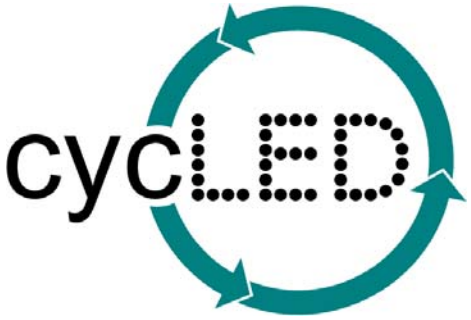

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Project acronym: cycLED

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Deliverable 8.2.
What are the barriers faced by producers involved in the ecodesign of LEDs?

Partner: IMT/TEM

Start date of project: 01.01.2012 Duration: 42 months

Main Author: Cédric Gossart (IMT/TEM)

Assisted by Altay Özaygen (IMT/TEM)

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Author(s)	Cédric Gossart, Altay Özaygen
EC Project Officer	Wojciech Klimek
Abstract	This document presents the barriers to ecodesign in the LED sector. These barriers have been collected through face-to-face interviews from the four cycLED partners in charge of developing a demonstrator (ONA, RIVA, BRAUN, ETAP), as well as through an online survey of European LED firms. This document also includes a study of women's participation in eco-innovation in the LED sector. It concludes by highlighting the benefits of its findings for cycLED partners as well as for other European LED companies.
Keywords	Barriers, ecodesign, eco-innovation, LED, SME, gender.

Project funded by the European Commission within the Seventh Framework Programme		
Dissemination Level		
PU	Public	**x**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

TABLE OF CONTENTS

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1. INTRODUCTION

This document is the Deliverable 8.2 of WP8. It summarises the results of our analysis of barriers to ecodesign collected from cycLED partners (Phase I) and from other LED firms (Phase II). On the basis of these findings, solutions will be formulated in D8.3 to help cycLED partners in charge of developing a demonstrator (ONA, RIVA, BRAUN, ETAP) as well as European LED firms to anticipate and overcome these barriers. Solutions for policy makers will also be suggested in D8.3. An eco-innovation is an innovation that enables greater environmental performance compared to existing alternatives. Like innovation itself, it is not only technological but can also be organisational, behavioural, systemic, etc. Factors leading to increased firms' innovativeness originate both from within and outside the firm. Besides, a specificity of eco-innovations is that they are strongly shaped by regulatory measures. In order to ensure their success, it is therefore essential to identify potential regulatory obstacles to eco-innovation that could be overcome by developing and enforcing regulatory instruments. Indeed, not enforcing a regulation that could support eco-innovation can also be considered as a regulatory barrier that firms could suffer from.

Many studies have sought to analyse barriers to innovation. In their analysis of revealed versus deterring barriers, but these studies have focused on financial variables, and that many of them have used econometric analyses and CIS survey data. On the other hand, few studies have explored a broader range of barriers, conducted case studies, or focused on barriers to eco-innovation. Moreover, barriers faced by SMEs have seldom been analysed. In the context of the cycLED project (WP8), a qualitative analysis of eco-innovation barriers has been conducted by carrying out case studies with cycLED SME partners, covering both regulatory barriers as well as barriers to ecodesign (Phase I). In a second phase, the analysis of these two categories of barriers has been extended to other stakeholders beyond the cycLED project by means of an online survey (Phase II). The methodologies and results of these two phases are presented below, with a focus on regulatory barriers. Regulatory barriers to eco-innovation are addressed in D8.1.

Ecodesign is the outcome of a strategy aiming to generate innovations with an increased environmental performance, namely "eco-innovations".[1] Therefore, to identify the barriers to ecodesign that LED firms might face when developing ecodesigned LEDs, we need to get a better understanding of the barriers to innovation in a first stage and of the barriers to ecodesign in a second stage. Indeed, many factors contribute to a successful ecodesign strategy, such as financial or human resources or firms' regulatory context. Therefore, by analysing the obstacles to ecodesign that originate within and outside firms, we will be able to get a full picture of the obstacles to ecodesign faced by LED companies.

