installed lighting products had to be manufactured within the USA. The products that Philips installed are manufactured in Philips's facilities located in San Marcos, Texas. These products were tested by Philips engineers for their reliability and life expectancy. Due to features of this deal, it is in Philips's best interest to extend the products' life time. The WMATA's RFP was indifferent to the type of the technology that will be deployed, as long as it generates energy savings and provides functional light at all times (WMATA, 2011).

Prior installing new lighting solutions, Philips established the baseline and current energy costs. This was done by directly measuring power consumption of the current lighting system at each garage for a minimum period of six weeks (Philips, 2013b). The WMATA required Philips to submit the audited baseline of the existing wattage consumption and energy costs (Philips, 2013a). Based on the characteristics of new lighting solution and controls, Philips estimated a 68% annual reduction in KWh (WMATA, 2013b). A lighting system of Philips had to meet the lighting criteria set by WMATA (WMATA, 2011). Once then installation is complete and verified WMATA will commence with 20 semi-annual payments to Philips Lighting. As indicated in the solicitation, WMATA required financing that is covered by energy savings (WMATA, 2011). So this type of financing is not a Philips Lighting's invention but a necessary requirement from WMATA.

Philips claims that the new lighting solution will ensure that WMATA's customers feel safe due to maintenance and technical characteristics of the products (Philips, 2013b). There are still no credible measurement and verification data to substantiate this claim. A customer safety can be, to a certain extent, related to better quality of light, but other safety aspects should be properly and fully addressed as well. As part of the value proposition Philips provided a 5 year warranty that covers all installed components (WMATA LaaS case study, 2015). It is unclear why a warranty period is not equal to contract period, i.e. 10 years. The warranty period provided by Philips could depend on the estimated lifetime of installed products but it should be further elaborated in the communication with procurers. The fact that responsibility for service and products is on Philips – results in increased concern about product life cycle, durability and end-of-life strategies.

### Value capture

Value in this deal is captured with continuous monitoring of the system over the contract duration, ensuring that the system is running optimally and making any necessary adjustments that can help WMATA better serve its customers (LED inside news report, 2014). A novelty of this deal is also the financial model as introduced in the request for proposal. WMATA wanted to avoid any upfront cost while the operating cost needed to be covered by energy savings. Financial insights into WMATA deal reveal \$2 million savings in energy and maintenance annually (WMATA, 2013b). "In addition to energy savings, the contract also includes the maintenance of the lighting system during the contract duration. This will allow deployment of resources to other operational and maintenance needs by redirecting approximately \$600,000 annually in labor and material resources" (WMATA, 2013b). By meeting WMATA's financial requirements Philips enabled them upgrade their infrastructure without long term impact on capital and operating budgets (WMATA, 2013b). Although Philips calculated direct and indirect costs of the proposed lighting solution, economic impacts that are related to WMATA values are not taken into account (e.g. authenticity, city branding, safety and security). In circular economy, more emphasis is needed on potential revenues of the total solution.

### *The service model and circular economy value capture for Philips*

The service model gives Philips a vested interest in reducing the energy consumption and prolonging the lifetime of the lighting solution. The service model includes circular economy building blocks. After reflecting on the value capture from WMATA's perspective, it is relevant to point out elements of this deal that resulted in the value capture for Philips (Philips Professional Lighting Solutions, 2012):

- Light as a service is enabled with maintenance paid for by projected energy savings.
- A new business model that shifted from selling products to a 10-year performance contract.
- There is a possibility for another 10 year contract extension or collaboration on future projects to meet specific sector needs.
- Collaboration has resulted with co-creation with the customer to provide a state-of-art lighting solution.
- Smart design enabled easy maintenance, durability, reparability and forward compatibility of products.
- WMATA deal is a flagship lighting service contract which changed the way Philips sells (shift from price to value).
- WMATA deal is a flagship for the Philips Circular Economy program.
- This deal positions Philips as a market leader in sustainability and as a highly credible LEDs provider.
- This deal serves as a template for other circular economy service projects and is in line with Philips' sustainability principles.

### **Relationship change elements**

Compared to a linear economy, circular economy offers a better learning curve through tighter relationships and value co-creation (Interview P3). That is exactly what happened in the WMATA deal where performance contracting lead to a better understanding of each other. From the WMATA deal it is highlighted that the greatest value of performance contracts and product service system business models lies in having a long term relationship with a supplier/procurer. "The effect of circular economy will have a huge effect on a relationship between supplier and public procurer only if there is no pressure on cost reduction" (Interview P1). But that is indeed what both parties want. So how can costs be reduced without compromising the relationship change? "In circular economy, cost reduction is possible only on the total cost of value, so throughout the whole value chain" (Interview P1). The value chain changes are possible with partnerships and collaboration. In reality, the relationship between suppliers and procurers depends on "how trustworthy they are, how the contracts are crafted, and how much initiatives they have to keep on working together" (Interview P6). An overview of various elements that changed in the Philips – WMATA relationship is presented in the Table 25 by stating the change element, its related outcome, and the supplier/public procurer quote.

Change element	Outcome	Quote
Benefits and risks	Philips holds more risk in this deal. The risk lies in the performance guarantee which is transferred into a service fee. Without a long term contract, Philips would not have a steady source of income from WMATA. On the other hand, WMATA has no risks and multiple benefits. So, there is a transfer of risk in this deal.	One of the WMATA's goals is having access to "best and newest available technology without the associated risk and maintenance concerns" (WMATA, 2011). "Once the risk is transferred to supplier, there is a possibility to use resources more effectively, because the responsibility of supplier does not lie only in delivery, but also in the life cycle of the product" (Interview P6 <sup>24</sup> ).
Business model	There is a focus on long-term optimization through attractive value propositions. In order to optimally capture economic opportunities, Philips shifted from price to value orientation.	"Moving towards circular economy results in having stronger business models, tighter relationships, and at the end, if suppliers include the risk and cost of uncertainties, they have a more economical offer" (Interview P5). "This business approach should be also applied in our facilities, service parking lots and tunnels" (Interview W1).
Collaboration	The collaboration is on a higher level because of the long term relationship. The knowledge sharing is channeled through education and training provided to WMATA.	"Suppliers and procurers are so interdependent and correlated that one cannot be successful without the other (Interview P1). "Philips was very good in understanding our goals and objectives" (Interview W2).
Contract	11 years (1 year for installation; 10 years post-installation), possible extension of 3 years without RFP, end-of-contract conditions include end of term residual value, end-of-life strategies, agreements on service levels, risk insurance, performance contract, roles and responsibilities clearly stated.	"WMATA contract clearly depicts obligations of each party as to avoid misunderstanding and potential conflicts" (Interview P9). "We wanted it to be long enough [the contract] so the vendor would have the benefit of being able to get operating experience, become more efficient and capable" (Interview W1).
Financial model	Hassle-free solution & no upfront costs for WMATA, 20 semi-annual payments from WMATA to Philips Lighting, payments are covered by energy savings (on Philips balance sheet financing)	"Any solution that increases our costs is not sustainable because it is passed on to our customers, either in reduced service or lack of investment somewhere else (Interview W2).

<sup>24</sup> Refers to Interview list's numbers at page 8.

Sustainability focus	Supplier was not asked to go beyond energy savings. There is no quantification of soft benefits while social and environmental assessments were not required. The focus of WMATA is on economic (financial) benefits. Although Philips had to comply with sustainability targets of WMATA, it is no clear why other elements, other than energy use, were not addressed.	“WMATA did not ask for social and environmental assessments” (Interview W1). “It was clear that the way we were going to make the sustainability projects attractive within the agency was to make them economically attractive” (Interview W2).
Long term oriented relationship	Co-creating the most value together, difficulty is in ensuring a fair competition between different suppliers, legal requirements	“The seed for a better supplier – public procurer relationship is to look beyond short-term horizon and recognize that the most value will be created by having partnerships” (Interview P5).
Risk management	Responsibility of the program manager, all stakeholders participated in the risk identification and analysis process, project team carried out risk management and mitigation services, includes assessment of severity & controllability	“For WMATA deal there were over 400 pages on risk management only” (Interview P3). The major risk categories for WMATA deal are: financial, resource, schedule, technical, management, communication, operational, political and organizational (Philips, 2013b). “Maybe they [Philips] took a risk, but this was a valuable solution for us” (Interview W2).
Roles and responsibilities	Suppliers have more responsibilities, suppliers have the product ownership - incentives to make things durable, Philips is responsible for a 48 hour response time and energy monitoring	“In order to optimize, whatever service is offered, suppliers need to be aware that all the responsibility is on them (Interview P7).
Products services systems value proposition	Market differentiation, higher margins, continuous cash flow, hassle – free solution, reliability, difficulties with service fee quantification, 13 service technicians are replaced by wireless control system, instead of 30 different fixtures new lighting system has only 6 fixture types (optimization for servicing)	“In the lighting business, Philips has no other alternative but to focus on service business. Being faced with low margins, strong competition and short-term boost in sales. If we don’t have a service proposition, we are out of the business” (Interview P2).
Tendering	No instant gratification, no focus on lowest cost, laws need to be adjusted, performance based contracts, sustainability – energy savings as a criteria, lengthy decision making process	“Tendering needs more flexibility, because often a tender will specify under which conditions you deliver the solution, but it does not specify the problem (Interview P9). “The decision making process took so long because of lack of familiarity with a deal like this on both parts” (Interview W1).

Transfer of ownership to supplier	Procurer avoids ownership risks, supplier designs and installs durable products, product life cycle strategies	“We decided that the performance contract approach would be the best approach because we could give the responsibility and ownership to a vendor to provide lighting” (Interview W1).
Transparency	No misunderstandings between parties, transparent tendering process – open to public	“Transparency is essential to remedy trust issues” (Interview P9). “It is very important for us to be as transparent as possible” (Interview W2).
Trust	Incentives to work together, firm agreements, better understanding of needs and demands, money and effort savings	“They only way we can design a customer out of circular economy is with trust. We have to convince them that it is easier, cheaper, better value and lower risk” (Interview P9).

Table 25 WMATA and Philips relationship change elements due to circular economy (Source: Author)

## 5.2. Application of sustainability assessment model on WMATA

The purpose of this subchapter is to compare sustainability impacts of service and product based value propositions as to challenge the sustainability claims the framework of a circular economy proposes. To avoid misunderstandings, one thing has to be clear: This study is not comparing the old lighting system WMATA used to have with the new system provided by Philips. The idea is to compare sustainability impacts of the new lighting system by having different maintenance and waste management practices. In this way, unbiased effects of a circular economy can be revealed. In order to assess the WMATA deal on sustainability impacts, the sustainability assessment model, as designed in Chapter 4, is applied. The first step of the assessment model is to set goal, scope and functional unit. Along these lines, the goal is to compare the sustainability impacts of a single lighting product with different maintenance and end of life scenarios. The scope and system boundaries are set on use and end-of-life phases since the main differences between product and service based value propositions are identified in these phases. At last, the functional unit is set to 20 years of services as an outdoor LED lighting luminaire. Despite the fact that the performance contract in the WMATA deal is signed for 10 years, this study required to take a longer time span as to identify the effects of a circular economy (in particular waste management).

Since the WMATA deal is still in the installation phase there is no real-time available data for use and end-of-life phases. That is why scenarios had to be created. Initially, 6 scenarios were considered and analyzed for the application of sustainability assessment model. The varied on the frequency of technology upgrades and module failure approaches. After consultations with Philips Lighting’s engineers and sales employees in USA, the final choice was to apply a sustainability assessment model on two scenarios (see Table 26). These two scenarios are most probable outlines for service and product based value propositions. On this wise, the scenarios are:

### I. WMATA owned and operated – linear.

In the first scenario the customer holds the ownership and is responsible for maintenance and end of life strategies; there is no performance contract; products are bought and once one lighting module fails the whole product is replaced. After 10 years all lighting fixtures need to be replaced since the product’s useful life expires.

## II. Philips owned and operated – circular.

In the second scenario Philips, as a supplier, has the ownership over the lighting system. The system is maintained by multi-skilled operators and product useful life is extended. When one lighting module fails, it is replaced with a single module, which reduces waste. Furthermore, in the period of 20 years partial technology upgrades take place every 5 years. For example, the amounts of products that fail between year 1 and 5 are replaced with available products from year one, while the products that fail between year 5 and 10 are replaced with technology upgraded products available at year 5.

Scenario	Product owner	Module fail	Value proposition	Technology upgrade	EoL strategy
Linear	WMATA	Take out product	Lighting products	Full at year 10	Recycling-35% <sup>25</sup> , energy recovery-12% and landfill-53%
Circular	Philips Lighting	Take out single module	Lighting products, services, dynamic and connected lighting, smart controls	Partial upgrades every 5 years	Refurbishment <sup>26</sup> , recycling-80%, energy recovery-10% and landfill 10%

Table 26 The WMATA scenarios characteristics (Source: Author)

Each LED light fixture type consists of the following primary components within the housing: circuit board, electrical driver, and controls. The average life of each of the primary components varies. The Philips system includes interior and exterior lighting of the parking garages and will include site-specific systems as well as modular design that can be configured to the lighting needs of each garage. An adaptive motion response system and the LimeLite™ wireless controls system allow the lighting system to dim when no one is present and seamlessly increase light levels when a space is occupied – creating a safe environment while achieving even higher energy savings - LimeLite™ contributes to additional energy savings through its wireless control capabilities. In total, the WMATA deal consists of 13.005 lighting fixtures. Instead of 30 different lighting fixtures that WMATA used to have, new lighting system includes only 6 different types of products. Table 27 displays lighting products used in the WMATA proposition and their share in total number of products.

Product	Quantity	% of total product base
PGL075 32LED	10.525	80.9%
PGL081 48LED	653	5.0%
LP32	735	5.7%
LPP2 128LED	226	1.7%
LLPI 48LED	835	6.4%
GP3	31	0.2%

Table 27 The lighting fixtures present in WMATA value proposition (Adapted from: Philips, 2012)

The research assumes that a product which accounts for 81% of the total lighting product base is most relevant to assess for sustainability impacts. Due to time constraints and complexity of data collection and analysis, this research analyzes only PGL075 32 LED products within given system boundaries. PGL075 32 LED fixture comprises 3 modules with different average life expectancies as

<sup>25</sup> More information on the waste management ratios in Washington, D.C. is available at: [http://www.epa.gov/waste/nonhaz/municipal/pubs/MSWcharacterization\\_fnl\\_060713\\_2\\_rpt.pdf](http://www.epa.gov/waste/nonhaz/municipal/pubs/MSWcharacterization_fnl_060713_2_rpt.pdf)

<sup>26</sup> The actual percentage is relative to the refurbishment potential of each lighting module.

based on estimates of Philips Lighting’s engineers (see Table 28). This product has 70 lumens per watt and an output of 5.250 lumens.<sup>27</sup> Detailed product information is available in Appendix 8.

Fixture module	Average life expectancy (yr)
Board	13.7
Driver	21.69
Control	12.56

Table 28 The life expectancy of different modules of PGL075 32 LED product (Adapted from: Philips, 2012)

### Assumptions

Several assumptions needed to be made for the purpose of this analysis.

- **Failure rates.** Since official failure rates, as calculated by Philips Lighting, could not be disclosed due to confidentially reasons, assumptions on failure rates had to be made. Taking reasonable shape and scale factor, based on average useful life of each module, a Weibul distribution of probability density is generated.<sup>28</sup> The failure rates of all three PGL075 32 LED fixtures are presented in Figure 22. Since fixtures have different estimated useful life, so the failure rates differ. These assumptions are verified by Philips Research engineer and therefore considered valid for the purpose of this analysis.
- **Labor wage and fixed cost per intervention.** The labor wage in Washington, D.C. is set to 16USD/hour, while fixed cost per intervention is 20USD. Since product is modular, the time per intervention is always 15 minutes. The same labor wage and fixed cost per intervention applies to both scenarios.
- **Inflation rate.** The inflation rate is 2%, which is used to adjust cost of labor, fixed cost per intervention and material cost throughout 20 years.
- **Price of electricity.** To avoid further complexity, electricity price is fixed to 12 USD cents. In the first scenario, all fixtures are taken out and replaced with new ones.
- **Installation duration at year 10 in WMATA owned scenario.** It takes 0.5 hours for WMATA’s employees for each intervention, while for employees of Philips it takes 0.25 hours (multi-skilled operators). It is already mentioned that in WMATA owned and operated scenario the full technology upgrade of the system takes place after 10 years. For that purpose 10.525 new lighting fixtures have to be installed. It is calculated that it takes almost 658 days for such installation. This is calculated by multiplying number of products with time per intervention and dividing it by number of hours that worker is allowed to work ( $10.525 \times 0,5 / 8 = 657,8$ ). Installation duration in days needed to be calculated as it is relevant for total labor cost of that year’s maintenance.
- **Waste management.** In the first scenario Washington, D.C. average e-waste management rates are taken: 35% recycling; 12% energy recovery; and 53% landfill. In the case where Philips owns the system and deals with waste management the following ratios are assumed; 80% of the product can be recycled<sup>29</sup>; 10% goes for energy recovery and 10% for landfill.

<sup>27</sup> Lumen per watt is a luminaire efficiency measure. Performance of LED board is measured in lumens (how much light is emitted), while the driver’s performance is measured by % of power out vs. power in (how much power is required). This means that PGL075 32 LED has 70 lumens and it produces 75 watts, which results in 5.250 lumens ( $70 \times 75$ ).

<sup>28</sup> The probability density is a chance that certain module will fail at given time.

<sup>29</sup> If Philips owns recycling process, up to 80% of each product can be recycled because of modular design.



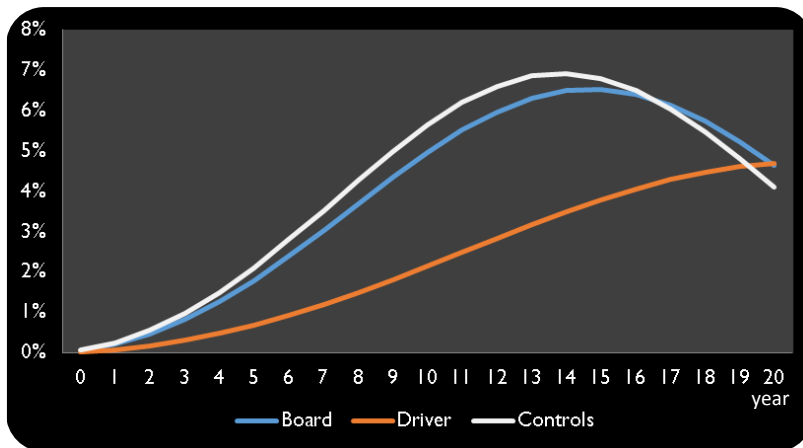


Figure 22 Failure rate assumptions for all three fixtures of PGL075 32 LED (Source: Author)

### Limitations

The initial idea of this research was to use the inventory flow data of PGL075 32 LED and calculate sustainability impacts of both scenarios. All steps in the designed sustainability assessment model would be covered by using one of the available sustainability assessment software (such as CMLCA or SimaPro). However, Philips could not administer a useful form of data for an impact assessment (inventory flow data or bill of material for PGL075 32 LED). Without knowing product material composition and associated weight, it is impossible to derive any software based impact assessment. To some extent, secondary data from available inventory databases can be used, but the focal point of every sustainability assessment remains primary data. Given these limitation, the sustainability assessment model could not be fully applied to the chosen product. The researcher was compelled to scale down its ambitions and withdraw from pursuing sustainability indicators and impact assessment categories. Rather, results relate to:

- Material costs (economic impact)
- Labor costs (economic impact)
- Electricity costs (environmental impact)
- Waste management (# of products that go to waste – environmental impact)

The relevance of such representation of results relates to identified priorities of WMATA. “The sustainability aspects of this deal were economic savings and energy efficiency – which results in carbon reduction” (Interview W1). From this statement, it is clear that WMATA’s priorities are cost savings (material and labor costs) and energy use (energy costs). The environmental and social impacts were less relevant which is substantiated with the following statement: “We were not going to be successful if they just had social or environmental benefits [...] it would not work if there were no economic savings” (Interview W1).

### Results

The results of the analysis are the following: In terms of material and labor costs, scenario 2 (thus Philips owned and operated) is cheaper for 37.5% (3.5 million USD). The total labor and material costs in scenario one are around 9.3 million USD, whereas in scenario 2 around 5.7 million USD (see Figure 23; and Appendices 9 & 10 for calculation details). The WMATA owned and operated scenario is less affordable because the whole lighting system is replaced with technology upgraded one at year 10, which results in increase of material costs. However, Philips owned and operated scenario sources for higher labor costs as a direct consequence of more frequent maintenance and interventions (module per module replacement). Due to upgrade of the entire lighting system at

year 10, the WMATA owned and operated scenario's labor costs are divided into installation and maintenance costs (see Figure 24).

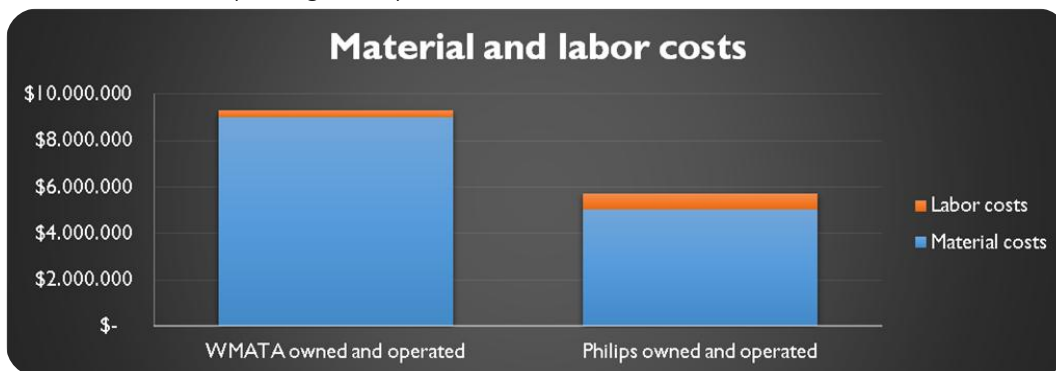


Figure 23 Material and labor costs (Source: Author)

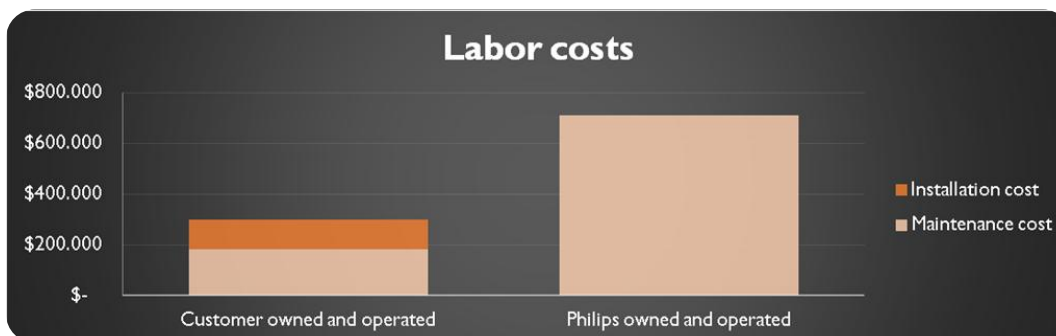


Figure 24 Separation of labor costs (Source: Author)

The only (economic) prosperity indicator that is found relates to number of education hours. In the Philips owned and operated scenario Philips Lighting University provides training and education (unknown number of hours). This study suggests collecting data over a longer period of time and assessing the WMATA deal also on other (economic) prosperity indicators, such as:

- Corruption – Corruption Perceptions Index (#)
- Fair salary (#) – difference between wage level and living wage
- Crime (replacement costs and legal fees €)

In regard to electricity use, the situation is diverse. According to projections of U.S. Energy Information Administration agency, the lumen/watt will increase up to 200 in the next 15 years meaning that the same number of lumens (light output) will cost less (see Figure 24). The WMATA owned and operated scenario, with a complete technology upgrade at year 10, results in significant electricity use reduction. However, Philips owned and operated scenario with its partial technology upgrades every 5 years does not generate such level of electricity savings. Thus, scenario I is 14,3% (or more than 2million USD) cheaper in terms of electricity costs (see Figure 26; and Appendix 11 for calculation details). The electricity use sources for environmental impacts. As the Philips owned and operated scenario requires more electricity it results in higher environmental impacts.