After a presentation of the methodologies used in Phase I and Phase II, we present the most important barriers to ecodesign faced by the four cycLED partners in charge of a demonstrator (Phase I), as well as the

[1] For a review of the literature on eco-innovation, see Cecere, G., N. Corrocher, et al. (2014). Lock-in and path dependence: An evolutionary approach to eco-innovations. *Journal of Evolutionary Economics* 24(5): 1037-1065.

barriers to ecodesign faced by European LED firms (Phase II). Solutions to overcome these barriers are presented in D8.3. We also underline the benefits of this work for industrial partners. For example, we suggest a method to enable LED companies, especially SMEs, to self-assess their barriers to eco-innovation (explained in greater detail in D8.3). This tool can also be used by any lighting company. We also present an analysis of the participation of women to LED eco-innovation.

2. METHODOLOGIES

The activities of WP8 are divided into two phases. The first phase aims to identify the barriers to eco-innovation faced by the four cycLED SMEs in charge of developing a demonstrator (ONA, RIVA, BRAUN, ETAP), and to suggest solutions for these four SMEs to overcome their own barriers (Phase I). The second phase seeks to identify barriers to eco-innovation beyond the cycLED project, and thus extended the identification of barriers and their related solutions to other stakeholders involved in the European LED sector (Phase II). The methodologies used in both phases are explained below.[2]

2.1. The methodology used in Phase I

In order to prepare the interview guideline that has helped us identify regulatory barriers to eco-innovation and barriers to ecodesign, a review of the literature has been prepared. A commonly used list of innovation barriers is also included in the Community Innovation Survey (CIS), which mentions three categories of barriers to innovation: Risk and finance, Knowledge-skill within enterprise, Knowledge-skill outside the enterprise, and Regulations. A study of the potential and challenges of solid state lighting (SSL) in Europe complemented the CIS barriers with the following barriers in the case of SSL: Cost, Payback time, Quality, Luminous efficacy, Lifetime, Educational barriers, Testing, Manufacturing, Lack/high cost of capital, Aversion to risk, Lack of time, Dramatic decline in the total number of lighting products. In order to complement these lists, other sources of information were used (see reference list in the Appendix n°1 of D8.1), which have enabled us to prepare a more detailed list of barriers. The information collected on regulatory barriers to eco-innovation and on barriers to ecodesign contained a mix of these two categories of barriers, but in our study we have separated these two categories and dealt with them in respectively D8.1 and D8.2.

[2] Sections 2.1 and 2.2 are equivalent to the ones of D8.1. They are reproduced here for readers who have not read D8.1.

By means of case studies, we have analysed barriers faced by cycLED SMEs and which originate both within their organisation and outside of their organisation.[3] Case studies consisted in in-depth interviews carried out with the support of the abovementioned interview guideline reproduced in the Appendix n°2 of D8.1, in which potential barriers were collected from the aforementioned literature review. The final guideline contained 144 barriers concerning both regulatory barriers and barriers to ecodesign.

Face-to-face interviews were conducted with the four SMEs of the project in charge of delivering demonstrators of ecodesigned LED products. For each of the 144 barriers, SMEs were asked to provide an evaluation about how important each barrier was for their organisation by using four different evaluation levels:

- 2 (Major barrier to eco-innovation for my organisation).
- 1 (Relevant barrier to eco-innovation for my organisation)
- 0 (Irrelevant barrier to eco-innovation for my organisation)
- -1 (Not a barrier but rather a support to eco-innovation)

They were also asked to suggest solutions to overcome each barrier; in this case their answers have been used in D8.3.

2.2. The methodology used in Phase II

After the qualitative analysis of barriers to eco-innovation within the cycLED project presented above, we have broadened the scope of our analysis of barriers to LED eco-innovation to other stakeholders. This has enabled us to formulate policy recommendations (cf. D8.3) to support the sustainability transition of the European lighting industry.

In order to analyse the barriers to eco-innovation of European LED firms, we have prepared an online questionnaire available in 6 languages.[4] The main risk associated with this strategy was a low response rate from LED firms, which we had to face despite the short duration required to fill in the questionnaire (15 to 20 minutes). In order to increase the number of responses to our email and telephone queries, we have also given the questionnaire during professional fairs where many firms were physically present. This strategy has enabled us to increase our response rate during the 2014 LED Forum in Paris, and in the June 2015 LED Forum in Lyon. This positive strategy has been renewed during the 2015 Metropolitan solutions

[3] In the interview guideline included in the Appendix n°2 of D8.1, we refer to barriers to ecodesign as "A. Barriers within your organisation". As for regulatory barriers to eco-innovation, they are termed "B. Barriers outside your organisation". As explained in the introduction of the interview guideline, this rephrasing has be adopted for pedagogical reasons in order to facilitate the interviews with firms, who had a clearer idea of what regulatory barriers and barriers to ecodesign were when using those terms.

[4] English, French, German, Italian, Spanish, and Turkish. See http://cycled-survey.eu/. These are the languages spoken in countries where we had contacts that could help us find interviewees.

conference in Berlin, which hosted the Smart Lighting conference. In this case, with the support of our IZM partner we recruited five Berlin-based students in other to help us give the questionnaire to as many people as possible by means of digital tablets connected to the wifi network of the conference hall. We also had back-up print outs of the questionnaire. This questionnaire has been used to prepare the self-assessment tool of barriers introduced in Section 4.2 of this document and explained in greater detail in D8.3.

Our web-based survey builds on the Community Innovation Survey (CIS) so as to enable the assessment of barriers to eco-innovation in the European LED sector. Our survey consists of a maximum number of 35 questions (since some questions are conditional that number could be lower), and contains four sections:

1. Information about the firm (Name, address, capital structure, market, active in LED production or not);
2. Eco-innovation activities;
3. Barriers to eco-innovation (financial, knowledge, market, other factors hampering eco-innovation);
4. Other information about the firm (revenues, patents, patent licence).

The next section presents the findings about barriers to ecodesign in the LED sector identified during the two phases of WP8.

3. BARRIERS TO ECODESIGN

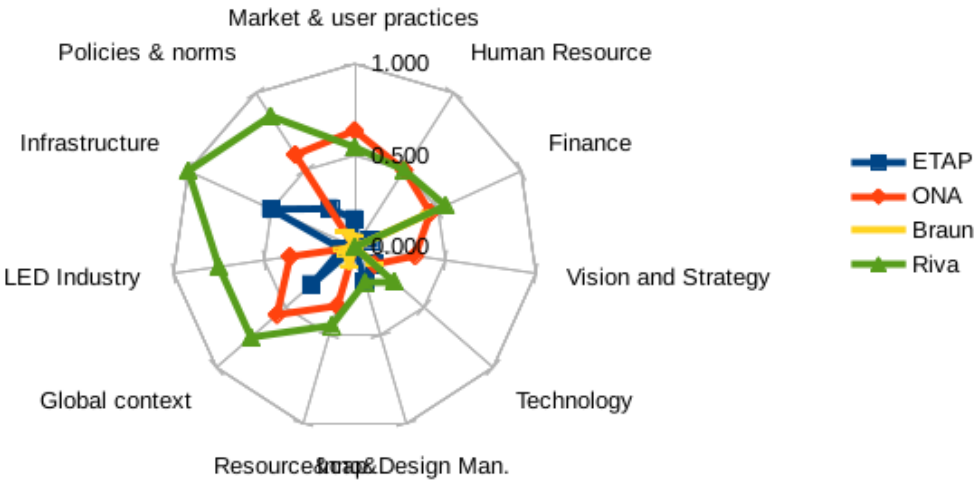
3.1. Results from Phase I

144 barriers to ecodesign were included in the interview guideline, of which 31% were barriers to ecodesign (45). As explained in the methodology (Section 2.1), we asked interviewees to evaluate each of the 144 barriers to eco-innovation (EI) by using the following evaluation levels:

How problematic is that barrier to EI for your organisation?			
-1	0	1	2
Not a barrier: a support to ecoinnovation	Irrelevant for my organisation	Relevant barrier for my organisation	Major barrier for my organisation

Our analysis has enabled us to examine how each category of barrier was perceived by cycLED SMEs, and to represent it graphically in the following figure (normalised with respect to the number of questions asked for a specific category). It includes categories of both regulatory barriers and barriers to ecodesign.