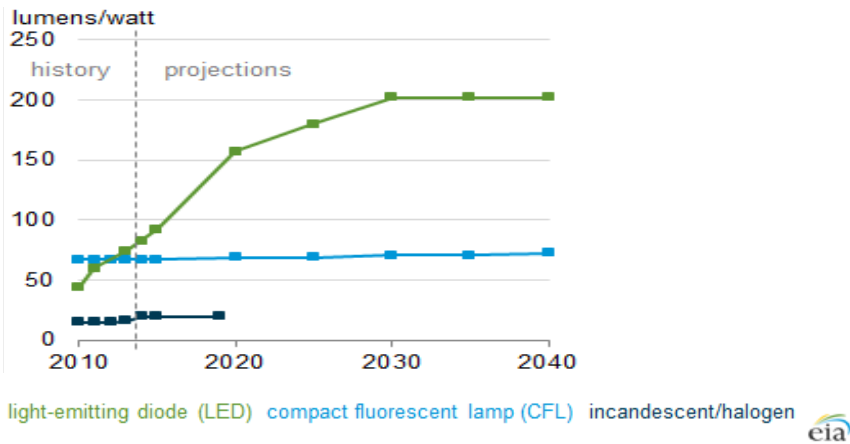


Figure 25 Lumen/watt projections until 2040<sup>30</sup>

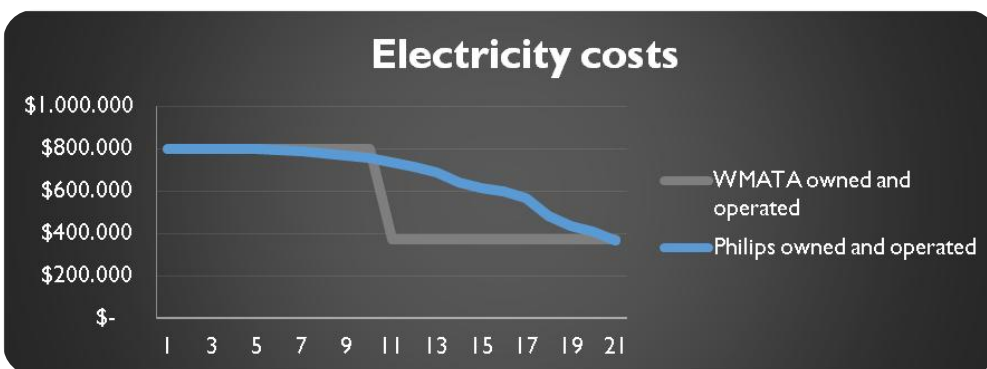


Figure 26 Energy costs for both scenarios (Source: Author)

When aggregating costs of material, labor and electricity, the Philips owned and operated scenario is still more affordable, to be precise it is 7% (1.5 mil USD) cheaper than WMATA owned and operated scenario. By analyzing the costs distribution, it is clear that energy accounts for most of the costs in both scenarios (see Figure 27). That means that the greatest environment impacts during the use phase origin from electricity use. Essential for this study is to run a sensitivity analysis to see how scenarios would react to a change in the main indicator - cost of electricity.

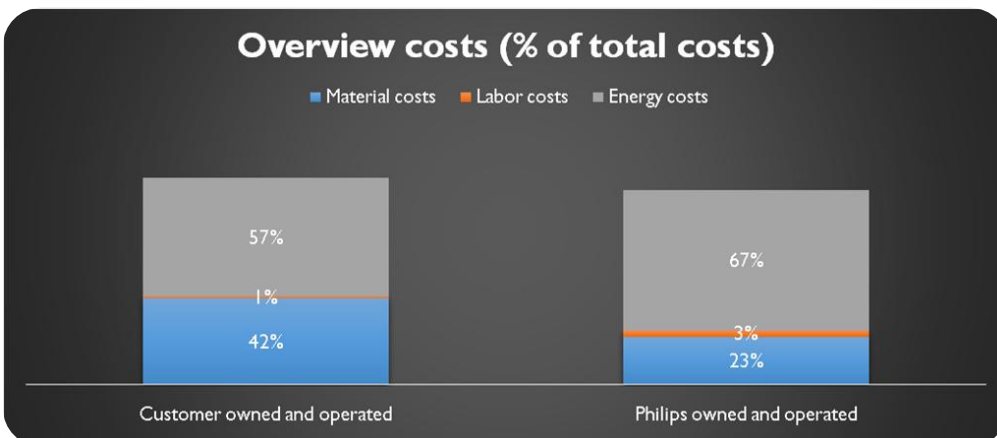


Figure 27 Costs distribution of both scenarios (Source: Author)

<sup>30</sup> More information available at: <http://www.eia.gov/todayinenergy/detail.cfm?id=15471>

In the initial scenarios set up, one of the assumptions related to no deviations in the price of electricity. However, since electricity accounts for the most environmental and cost contributions in the use phase, it is important to show how both scenarios react to change in electricity price (see Figure 28). With an annual increase of 2% in the price of electricity (throughout 20 years), the electricity costs difference between two scenario decreases (from 14% to 10%). It drops off even further (from 17% to 10%) with a steady annual increase of 4% (throughout 20 years). In the situation where electricity price increases 6% on annual bases (throughout 20 years), the cost of electricity is slightly lower (0,3%) in the Philips owned and operated scenario. This is because frequent and partial technology upgrades in Philips owned and operated scenario source for lower electricity cost compared to a single full technology upgrade in the WMATA owned and operated scenario. The results of this sensitivity analysis reveal that WMATA owned and operated scenario is more sensitive to changes in price of electricity (see Appendix 12 for calculation details).

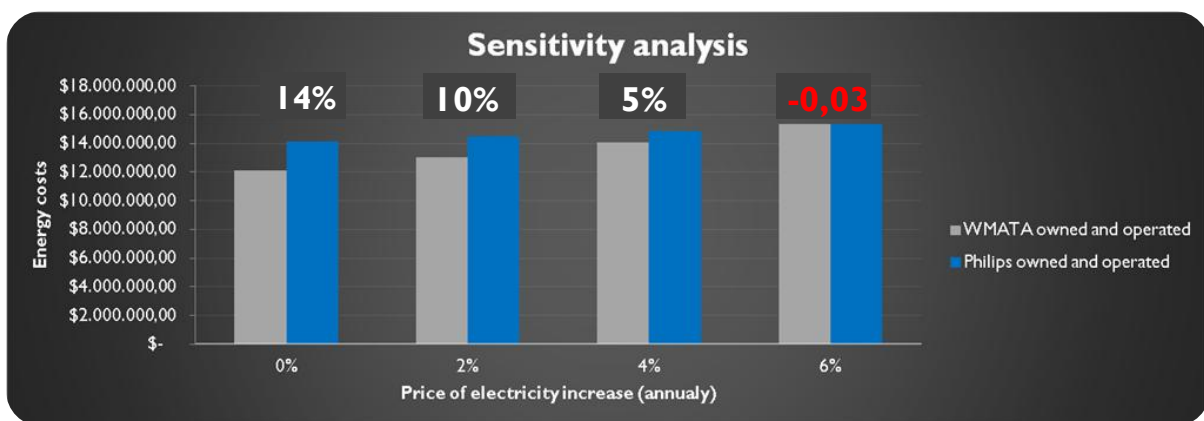


Figure 28 Sensitivity analysis based on the price of electricity (Source: Author)

By applying failure rates of each module and taking into account presented maintenance approaches, the following results are presented. The Philips owned and operated scenario, characterized by module per module replacement, leads to extended products' life. However, WMATA owned and operated scenario is quite different. The product per module replacement and change of the entire system at year 10 results in more than a double waste generated compared to the Philips scenario. In addition, environmentally least sound and most expensive way of handling waste, i.e. landfilling, is higher than the total waste generated in the Philips scenario (see Figure 29). The 80% recycling rate in the Philips scenario significantly reduces depletion of resources in the production phase. The result of waste management scenarios reveal that the Philips owned and operated scenario results in much lower environmental impacts in the end of life phase. In this research, waste is seen as a number of product modules that are replaced, but even better outlook would be to calculate environmental indicators such as climate change, ozone depletion, human toxicity, particulate matter, acidification, eutrophication, land use, land use and depletion of water. This would be enabled by having the inventory flow data for the analyzed product.

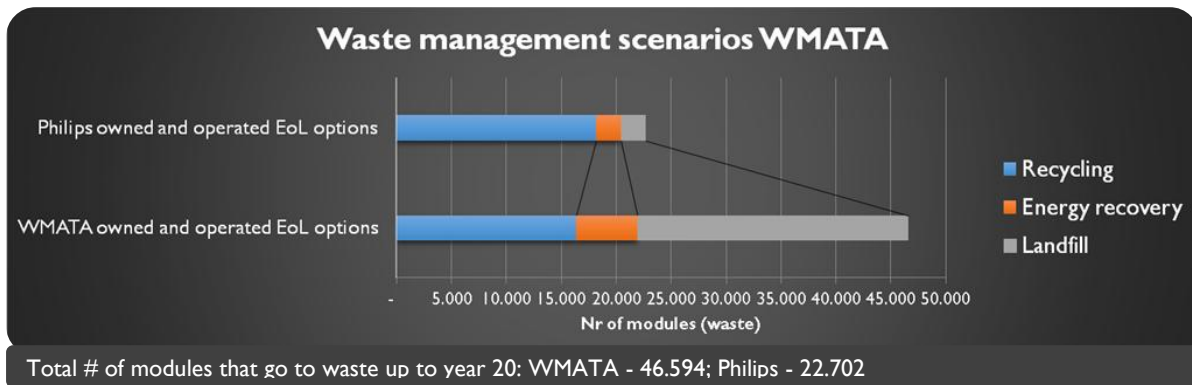


Figure 29 Waste management results (Source: Author)

The social impacts are difficult to calculate for use and end-of-life phase of this product, since WMATA is still in installation phase. Social impacts need to be measured and verified in a longer period of time. Social impacts are very important for public actors as they are responsible toward their citizens. For example, measuring decrease in crime due to better light could contribute to better social conditions. Therefore, this research suggests possible social impacts on which WMATA deal could be measured and used as a proof-point for other similar lighting cases:

- Injuries intensity (#) – number of injuries
- Multi skilled operators (%) - % of multi-skilled operators
- Worked hours (h) – hours of work per employee and monthly average
- Security (#) – number of crimes



This research provided only a partial sustainability impacts assessment of the presented scenarios. The economic impacts (namely combination of material and labor costs for the use phase) are 37,5% lower in the Philips owned and operated scenario. The only (economic) prosperity indicator that is presented in both scenarios is education as training hours given by Philips Lighting University in the Philips owned and operated scenario. When it comes to environmental impacts of the use phase, WMATA owned and operated scenario, with full technology upgrade at year 10, results in 14% less electricity use compared to Philips owned and operated scenario. In other words, the environmental impacts of the Philips owned and operated scenarios are higher for the use phase. Of course, electricity use is not the only environmental impact source that needs to be taken into account, but given the limitations of this research it is the only source that could be addressed. The assessment of the end of life phase is only focused on environmental impacts (economic and social impacts are not addressed). Given the waste that is generated in the WMATA owned and operated scenario (# of products that go to waste) it can be claimed that the environmental impacts of this scenario are disturbingly high. This is due to a low recycling rate (35%) and a high landfilling rate (53%). To what extent circular economy initiates better social conditions is still ambiguous because social conditions could be a part of a company's policies even before the deployment of a service based model.