Figure 1. Categories of barriers perceived by cycLED SMEs



We can see that no category of barrier clearly stands out for the four SMEs,[5] except maybe for the regulatory barrier category "Global context", which can be explained by the fact that the economic crisis affects most businesses. On the contrary, categories of barriers to ecodesign such "Technology", "Design management" or even "Vision and strategy" are not perceived as obstacles to ecodesign. This suggests that despite their size, cycLED SMEs feel that they have a solid vision and strategy to develop ecodesigned LEDs, and have a good command of the technological and design drivers to do so. This corroborates findings according to which firm's size does not seem to affect SMEs' innovation capability. This heterogeneity in the barriers to eco-innovation perceived by cycLED SMEs implies that solutions to overcome eco-innovation barriers should be specific to each SME, which is what we have done in the project, as explained in the Section 3.1 of Deliverable 8.3.

Since four firms were interviewed, we could collect a total of 576 evaluations. In order to bring to the fore the most important barriers to eco-innovation for cycLED SMEs, we can use two different approaches:

Approach n°1: For each barrier, examine the number of evaluations given by each firm for each level (-1, 0, 1, 2); the most significant barriers are the ones which most often receive a Level 2.

Approach n°2: For each barrier, add up the scores of their evaluations (-1, 0, 1, 2); the higher the score the more significant the barrier.

Let us proceed with the first approach (**Approach n°1**). The following table shows the distribution of the evaluations received for barriers to ecodesign per evaluation level. It shows that 28% of these evaluations have identified major barriers (51 Level 2 evaluations). Among these, only 7 evaluations targeted major

[5] See the discussion in the Section 3.1 of D8.1 about the heterogeneity of the evaluations of barriers to eco-innovation by cycLED SMEs.

barriers to ecodesign (yellow line in the table below), the remaining 46 evaluations corresponded to regulatory barriers.

Table 1. Distribution of evaluations per level for barriers to ecodesign

Evaluation levels	Number of evaluations per level	%
2	7	4%
1	44	24%
0	121	66%
-1	12	7%
Total	**184**	**100%**

This table shows that seven evaluations have identified major barriers to ecodesign; the following table shows which barriers have received these evaluations. One barrier has received two Level 2 evaluations (see green line in the table below), and five barriers have received one Level 2 evaluation.

Table 2. Major barriers to ecodesign

CATEGORY	BARRIER
FINANCE	Lack of in-house sources of finance
TECHNOLOGY	LED drivers are barriers to ecodesign (too fragile e.g.)
FINANCE	The gross intrinsic value is too low, which discourages innovation in recycling technologies
FINANCE	Eco-innovation costs are too difficult to control
RESOURCES & CAPABILITIES	Information systems are sources of rigidity that discourage eco-innovation
HUMAN RESOURCES	Lack of technical personnel to ecoinnovate

A first interesting conclusion is that not a single barrier to ecodesign was deemed major by the four firms altogether. Only one barrier was deemed major by two firms together; all the other major barriers to ecodesign were given a Level 2 evaluation by only one firm. This heterogeneity in the perception of the main obstacles to ecodesign of four firms pertaining to the same sector, and in the cases of Riva and Braun which are both German, can be explained by the fact that their market and internal dynamics are very different, as well as the local context in which they operate.

We can also notice that three major barriers to ecodesign, including the first one in the above table, belong to the category “Finance”. When looking at the details of the evaluations, we can notice that the largest of the 4 cycLED SMEs did not deem relevant these financial barriers, suggesting that these are more acutely perceived as obstacles to ecodesign by smaller firms. As argued in D8.1, financial support seems to be crucial to unlock eco-innovation in LED SMEs. The solutions to each of these seven major barriers to ecodesign are discussed in D8.3 (Section 3.1).

Regarding the 44 evaluations that were given a Level 1 (i.e. 24% of the evaluations given to barriers to ecodesign), they concern 28 barriers distributed across 7 categories (see their list in Appendix n°1, too long to be reproduced in a table here). As shown in the next table, one third of the relevant barriers to

ecodesign are related to financial issues. The most important of these barriers will be discussed with their solutions in the next section.