To conclude, it can be claimed that the effects of circular economy are trivial when it comes to electricity use and labor costs. However, when referring to material costs and waste management the effects are noticeable and meaningful. This study suggests that sustainability impacts of the use phase depend greatly on the products' characteristics. The importance of a circular economy is significant in the end of life phase where superior waste management practices and know-how result in much lower environmental impacts and reflect back to the use of virgin resources (high recycling rates source for less depletion of natural resources).

# CHAPTER 6 DISCUSSION

In this selection, a discussion of key findings in support of both, main and sub-research questions is presented, as well as limitations of the study. For that purpose research questions are revisited. The main research question that is answered in this thesis is the following:

*How does a circular economy affect the relationship between supplier and public procurer, and how can these economic actors assess economic, environmental and social impacts associated to a product service system value proposition?*

In order to support the steering function of the main research question, several sub-research questions were answered:

1. What are the elements of change in the supplier - public procurer relationship caused by circular economy?
2. What is the value proposition of a product service system business model in the context of circular economy?
3. How to design a sustainability assessment model as to reveal economic, environmental and social impacts across product life cycles?
4. What is the added value of sustainability assessment model results for supplier and public procurer?

## 6.1. Discussion of main findings

### Relationship change – from a transaction to a long-term relationship

In linear economy, suppliers' and public procurers' relationship is characterized as transactional with focus on cost optimization (Ellen MacArthur Foundation, 2014). The value is created by suppliers who are responsible to provide products with certain specifications and limited guarantee on performance. Hence, products are optimized for the moment they are sold while supplier's responsibility is diluted. Several disruptions source for motivation to change existing business practices and make the transition to a circular economy. The major incentive for companies to engage in this novel approach, as suggested by the literature review, is the opportunity to build a much closer and direct relationship (OECD, 2012). The analyzed case study revealed that both parties are less interested in the relationship and more in the financial implications of the deal. The literature claims that public procurers are sensitive to sustainability which is reflected in their needs and affects supplier's offer (Arrowsmith, 2004; Li & Geiser, 2005; Elder & Georghiou, 2007; Walker & Brammer, 2009). It is true that WMATA was influenced by various sustainability targets, but their scope of sustainability is quite narrow. The WMATA's sustainability initiatives are energy efficiency and financial savings driven while their supply chain activities are concentrated on waste which are far from the complete sustainability focus. Therefore, Philips had neither obligations nor incentives to address social and other environmental elements of their value proposition. The motivation triggers for WMATA to enter this deal are reputation gains, lack of technology and maintenance knowledge.

The analysis of Philips Lighting case study revealed that having elements of circular economy in the value proposition affects certain elements of the relationship between supplier and public procurer. In line with transition to circular economy and performance contracting the literature review outlined shift in ownership, responsibilities and risks between parties (Steane & Walker, 2000; Erridge & Greer, 2002, EMF, 2013). The analyzed case study confirms these claims since the

WMATA deal is characterized by performance and financial risks on the supplier side as a result of novel solicitation requirements and performance guarantee. The WMATA deal outlined public procurer's need to buy-off risks and unlock resources generated by energy savings. Having ownership over the installed lighting system created an incentive for Philips to facilitate end-of-life strategies and design for longevity. WMATA was tendering with multiple suppliers, but the final decision was based on the value rather than on price. A 10 year performance based contract states that Philips is responsible to supply various services (proactive and reactive maintenance, upgrades, controls, monitoring, financing, products disposal), while WMATA has to provide 20 semi-annual payments which are covered by energy savings. Although circular economy puts pressure on altering current procurement and legislative procedures, the WMATA case study disclosed issues related to internal familiarity with performance contracting. This resulted in a lengthy decision making process that makes the efficiency of the procedure debatable and calls for new lean processes. Compared to internal barriers WMATA experienced less difficulties with external legislative and legal rules.

Focusing on services, instead on products, led to a redefined relationship between Philips and WMATA. It influenced the level of engagement and the focus of the relationship itself. When it comes to communication, trust and transparency there is a gap between literature and case study findings. The literature review claims the importance of these elements in a circular economy, but the case study revealed divergent perspectives. Although possible suppliers were fully informed of WMATA's requirements in the solicitation they issue, WMATA failed to provide any kind of information during the lengthy decision making process. Also, the interest in trust and transparency, towards each other, is not fully articulated by both parties.

#### Circular economy value proposition – moving towards the total value of ownership

The literature review outlines the importance of service provision, product's life-time extension, reuse, repair and recycling (Lindic & Silva, 2011, OECD, 2012, Bocken et al., 2014, EMF, 2014). In addition, literature emphasizes the gap between orientation on economic return and sustainability concerns (Tukker, 2004; Grönross, 2008; Lepak, Smith & Taylor, 2007; Bocken et al., 2014). This Philips Lighting case study confirms these connotations as the value proposition of WMATA consists of maintenance services, performance guarantee, energy savings, reuse (reuse of parts increases average profitability of lighting industry) and recycling (closed loop recycling is an important lever of risk management). Although a product service system business model generates great potential for a sustainable change the value proposition of Philips included only estimation of energy savings. The new lighting proposition offered WMATA a high lighting performance and energy efficiency - 68% more efficient than previous lighting system (Philips 2013b, Philips 2015). This estimation of energy savings will be verified by WMATA once the installation is complete. The comparison of old versus new lighting system is not in the focus of this study due to unambiguousness of possible differences. Instead, this study decomposes a new value proposition and puts it into perspective of the best available competitor in the market. Furthermore, this research omitted to confirm the energy savings claims of Philips but chose to confront them with energy savings of the exact same product with a different maintenance scenario. The sustainability impacts and end-of-life strategies are only partly addressed. Clearly, more progress needs to be made in regard to social and environmental impacts, second hand lighting market, lighting fixtures refurbishment and part harvesting. The analysis of the case study reveals that a product service system was not fully deployed as it failed to address environment, customers and local community.

A circular economy value propositions calls for collaboration with credible partners, as in the WMATA deal. Collaboration is very important for services as it generates more influence and impact, and results in transparent long-term relationship (Black, Akintoye, & Fitzgerald, 2000; Seuring & Müller, 2008; Vermeulen & Seuring, 2009; Eriksson & Westerberg, 2011). For years, lighting industry has been looking at cost of lighting from the total cost of ownership perspective. But the next step is to look at the value of lighting beyond cost of ownership. In addition to energy savings and maintenance, other values need to be captured, such as safety, security, good air quality, low carbon footprint and livability. If Philips would link these values with the circular economy outcomes, it would be possible to include them in the value proposition. In that way the shift from the total cost of ownership to the total value of ownership would be made. A circular economy has the potential to achieve this differentiation, but not without customer acceptance, mindset change (both service provider and customer), cross-chain and cross-sector collaboration, and enabling legal framework. Both suppliers and procurers need to adjust their habits and shed traditional ways of thinking about value, ownership and product use.

#### Sustainability assessment model - substantiating the sustainability claims

Due to ambiguity of manifold sustainable development initiatives, there is no consensus on terminology, data and methods of measurement (Weidema, 2006; Valdivia et al., 2011, Sala et al., 2013a). Aiming to contribute to the existing sustainability assessment methodology, this research suggested an integrated sustainability assessment. The purpose of this model is to establish and reveal social, environmental and economic impacts throughout the product's life cycle. To this end, existing theory and methodology of LCSA is adapted. Acknowledging different sustainability focus streams, this research chooses an impact oriented approach and suggests using only sustainability indicators that result in impacts of a certain product/supply chain activity. In other words, the indicators that address compliance (for example presence of an anti-corruption policy) or source of impact (for example community involvement and development) fail to have an assessment character and therefore are not in the focus of this study. Finding sources for environmental indicators was rather easy because they are standardized, while the choice of social and economic/prosperity indicators differed per each analyzed sustainability initiative. This study sets focus on workers as a stakeholder group in social indicators as they are directly affected by economic activities during the maintenance phase. The economic indicators are chosen based on their relevance for the decision maker over the full life cycle (in this case the decision maker is supplier as it bears the risks of ownership and full responsibility for the performance). Since supplier's costs do not address the global costs it was important to introduce the economic prosperity dimension. Therefore, the economic indicators embody two categories: organization's operating costs (labor and material costs) and direct economic prosperity (corruption, income distribution, crime and education). Evidently, the literature offers different perspectives on the choice and inclusion of sustainability indicators, but also on other elements of a sustainability assessment model: impact assessment methodology, software tools, life cycle inventory databases and life cycle impact databases (Guinée, 2002; Goedkoop et al., 2009; UNEP/SETAC, 2011; Boër et al., 2013). The initial idea was to apply the designed sustainability assessment model on the WMATA deal as to establish differences between a product-based and product service system value proposition. For that purpose two scenarios are analyzed: (1) WMATA owned and operated (lighting system) and (2) Philips owned and operated. Due to lack of inventory flow data the researcher had to scale down its ambitions and withdraw from pursuing sustainability indicators and impact assessment methodologies. Instead, the results relate to material cost, labor cost, electricity use and waste management. This study revealed a gap between the data availability of companies and the opportunity to perform a full LCSA.



The results show that the WMATA owned and operated scenarios includes higher energy savings, which means lower environmental impact in the use phase. This scenario, with a complete technology upgrade at year 10, results in 14% less electricity costs compared to the Philips owned and operated scenario. But a full technology upgrade at year 10 also results in 56% higher material costs which reflect the need for more virgin materials. With respect to labor costs, Philips owned and operated scenario sources for higher labor costs (68% higher than in the WMATA scenario) as a direct consequence of more frequent maintenance and interventions (module per module replacement). However, with respect to the end of life phase, having no skills for modular remanufacturing, results in extremely high waste level generated by the WMATA scenario. This scenario sources for 49% more waste than in the Philips scenario. What is even more disturbing are WMATA waste management options: recycling 35%; energy recovery 12%; and landfill 53%. The amount of material that ends up as landfill in the WMATA scenario is for 9% higher than the total amount of waste generated in Philips scenario. That means that modular design, multi-skilled employees, refurbishment activities and part harvesting are greatly contributing to sustainability claims of circular economy. The results of this partial sustainability assessment imply that environmental impacts of the use phase depend, to a greater extend, on product's characteristics rather than on maintenance scenarios. In other words, the greatest environmental impact in the use phase comes from electricity use which depends on the lighting technology. This study reveals that circular economy's contribution to sustainability is related to end-of-life strategies and product's design phase.

In shortage of on-site data this research resides on many assumptions. Although these assumptions were approved by Philips, the relevance of the study would be on a higher level if the real data was available. Even if companies are driven only by financial aspects, they should not forget to deliver and monitor sustainability performances. Sustainability assessments need to be applied on some running cases which will help to develop sustainability practices. In order to prove that a new lighting system is better in terms of PPP it needs to be measured and verified on a longitudinal scale using real data. For that purpose, Philips needs extensive data collection, ranging from pre- to post-installation data. Right now, Philips's practices focus only on the environmental assessment. So every time that a new LED system is deployed, it is compared to a previous one. As data is scattered and difficult to access, the biggest challenge in doing a sustainability assessment poses data collection. The data collection problem can be mitigated if people understand the usefulness of delivering supply chain data. By having comprehensive insights of impacts, Philips can identify value leakage points and modify them. Also, having quantitative and qualitative data systems can support transition to circular economy by communicating multiple benefits to leaders and decision makers and make them aware of the future that circular economy is capable to create.

#### [Sales approach - communicating the circular value](#)

The literature review and case study findings suggest that fear, resistance to change and lack of information are major internal drawbacks for the transition to a circular economy (Stahel, 2010; Bilitewski, 2012; EMF, 2013). The study identified lack of interest on the public procurer's side to require disclosure of sustainability impacts. Rather, the focus remains on the financial perspective of the deal and energy savings. Such situation has repercussions on the need to capture and communicate a circular economy added value on the supplier's side. Despite of the financial focus, the literature review suggests that suppliers will be tested on their ability to proof point better sustainability results of their value propositions (Sudarsan et al., 2005; Schmidt & Schwegler, 2008; Stark, 2011). Information is going to be a key and critical element of decision making. In moving from compliance to performance processes suppliers needs to build a better communication platform for

decision making (Seuring & Müller, 2008; Müller, Vermeulen & Glasbergen, 2009; Carter & Easton, 2011). This research proposed a circular economy communication tool that can support the sales approach (see Figure 18). Namely, it consists of three elements: the value proposition composition; the cost-benefit analysis; and the added value. The first part informs a customer about the possible contract duration, products that can be installed and display the available service packages. The input for the first part is taken up for a cost and benefit analysis of each contract year. The customer is introduced with total benefits, investments, profit before tax, taxes, profit after taxes, net present value, return on investment and months to payback each year. The suggested elements of a CBA are, by this research, assumed to be relevant but what to exactly to include is open for discussion and depends upon how much a supplier is willing to disclose. Finally, the added value of a circular economy is calculated, based on value proposition elements. Depending on the customer interests and level of engagement, environmental, social and economic indicators can be chosen. Results are presented as total impact, but the breakdown per product life cycle phase is also possible, as to see which phase sources for most impact.

To conclude, information about materials and processes leads to a better decision making. But, options have to be made visible, comparable, and easy to communicate. There is a growing public pressure to be transparent and share information (UNEP/SETAC 2009). This study assumes that communicating circular economy value in presented way cycle can increase awareness of sustainability reporting, support sales approach, generate trust, and lead to improved supplier - procurer relationship. In order to test and validate this assumption an empirical application of the presented communication tools is needed.

## 6.2. Limitations

Despite all the efforts, some limitations rest upon research results. First, the literature on circular economy is scarce, while reflections on supplier – public procurer relationship change are extremely limited. As to address this limitation, insights from other theoretical fields, in particular sustainability, were used to support the research.

Second, because of the time restriction and complexity, only a supplier – public procurer relationship is analyzed, addressing the tendering and installation phase of the deal. This can be remediated by focusing on other types of relationships and longitudinal research.

Third, perhaps the research results are too narrow to do the justice to the complexity of theories used, as the empirical part stems from a single case study. However, it does highlight the importance of continuous research on the development of a circular economy. A single case study does not generate a high level of generalizability, but as the research field is still in infancy, it is necessary to contribute to the existing knowledge and insights. Future research can diminish this limitation by focusing on multiple cases and comparing them.

Furthermore, as interviewees were intentionally chosen in relation to the insights they have on the WMATA deal and engagement in a circular economy, there is a possibility that the results of this research could have varied if other interviewees were chosen. The author believes that, in terms of validity, the chosen approach did not limit the results.

In addition, this research assumes that both suppliers and public procurer will abide by the signed performance contract (in this case Philips Lighting and WMATA). Potential conflicts and risk management are out of the scope of this research. The same holds also for the analysis of other circular economy pioneers. Both, quantitative and qualitative data for case study is from a Philips

Lighting project. Perhaps, analysis of cases or products from other companies and industries would generate different results. However, the findings in this report cannot be generalized to all lighting companies, neither to all procurers. There might be differences between public and private procurers.

Finally, with regard to the quantitative data results of this research, there are some things that need to be taken into account. A final limitation relates to the reported LCSA results choosing one Philips Lighting product used in the WMATA deal. Due to complexity and time constraints a single product was chosen for the application of the sustainability assessment model. Moreover, the scope of this study is on the use and the end-of-life phases, as it is believed that these phases source for differences in sustainability impacts between product based and product service system. Important to mention is that several assumptions were used in the scenario analysis (fixed cost per intervention, inflation rate, time per intervention and failure rates), while the input for impact assessment step of LCSA depends on the accuracy and reliability of obtained inventory data. This may have affected the outcomes. An amendment would be to set the scope of LCSA to all phases of a product life cycle and assess every single product used in the WMATA deal using on site data.

# CHAPTER 7 CONCLUSION

## 7.1. Conclusion

The most recent developments in circular economy, sustainable supply chain and public procurement theories were confronted with case study insights. This Philips Lighting case study showed that increasing competitive challenges created incentive for Philips to change current business practices and deploy a product service systems business model. On the WMATA, i.e. public procurer side, maintenance and ownership risk were avoided by shift in ownership while costs are covered by energy savings. Therefore the main relationship change elements are identified in the transfer of risks and responsibilities to the supplier. The behavioral change, familiarity with performance contracting and appropriateness of procurement and legal rules are still not in place which made the decision making process of submitted proposals too lengthy. Because of the characteristics of performance contracting and product service business models there is a focus on long-term relationship and collaboration. This study also revealed a shift in benefits to WMATA, namely in no upfront costs, energy and financial savings, a hassle free solution and no waste management commitment. An aspect of relationship change, as identified in the literature review, is disclosure of sustainability impacts and emphasis on transparency and trust. The actors in the analyzed case study failed to fully address these aspects, namely the disclosure of sustainability impacts of a circular economy deal. Certainly, more transparency and clarity are needed with respect to communication of a circular economy value. To that end, this research suggests a three step approach that includes (1) value proposition elements, (2) cost & benefit results, and (3) impact assessment on people, planet, prosperity. To validate the benefits of this communication approach suppliers should apply in the initial contact phase. To further analyze relationship change elements between suppliers and public procurers and develop a circular economy area of study there is a need for longitudinal analysis in different industries.

The potential of a circular economy is not fully realized which impedes with the potential to increase business resilience and sustainable development. Albeit numerous benefits from adopting sustainability strategies across the supply chain, as mentioned in the introduction of this thesis, empirical results support the claim that orientation on financial aspects is still a priority for suppliers and public procurers. A circular economy approach, as applied in the WMATA case, includes orchestrating services and reducing waste. The sustainability claims of circular economy are challenged by comparing impacts of circular and linear scenarios over the period of 20 years in the WMATA deal. This research recognizes circular scenario as marginally more sustainable. That means that sustainability impacts of a certain project depend to a greater extent on product specifications, rather than maintenance scenarios. Therefore, there is a need for modular design and use of recycled materials in the production phase. The effect of product's extended life time, i.e. circular economy, is most relevant in regards to waste generation and recycling rates (which means positive contribution to use of virgin materials).

The struggles with data are remarkable. There are two different narratives in regard to data collection and use. In the answer to WMATA's solicitation it is clear that Philips collects certain product data but the level of detail of data collection and its use remains ambiguous. In order to completely apply the designed sustainability assessment model, it is crucial to have access to inventory flow database for every product life cycle stage. Therefore, Philips should collect the useful form of data (full inventory flow data) and use it to tap the internal information better and translate

it into disclosure of sustainability impacts. It is suggested to re-assess the WMATA deal by collecting and measuring social and prosperity impacts for a longer period of time and using a full inventory flow database for measuring environmental impacts. By taking these actions, a more accurate comparison between service and product based business models can be generated.

### **7.1. Directions for future research**

There are a number of ways in which this research could be taken further. Although the circular economy terminology is a rather new concept, many companies are becoming interested in it. What this research revealed is scarcity of literature on circular economy, so future research on this topic is highly recommended. Definitely more research needs to be done on the contextual analysis in regard to circular economy. In particular, addressing the role of government would provide valuable insights since the current regulatory framework for performance contracting is one of the top barriers. Moreover, as the concept of a circular economy is interesting for businesses, it might be a good idea to advance the end-of-life strategies (e.g. second hand market for lighting products). Paucity of research on this topic calls for further research of qualitative and quantitative nature.

In general, the circular economy relationship change, as a phenomenon, is far from a maturity phase. As the study was limited to a single case study and B2G sector, the future research could study several cases, different temporal character and relationship change focus. Therefore, conducting a research that would compare relationship change at other levels is highly recommended, e.g. B2B and B2C. This would allow for more discussion and possible correlations, since the quest for a general theory of relationship changes caused by circular economy is very elusive. As empirical focus of this research was on the lighting industry, research on other industries is needed in order to establish differences and similarities. Subsequently, another possible area for future research relates to the identity and the mindset change, as a necessary requirement in the transition to a circular economy. To that end, it is necessary to analyze how companies change their identity, as well as organizational learning and culture.

Although this research reflects only on the product service system business model, there are other alternative business models that fall under the scope of circular economy such as circular supplies, resource recovery, product life extension, sharing platform (Accenture, 2014). Generally more research has been done to capture the B2B scope of product service system, while there is a need for empirical studies to address the view of individual customers (perceived advantages compared to alternatives, needs analysis, perception of fixed and variable costs, insights in total life cycle costs, uncertainties, risk, and affordability). For example, investigating the balance of commercial value for companies and added value for customers, as a factor that encourages integration of products and services, would be very interesting.

Furthermore, this paper calls for a deeper empirical work on sustainability assessment methodology. Further research should take the form of longitudinal case studies to track circular economy induced changes throughout the whole product life cycle. Case studies and methodological discussion will help build the knowledge and the practice. In addition, addressing impact assessment from a stakeholder perspective would be highly valuable in the prospect to “improve performance of organizations and ultimately the well-being of stakeholders” (UNEP/SETAC, 2009). The life cycle sustainability assessment literature has succeeded to emphasize the importance of sustainability assessment of products, services and processes. However, accurate assessment is elusive, because most companies either do not understand the importance of LCSA, or do not have the data necessary for such assessment. A comprehensive and unique methodological approach is probably

impossible in the area of life cycle assessment, because of the uncertainties, lack of data and willingness to report in 2nd and 3rd value chain tiers. Despite of the willingness, the main challenge of this research was the quantitative data collection related to WMATA deal, which makes the analysis process time consuming and costly. Further research on data collection challenges is desirable because rules and policies that underlie the flow of materials, information, services and products between suppliers is an important issue. In order to track down value leakage and value creation phases of a product life cycle, data needs to be gathered, analyzed, distributed and communicated. For LCSA to become widely used, it is essential to develop or adjust existing communication schemes, computer models, software tools and databases that are scalable and can easily compare alternatives.

Finally, additional direction of future research should be on performance indicators of a circular economy as to be able to quantify, monetize and communicate the added value. Once the LCSA impacts are known, the next step includes translating the social and environmental impacts into financial values, in order to make them relevant for the decision making process. Added value for each stakeholder is the enabler of a circular economy. If added value can be identified, it can easily be compared with the current model. Soft benefits of a value proposition should also be quantified. Ideally, every impact should be taken into account, but to avoid complexity and confusion, it is better to communicate only the benefits that are interesting for a specific stakeholder.

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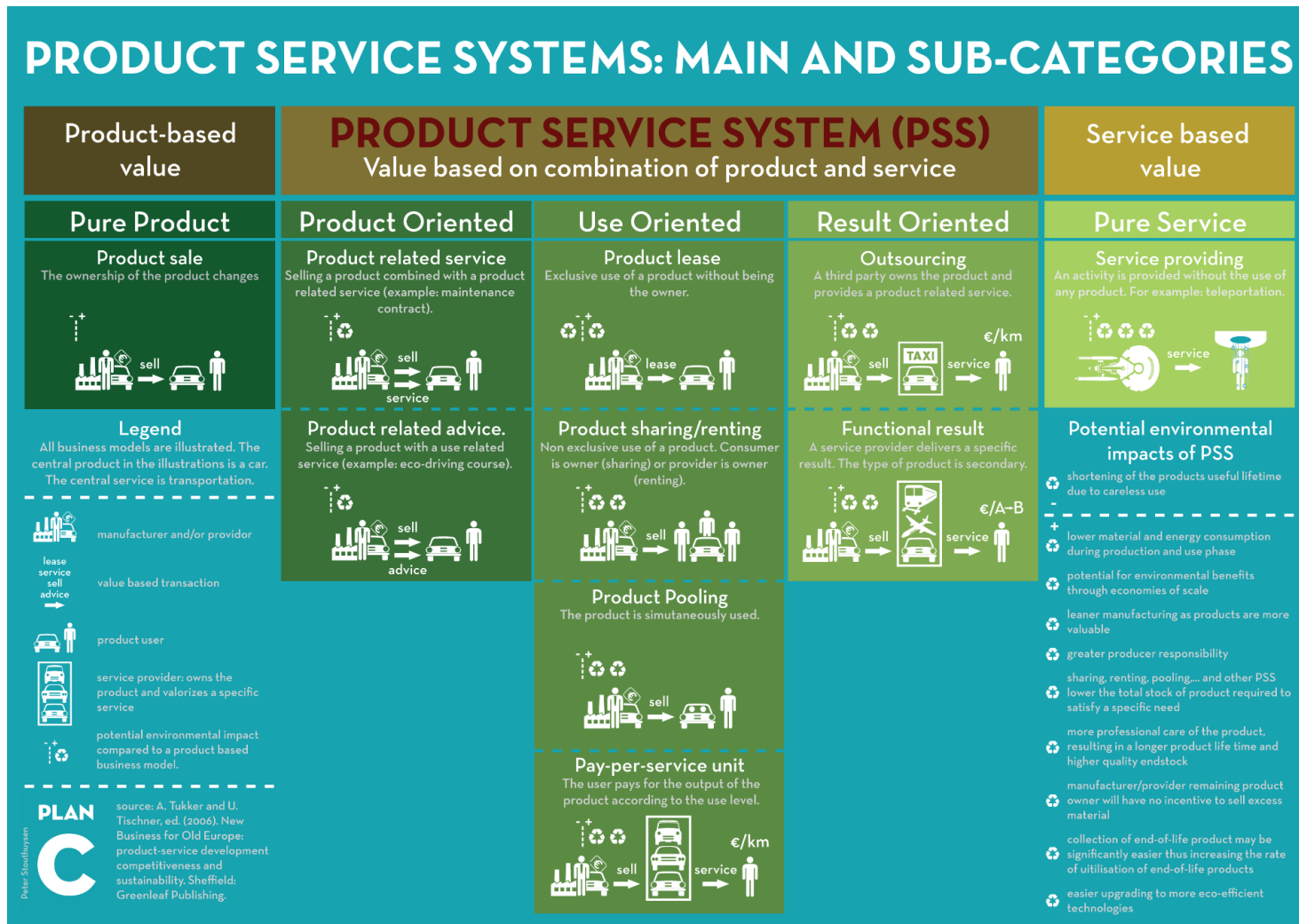
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# APPENDICES

Appendix I Product service systems: Main and sub-categories (Source: Tukker & Tischner, 2006)



**Appendix 2 UNEP/SETAC suggested S-LCA stakeholder impact categories and sub-categories** (Source: UNEP/SETAC 2009)

Stakeholder categories	Subcategories
Stakeholder “worker”	Freedom of Association and Collective Bargaining Child Labour Fair Salary Working Hours Forced Labour Equal opportunities/Discrimination Health and Safety Social Benefits/Social Security
Stakeholder “consumer”	Health & Safety Feedback Mechanism Consumer Privacy Transparency End of life responsibility
Stakeholder “local community”	Access to material resources Access to immaterial resources Delocalization and Migration Cultural Heritage Safe & healthy living conditions Respect of indigenous rights Community engagement Local employment Secure living conditions
Stakeholder “society”	Public commitments to sustainability issues Contribution to economic development Prevention & mitigation of armed conflicts Technology development Corruption
Value chain actors* not including consumers	Fair competition Promoting social responsibility Supplier relationships Respect of intellectual property rights

**Appendix 3 Interview questions**

**Presentation of myself**

- a) *Who am I?*
- b) *What I am doing in Philips?*
- c) *What is the aim of my research and intention of this interview?*

**Interview introduction**

- a) *Inform about the recording of the interview.*
- b) *Guarantee of anonymity.*
- c) *Ask for the permission to quote and disclose the name and position in the final report.*
- d) *Name and position in organization.*

**RQ 1: What are the elements of change in the supplier – public procurer relationship caused by CE?**

1. *How would you characterize the relationship between supplier and public procurer in a linear economy?*

2. What are the triggers and motivation for a supplier to change their business practices towards CE<sup>31</sup>?
3. What are the triggers and motivation for a public procurer to change their business practices towards CE?
4. How are roles and responsibilities shifted as a result of CE?
5. How are risks and benefits shifted as a result of CE?
6. How does CE change the relationship between supplier and public procurer?
  - Co-creation process
  - Interdependence
  - Performance
  - Satisfaction
  - Tendering procedures
  - Collaboration

**RQ 2: What is the value proposition of a PSS<sup>32</sup> business model in the CE context?**

7. There are different models that are suitable for the uptake of CE. One of them is PSS. What should the value proposition of a PSS business model have to be in the context of CE?
8. Where do you recognize the value in service-based business models?

**RQ 3: How to design a sustainability assessment model as to reveal economic, environmental and social aspects associated with product service systems value propositions?**

9. A sustainability model results would meet the information needs related to life cycle costs, environmental life cycles and social life cycles of a value proposition.
  - a) How would you develop this model?
  - b) Which elements would you include?

10. To what extent would sustainability results meet the needs in this changing relationship?

	Low	Medium	High
Communication			
Conflicts			
Information symmetry			
Relationship success			
Transparency			
Trust			

Please indicate one answer per row.

<sup>31</sup> Circular economy refers to an industrial economy that is restorative by intention; aims to rely on renewable energy; minimizes, tracks, and hopefully eliminates the use of toxic chemicals; and eradicates waste through careful design. The term goes beyond the mechanics of production and consumption of goods and services, in the areas that it seeks to redefine (examples include rebuilding capital including social and natural, and the shift from consumer to user). The concept of the circular economy is grounded in the study of non-linear, particularly living systems.

<sup>32</sup> Product as a Service business model provides an alternative to the traditional model of “buy and own.” Products are used by one or many customers through a lease or pay-for-use arrangement. This business model turns incentives for product durability and upgradability upside down, shifting them from volume to performance.

## Appendix 4 Atlas.ti coding report – Final list of code families and their members

See Chapter 2 - Interview data analysis 1/3

### Families: List of Code Families and their Members

Code Family	Codes
CE enablers and barriers	<ul style="list-style-type: none"> <li>• CE transition barrier</li> <li>• CE transition barriers</li> <li>• CE transition enablers</li> <li>• Circular economy</li> <li>• Linear economy</li> </ul>
CE results	<ul style="list-style-type: none"> <li>• CE consequences</li> <li>• Circular economy</li> <li>• Link with private - public partnerships</li> <li>• Work</li> </ul>
Relationship change elements	<ul style="list-style-type: none"> <li>• Benefits and risks</li> <li>• Co-creation</li> <li>• Collaboration</li> <li>• Interdependence</li> <li>• Performance</li> <li>• Public procurer motivation to change</li> <li>• Roles and responsibilities</li> <li>• Supplier - public procurer relationship</li> <li>• Supplier motivation to change</li> <li>• Tendering</li> <li>• Transparency</li> <li>• Trust</li> </ul>
Sustainability assessment	<ul style="list-style-type: none"> <li>• Data collection</li> <li>• Sustainability assessment tool</li> <li>• Sustainable development</li> <li>• TBL</li> </ul>
WMATA	<ul style="list-style-type: none"> <li>• Circular economy</li> <li>• Linear economy</li> <li>• WMATA specifics</li> </ul>

## Appendix 5 List of quotations

Interview data analysis 2/3

Quotation Manager [HU: analysis]

Quotations Edit Miscellaneous Output View

Search (Id, Name)

Id	Name	Codes	Size	Start	De...	Author	Created
3:22	What we do now in sustainabil...	Sustainability assessment	0:3...	2:2...	1	Super	02/16/20...
3:23	Until now, broader sustainabil...	Sustainability assessment	0:2...	2:2...	1	Super	02/16/20...
3:24	Because sustainability assessm...	Sustainability assessment	0:1...	3:6...	1	Super	02/16/20...
3:26	. But supplier has to be caref..	Sustainability assessment	0:4...	3:7...	1	Super	02/16/20...
3:27	Weighting system - Suppliers h...	Sustainability assessment	0:5...	3:1...	1	Super	02/16/20...
3:29	Collecting data is the most co...	Sustainability assessment	0:6...	3:2...	1	Super	02/16/20...
3:30	Philips does sustainability as...	Sustainability assessment	0:6...	3:2...	1	Super	02/16/20...
4:10	Monetizing every element of th...	Sustainability assessment	0:96	2:1...	1	Super	02/16/20...
4:11	Services that are concrete can...	Sustainability assessment	0:4...	2:1...	1	Super	02/16/20...
4:12	This kind of tool would really...	Supplier - public procurer relatio...	0:2...	2:2...	2	Super	02/16/20...
4:13	You could include everything b...	Supplier - public procurer relatio...	0:2...	3:1...	2	Super	02/16/20...
5:17	aving PPP insights and discuss...	Sustainability assessment	0:59	2:2...	1	Super	02/17/20...
5:21	Different products and service...	Sustainability assessment	0:2...	3:1...	1	Super	02/17/20...
7:18	I am sure that a number of cus...	Sustainability assessment	0:3...	4:1...	1	Super	02/17/20...
7:20	Addressing social and environm...	Sustainability assessment	0:1...	4:2...	1	Super	02/17/20...
10:8	Similar kind of assessments ar...	Sustainability assessment	0:6...	3:1	1	Super	02/17/20...
11:...	Economic impacts need to be re...	Sustainability assessment	0:1...	4:2...	1	Super	02/17/20...

17 Quotations

No item selected All Id - Index (eg. 233)

## Appendix 6 Initial list of codes

Interview data analysis 3/3

Code Manager [HU: analysis]

Codes Edit Miscellaneous Output View

Search (Name)

Name	Grou...	De...	Author	Created	Modi
Benefits and risks	5	0	Super	02/17/20...	02/17/...
CE consequences	25	0	Super	02/16/20...	02/17/...
CE transition barrier	1	0	Super	02/16/20...	02/17/...
CE transition barriers~	24	0	Super	02/16/20...	02/17/...
CE transition enablers	33	0	Super	02/16/20...	02/17/...
CE value proposition	24	0	Super	02/16/20...	02/16/...
Circular economy	7	0	Super	02/17/20...	02/17/...
Co-creation	2	0	Super	02/17/20...	02/17/...
Collaboration	5	0	Super	02/17/20...	02/17/...
Data collection	1	0	Super	02/17/20...	02/17/...
Interdependence	4	0	Super	02/17/20...	02/17/...
Linear economy	6	0	Super	02/17/20...	02/17/...
Link with private - public part...	1	0	Super	02/17/20...	02/17/...
Performance	1	0	Super	02/17/20...	02/17/...
Public procurer motivation to ...	10	0	Super	02/17/20...	02/17/...
Roles and responsibilities	9	0	Super	02/17/20...	02/17/...
Supplier - public procurer rela...	59	0	Super	02/16/20...	02/17/...
Supplier motivation to change	14	0	Super	02/16/20...	02/17/...
Sustainability assessment tool	9	0	Super	02/17/20...	02/17/...
Sustainable development	4	0	Super	02/17/20...	02/17/...
Sustainability assessment	17	0	Super	02/16/20...	02/17/...
TBL	6	0	Super	02/17/20...	02/17/...
Tendering	8	0	Super	02/17/20...	02/17/...
Transparency	2	0	Super	02/17/20...	02/17/...
Trust	4	0	Super	02/17/20...	02/17/...
WMATA specifics	9	0	Super	02/16/20...	02/17/...
Work	7	0	Super	02/17/20...	02/17/...

27 Codes

No item selected All Name - Title

## Appendix 7 Sustania 100 – WMATA deal

(Available at: [http://www.sustania.me/resources/publications/3rd\\_sustania100\\_2014.pdf](http://www.sustania.me/resources/publications/3rd_sustania100_2014.pdf))

Cities

# Energy Savings Finance the Switch to LED Lighting

Solution by: **Philips**



The Triple Bottom Line



ENVIRONMENTAL

*The LED installations will lead to a 68% reduction in energy consumption and prevent 11,000 tons of CO2 emissions.*



SOCIAL

*Improved lighting conditions will increase safety levels for 66,000 garage users.*



ECONOMIC

*According to WMATA, this arrangement will create \$600,000 in maintenance savings alone.*



Developed:  
USA



Deployed: **USA**



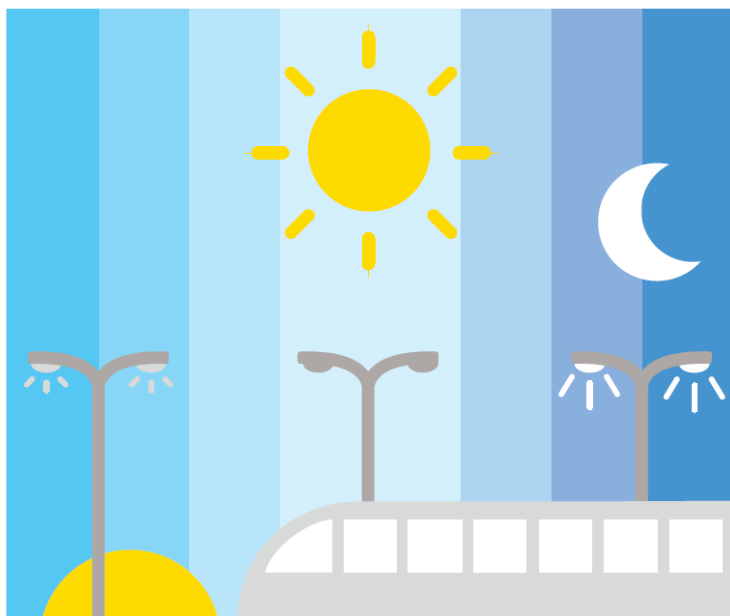
→ Washington D.C., USA: By means of a 10-year performance lighting contract, Philips will install LED lights in the city at no upfront cost.

Having secured a 10-year performance lighting contract with the Washington Metropolitan Area Transit Authority (WMATA), **Philips will upgrade more than 13,000 garage lighting fixtures** in the city. While Philips will be responsible for installation and continual maintenance, **the city will benefit from the opportunity to circumvent the upfront costs of LED installation.** The company will receive payment from the \$2 million in savings that WMATA expects to achieve annually.

The modular and adaptable lighting technology will also provide live data on energy consumption, while **further energy savings will be secured as bulbs automatically vary in brightness** according to motion and the availability of natural light.

Why a Sustania100 solution?

Although streetlights consume around one percent of all electricity in the United States,<sup>1</sup> many cities are prevented from switching to more efficient LEDs. A survey of 288 cities reveals that LEDs are a high priority for 82% of mayors, while 71% reported upfront costs to be a significant barrier.<sup>2</sup> By eliminating this obstacle, performance contracts can help many more cities cut costs and reduce their energy consumption.



## Appendix 8 PGL075 32 LED product information

(Available at: [http://www.stonco.com/uploads/library/resources/stonco\\_PGL\\_2pg\\_312.pdf](http://www.stonco.com/uploads/library/resources/stonco_PGL_2pg_312.pdf))

1/2



## PGL LED Parking Garage Luminaire

Solid State, Solid Solutions.

### New LED Parking Garage Luminaire improves illumination and savings

The PGL series luminaires is recommended for indoor applications where ceiling mounting height does not exceed 15 feet. Typical applications include parking garages, freezers, storage areas and corridors.

#### Lower operating and maintenance costs equals faster payback

The PGL series LEDs lasts four times longer than standard MH and use up to 50% less electricity for the same lumen output. The result is fewer relamping charges and less energy consumption for an overall accelerated payback on your investment.

#### Optical performance second to none

The high efficiency LEDs are coupled with precise optical control lenses located over each LED that deliver even illumination over the 60,000 hour L70 lifetime of the luminaire. The result is a symmetrical Type V distribution available in neutral (4K) color temperature. Computer-designed heat sink for excellent thermal management.

#### Contractor-friendly design for faster installation

The QuickMount Plate on the PGL eliminates the need to open the fixture during installation. Simply mount the QuickMount Plate to the splice box, hang fixture, complete a hands-free wiring and lock canopy into place.

#### Combining traditional value fixtures with advanced technology

Stonco's PGL LED luminaires combine traditional-value fixtures with advanced technology for affordable sustainability at Contractor-Friendly price points. Stonco has fixtures for most applications, and the traditional luminaire design ensures architectural integrity.

#### Meeting today's sustainable attributes

Stonco's PGL LED parking garage luminaires are lead free and conform to RoHs and DLC compliance.



Stonco is a Philips company

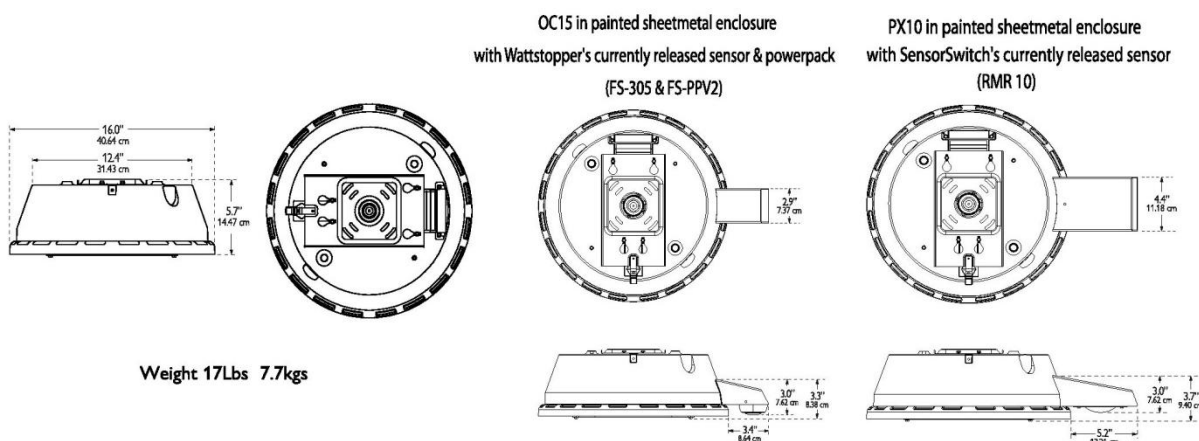


## Product Features

<b>Housing:</b>	Precision die-cast aluminum
<b>Life rating:</b>	60,000 hours L70
<b>No. of LEDs:</b>	32 or 48 high-output LEDs
<b>System watts:</b>	72.4W or 78.8W
<b>Initial lumens:</b>	72.4W - 5,063; 78.8W - 5,911
<b>Operating ambient:</b>	35°C
<b>Temperatures range:</b>	-30°C to 40°C
<b>Driver:</b>	Electronic Class II LED driver accepts 120-277V, 50/60hz input (constant current)
<b>Color temperature:</b>	32 LED - 4092K (neutral) 48 LED - 4145K (neutral)
<b>CRI:</b>	72
<b>Finish:</b>	Duraplex II wrinkle polyester in white, titanium, bronze and black
<b>Warranty/Ratings:</b>	5 year/60,000 hour; ETL Listing Wet Locations



## Dimensional Data



## Ordering Information

<b>PG</b>	<b>L</b>	<b>075</b>	<b>48</b>	<b>4K</b>			<b>8</b>
<b>Engine</b>							

Fixture	Lamp	Wattage	Lumens	Color Temp.	Finish	Options	Voltage
<b>PG</b> -Parking Garage Luminaire	<b>L</b> -LED	<b>075</b> → <b>081</b> →	<b>48</b> - 5063 <b>57</b> - 5911	<b>4K</b> - Neutral White	<b>W</b> - White <b>T</b> - Titanium <b>P</b> - Bronze <b>B</b> - Black	<b>F</b> - Fusing (Specify Voltage) <b>P</b> - Pendant  Consult factory for motion response options	<b>1</b> - 120v <b>2</b> - 208v <b>3</b> - 240v <b>4</b> - 277v <b>8</b> - 120-277v

Stonco Lighting reserves the right to change specifications and dimensions without notice. Light sources and electrical specifications / availability subject to change by manufacturer without notice. Please refer to detailed specifications sheets for additional information and spec details.



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Union, NJ 07083  
800-334-2212  
www.crescent-stonco.com



Stonco is a Philips company  
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## Appendix 9 Material and labor costs for WMATA owned and operated scenario

(Source: Author)

<b>Customer owned and operated</b>													
Year	Board cost	Driver cost	Controls cost	Board fail %	Driver fail %	Controls fail %	Board fail #	Driver fail #	Controls fail #	New products #	Material cost	Labor cost	Total (M&L)
0	\$ 269,17	\$ 65,68	\$ 131,70	0,05%	0,02%	0,06%	5	2	6	6	\$ 2.997,83	\$ 179,91	\$ 3.177,74
1	\$ 274,55	\$ 66,99	\$ 134,33	0,21%	0,08%	0,24%	22	8	26	26	\$ 12.213,71	\$ 733,01	\$ 12.946,72
2	\$ 280,04	\$ 68,33	\$ 137,02	0,46%	0,17%	0,55%	49	18	58	58	\$ 27.922,28	\$ 1.675,76	\$ 29.598,04
3	\$ 285,65	\$ 69,70	\$ 139,76	0,81%	0,31%	0,96%	86	32	101	101	\$ 50.252,52	\$ 3.015,91	\$ 53.268,43
4	\$ 291,36	\$ 71,09	\$ 142,56	1,26%	0,48%	1,49%	132	50	157	157	\$ 79.101,71	\$ 4.747,29	\$ 83.849,00
5	\$ 297,19	\$ 72,52	\$ 145,41	1,78%	0,68%	2,10%	188	72	221	221	\$ 114.052,39	\$ 6.844,85	\$ 120.897,25
6	\$ 303,13	\$ 73,97	\$ 148,32	2,38%	0,92%	2,79%	250	97	294	294	\$ 154.302,06	\$ 9.260,44	\$ 163.562,50
7	\$ 309,19	\$ 75,45	\$ 151,28	3,02%	1,19%	3,52%	317	125	371	371	\$ 198.617,13	\$ 11.920,01	\$ 210.537,14
8	\$ 315,38	\$ 76,95	\$ 154,31	3,68%	1,48%	4,26%	387	156	449	449	\$ 245.323,85	\$ 14.723,11	\$ 260.046,96
9	\$ 321,68	\$ 78,49	\$ 157,39	4,33%	1,80%	4,98%	456	190	524	524	\$ 292.347,46	\$ 17.545,23	\$ 309.892,70
10	\$ 328,12	\$ 80,06	\$ 160,54	0,05%	0,02%	0,06%	5	2	6	10531	\$ 5.989.451,77	\$ 118.896,04	\$ 6.108.347,81
11	\$ 334,68	\$ 81,66	\$ 163,75	0,21%	0,08%	0,24%	22	8	26	26	\$ 14.888,45	\$ 893,53	\$ 15.781,98
12	\$ 341,37	\$ 83,30	\$ 167,03	0,46%	0,17%	0,55%	49	18	58	58	\$ 34.037,11	\$ 2.042,74	\$ 36.079,84
13	\$ 348,20	\$ 84,96	\$ 170,37	0,81%	0,31%	0,96%	86	32	101	101	\$ 61.257,55	\$ 3.676,37	\$ 64.933,92
14	\$ 355,16	\$ 86,66	\$ 173,78	1,26%	0,48%	1,49%	132	50	157	157	\$ 96.424,54	\$ 5.786,92	\$ 102.211,46
15	\$ 362,27	\$ 88,40	\$ 177,25	1,78%	0,68%	2,10%	188	72	221	221	\$ 139.029,23	\$ 8.343,84	\$ 147.373,07
16	\$ 369,51	\$ 90,16	\$ 180,80	2,38%	0,92%	2,79%	250	97	294	294	\$ 188.093,35	\$ 11.288,42	\$ 199.381,77
17	\$ 376,90	\$ 91,97	\$ 184,41	3,02%	1,19%	3,52%	317	125	371	371	\$ 242.113,17	\$ 14.530,42	\$ 256.643,59
18	\$ 384,44	\$ 93,81	\$ 188,10	3,68%	1,48%	4,26%	387	156	449	449	\$ 299.048,40	\$ 17.947,39	\$ 316.995,79
19	\$ 392,13	\$ 95,68	\$ 191,86	4,33%	1,80%	4,98%	456	190	524	524	\$ 356.369,93	\$ 21.387,54	\$ 377.757,47
20	\$ 399,97	\$ 97,60	\$ 195,70	4,95%	2,13%	5,64%	521	225	593	593	\$ 411.175,46	\$ 24.676,70	\$ 435.852,15
											<b>\$ 9.009.019,89</b>	<b>\$ 300.115,43</b>	<b>\$ 9.309.135,33</b>

## Appendix 10 Material and labor costs for Philips owned and operated scenario

(Source: Author)

<b>Philips owned and operated scenario (material and labor costs)</b>													
Year	Board cost	Driver cost	Controls cost	Board fails %	Driver fails %	Controls fails %	Board fails #	Driver fails #	Controls fails #	# interventions	Material cost	Labor cost	Total (M&L)
0	\$ 269,17	\$ 65,68	\$ 131,70	0,05%	0,02%	0,06%	5	2	6	14	\$ 2.436,02	\$ 332,62	\$ 2.768,65
1	\$ 274,55	\$ 66,99	\$ 134,33	0,21%	0,08%	0,24%	22	8	26	55	\$ 9.926,67	\$ 1.355,49	\$ 11.282,16
2	\$ 280,04	\$ 68,33	\$ 137,02	0,46%	0,17%	0,55%	49	18	58	124	\$ 22.705,34	\$ 3.100,78	\$ 25.806,12
3	\$ 285,65	\$ 69,70	\$ 139,76	0,81%	0,31%	0,96%	86	32	101	219	\$ 40.904,03	\$ 5.587,37	\$ 46.491,40
4	\$ 291,36	\$ 71,09	\$ 142,56	1,26%	0,48%	1,49%	132	50	157	339	\$ 64.492,05	\$ 8.812,75	\$ 73.304,79
5	\$ 297,19	\$ 72,52	\$ 145,41	1,78%	0,68%	2,10%	188	72	221	481	\$ 93.215,85	\$ 12.745,11	\$ 105.960,96
6	\$ 303,13	\$ 73,97	\$ 148,32	2,38%	0,92%	2,79%	250	97	294	641	\$ 126.546,30	\$ 17.316,39	\$ 143.862,69
7	\$ 309,19	\$ 75,45	\$ 151,28	3,02%	1,19%	3,52%	317	125	371	813	\$ 163.640,56	\$ 22.417,33	\$ 186.057,88
8	\$ 315,38	\$ 76,95	\$ 154,31	3,68%	1,48%	4,26%	387	156	449	992	\$ 203.327,33	\$ 27.895,48	\$ 231.222,81
9	\$ 321,68	\$ 78,49	\$ 157,39	4,33%	1,80%	4,98%	456	190	524	1170	\$ 244.122,96	\$ 33.557,46	\$ 277.680,42
10	\$ 328,12	\$ 80,06	\$ 160,54	4,95%	2,13%	5,64%	521	225	593	1339	\$ 284.284,48	\$ 39.175,82	\$ 323.460,30
11	\$ 334,68	\$ 81,66	\$ 163,75	5,51%	2,48%	6,19%	580	261	651	1491	\$ 321.901,54	\$ 44.501,21	\$ 366.402,75
12	\$ 341,37	\$ 83,30	\$ 167,03	5,96%	2,82%	6,60%	628	297	695	1619	\$ 355.024,32	\$ 49.278,90	\$ 404.303,22
13	\$ 348,20	\$ 84,96	\$ 170,37	6,30%	3,16%	6,85%	663	332	721	1716	\$ 381.817,82	\$ 53.268,82	\$ 435.086,65
14	\$ 355,16	\$ 86,66	\$ 173,78	6,49%	3,48%	6,91%	683	366	728	1777	\$ 400.727,30	\$ 56.266,76	\$ 456.994,07
15	\$ 362,27	\$ 88,40	\$ 177,25	6,52%	3,78%	6,79%	687	398	715	1799	\$ 410.634,44	\$ 58.124,12	\$ 468.758,56
16	\$ 369,51	\$ 90,16	\$ 180,80	6,40%	4,05%	6,49%	674	426	683	1784	\$ 410.982,05	\$ 58.763,40	\$ 469.745,45
17	\$ 376,90	\$ 91,97	\$ 184,41	6,13%	4,28%	6,04%	645	451	635	1731	\$ 401.846,69	\$ 58.186,82	\$ 460.033,51
18	\$ 384,44	\$ 93,81	\$ 188,10	5,73%	4,47%	5,46%	603	470	574	1648	\$ 383.944,48	\$ 56.476,24	\$ 440.420,72
19	\$ 392,13	\$ 95,68	\$ 191,86	5,22%	4,60%	4,79%	549	484	505	1538	\$ 358.564,80	\$ 53.783,99	\$ 412.348,80
20	\$ 399,97	\$ 97,60	\$ 195,70	4,64%	4,68%	4,09%	488	493	430	1411	\$ 327.438,09	\$ 50.315,67	\$ 377.753,76
											<b>\$ 5.008.483,12</b>	<b>\$ 711.262,53</b>	<b>\$ 5.719.745,65</b>

## Appendix II Energy cost for both scenarios

(Source: Author)

Year	Watt input	Lumens/ watt	Wanted lumens	Price kwh input per	# products changed	Scenario 1 M&L costs	Scenario 1 energy costs	Boards fail scenario 2	Scenario 2 M&L costs	Scenario 2 energy costs
0	72	70	5063	\$ 76,03	6	\$ 3.152,0	\$ 800.235	5	\$ 2.769	\$ 800.235
1	65	78	5063	\$ 68,23	26	\$ 12.842,0	\$ 800.235	22	\$ 11.282	\$ 800.235
2	58	87	5063	\$ 61,18	58	\$ 29.358,6	\$ 800.235	49	\$ 25.806	\$ 800.235
3	53	95	5063	\$ 56,02	101	\$ 52.837,6	\$ 800.235	86	\$ 46.491	\$ 800.235
4	50	102	5063	\$ 52,18	157	\$ 83.170,8	\$ 800.235	132	\$ 73.305	\$ 800.235
5	47	108,5	5063	\$ 49,05	221	\$ 119.919,4	\$ 800.235	188	\$ 105.961	\$ 795.167
6	44	114,5	5063	\$ 46,48	294	\$ 162.239,6	\$ 800.235	250	\$ 143.863	\$ 788.419
7	42	120	5063	\$ 44,35	371	\$ 208.834,3	\$ 800.235	317	\$ 186.058	\$ 779.856
8	39	130	5063	\$ 40,94	449	\$ 257.943,7	\$ 800.235	387	\$ 231.223	\$ 769.415
9	36	140	5063	\$ 38,02	524	\$ 307.386,2	\$ 800.235	456	\$ 277.680	\$ 757.110
10	34	150	5063	\$ 35,48	21056	\$ 6.038.284,1	\$ 373.443	521	\$ 323.460	\$ 735.966
11	32	160	5063	\$ 33,26	26	\$ 15.654,3	\$ 373.443	580	\$ 366.403	\$ 712.459
12	30	170	5063	\$ 31,31	58	\$ 35.788,0	\$ 373.443	628	\$ 404.303	\$ 687.002
13	28	180	5063	\$ 29,57	101	\$ 64.408,7	\$ 373.443	663	\$ 435.087	\$ 642.879
14	27	190	5063	\$ 28,01	157	\$ 101.384,8	\$ 373.443	683	\$ 456.994	\$ 613.927
15	25	200	5063	\$ 26,61	221	\$ 146.181,1	\$ 373.443	687	\$ 468.759	\$ 598.493
16	25	200	5063	\$ 26,61	294	\$ 197.769,1	\$ 373.443	674	\$ 469.745	\$ 565.190
17	25	200	5063	\$ 26,61	371	\$ 254.567,8	\$ 373.443	645	\$ 460.034	\$ 481.953
18	25	200	5063	\$ 26,61	449	\$ 314.431,9	\$ 373.443	603	\$ 440.421	\$ 436.715
19	25	200	5063	\$ 26,61	524	\$ 374.702,1	\$ 373.443	549	\$ 412.349	\$ 406.930
20	25	200	5063	\$ 26,61	593	\$ 432.326,9	\$ 373.443	488	\$ 377.754	\$ 368.200
					26056	\$ 9.213.183	\$ 12.110.217	8613	\$ 5.719.746	\$ 14.140.855

## Appendix 12 Sensitivity analysis

(Source: Author)

		Electricity price change% (annually)							
0%		2%		4%		6%			
Sc 1	Sc 2	Sc 1 (2%)	Sc 2 (2%)	Sc 1 (4%)	Sc 2 (4%)	Sc 1 (6%)	Sc 2 (6%)		
\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63		
\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63		
\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63		
\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63		
\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63	\$ 800.234,63		
\$ 800.234,63	\$ 795.167,42	\$ 800.234,63	\$ 796.126,33	\$ 800.234,63	\$ 797.163,47	\$ 800.234,63	\$ 798.283,53		
\$ 800.234,63	\$ 788.418,94	\$ 800.234,63	\$ 790.654,92	\$ 800.234,63	\$ 793.073,31	\$ 800.234,63	\$ 795.685,07		
\$ 800.234,63	\$ 779.856,36	\$ 800.234,63	\$ 783.712,70	\$ 800.234,63	\$ 787.883,65	\$ 800.234,63	\$ 792.388,09		
\$ 800.234,63	\$ 769.415,16	\$ 800.234,63	\$ 775.247,37	\$ 800.234,63	\$ 781.555,39	\$ 800.234,63	\$ 788.367,77		
\$ 800.234,63	\$ 757.110,08	\$ 800.234,63	\$ 765.270,88	\$ 800.234,63	\$ 774.097,46	\$ 800.234,63	\$ 783.629,77		
\$ 373.442,83	\$ 735.965,99	\$ 455.224,73	\$ 748.178,42	\$ 552.786,61	\$ 761.838,41	\$ 668.779,23	\$ 777.117,21		
\$ 373.442,83	\$ 712.458,71	\$ 455.224,73	\$ 729.175,61	\$ 552.786,61	\$ 748.209,21	\$ 668.779,23	\$ 769.876,77		
\$ 373.442,83	\$ 687.002,05	\$ 455.224,73	\$ 708.596,95	\$ 552.786,61	\$ 733.449,79	\$ 668.779,23	\$ 762.035,91		
\$ 373.442,83	\$ 642.879,43	\$ 455.224,73	\$ 666.185,32	\$ 552.786,61	\$ 693.237,23	\$ 668.779,23	\$ 724.661,47		
\$ 373.442,83	\$ 613.927,20	\$ 455.224,73	\$ 641.927,91	\$ 552.786,61	\$ 674.422,56	\$ 668.779,23	\$ 712.094,13		
\$ 373.442,83	\$ 598.492,68	\$ 455.224,73	\$ 636.865,08	\$ 552.786,61	\$ 682.508,72	\$ 668.779,23	\$ 736.810,47		
\$ 373.442,83	\$ 565.190,44	\$ 455.224,73	\$ 609.764,94	\$ 552.786,61	\$ 663.568,98	\$ 668.779,23	\$ 728.551,28		
\$ 373.442,83	\$ 481.952,93	\$ 455.224,73	\$ 514.014,47	\$ 552.786,61	\$ 551.354,63	\$ 668.779,23	\$ 594.788,55		
\$ 373.442,83	\$ 436.714,68	\$ 455.224,73	\$ 468.776,22	\$ 552.786,61	\$ 506.116,38	\$ 668.779,23	\$ 549.550,31		
\$ 373.442,83	\$ 406.930,27	\$ 455.224,73	\$ 444.038,76	\$ 552.786,61	\$ 488.019,42	\$ 668.779,23	\$ 540.144,61		
\$ 373.442,83	\$ 368.199,77	\$ 455.224,73	\$ 404.742,61	\$ 552.786,61	\$ 447.979,02	\$ 668.779,23	\$ 499.130,12		
\$ 12.110.217,47	\$ 14.140.855,27	\$ 13.009.818,33	\$ 14.484.451,64	\$ 14.082.999,11	\$ 14.885.650,81	\$ 15.358.917,89	\$ 15.354.288,25		
	\$ 2.030.637,79		\$ 1.474.633,31		\$ 802.651,71		\$ -4.629,64		
	17%		11%		6%		-0,03%		