Table 3. Number of relevant barriers (Level 1) to ecodesign per category of barrier

Category of barrier	Number of barriers	%
FINANCE	9	32%
HUMAN RESOURCES	6	21%
RESOURCES & CAPABILITIES	6	21%
TECHNOLOGY	4	14%
INNOVATION & DESIGN MANAGEMENT	2	7%
VISION & STRATEGY	1	4%
TOTAL	**28**	**100%**

As explained before, a second way to examine the relative importance of barriers to ecodesign is to analyse their global score (**Approach n°2**). The following table shows the distribution of barriers to ecodesign in terms of their aggregated score.

Table 4. Distribution of barriers to ecodesign ranked by total score

Total scores	Number of barriers per score	%
4	3	6%
3	4	13%
2	9	19%
1	11	23%
0	10	21%
-1	8	17%
TOTAL	**45**	**100%**

This table reveals that only three barriers to ecodesign have obtained a total score of 4 (yellow line), the highest global score for barriers to ecodesign, and that two of these are related to financial issues, which corroborates the fact that these issues seem to be major obstacles to ecodesign for LED SMEs. The next table presents these three major barriers to ecodesign.

Table 5. Barriers to ecodesign with a total score of 4

Categories of barriers	Barriers	Firms' evaluations				Total score
		A	B	C	D	
TECHNOLOGY	LED drivers are barriers to eco-innovation	1	2	0	1	**4**
FINANCE	Lack of in-house sources of finance	0	2	2	0	**4**
FINANCE	The gross intrinsic value is too low	0	1	2	1	**4**

The following table also underlines the importance of financial barriers for LED SMEs' ecodesign capabilities, since three of the four barriers that obtained a total score of three belong to the category "Finance" of barriers to ecodesign.

Table 6. Barriers to ecodesign with a total score of 3

Categories of barriers	Barriers	Firms' evaluations				Total score
		A	B	C	D	
FINANCE	Eco-innovation costs are too difficult to control	0	2	0	1	3
FINANCE	Economies of scale are too small to reduce costs	0	1	1	1	3
FINANCE	The pay-off period of eco-innovation is too long	1	1	1	0	3
RESOURCES & CAPABILITIES	Information systems are sources of rigidity that discourage eco-innovation	2	1	0	0	3

Finally, by combining the two aforementioned approaches that can be used to identify the most important barriers to ecodesign, the following table shows the six most important barriers to ecodesign perceived by cycLED SMEs. This final result corroborates the strong importance given by cycLED SMEs finance-related barriers to ecodesign, since half of these barriers are related to financial issues. They are discussed in detail with their solutions in the Section 3.1 of D8.3.

Table 7. Major barriers to ecodesign

CATEGORY	BARRIER
FINANCE	Eco-innovation costs are too difficult to control
FINANCE	Lack of in-house sources of finance
FINANCE	The gross intrinsic value of the LED product is too low
HUMAN RESOURCES	Lack of technical personnel to ecoinnovate
RESOURCES & CAPABILITIES	Information systems are sources of rigidity that discourage eco-innovation
TECHNOLOGY	LED drivers are barriers to eco-innovation

3.2. Results from Phase II

The survey questions dealing with barriers to eco-innovation were divided into four different groups: financial barriers, knowledge barriers, market barriers, and other barriers. Market and other barriers are taken as regulatory barriers and are thus dealt with in D8.1. This deliverable addresses financial and knowledge barriers, which are taken as barriers to ecodesign.

38 firms outside the cycLED project completed the on-line survey. Their capital structure shows that they are in majority privately owned (87%). 56% of them carry out research on or are involved in the manufacturing of LED products, but 37% of them are also dealing with other lighting technologies (only 13% are not involved in LED technologies and operate in other lighting activities). The majority of the surveyed firms are active at local and national levels (82%). 76% are active in the EU, 45% in Asia, 39% in Africa, 34% in North America, and 31% in Australia. 68% of surveyed firms own granted patents.

Regarding the types of activities carried out by eco-innovative firms, over the past four years 33% of surveyed firms eco-innovated to reduce their energy consumption during the manufacturing phase. 84% did it to reduce the energy consumption of their products in the use phase, 45% to reduce the use of hazardous materials in products or during production, and 32% to reduce air, water or soil emissions.

Finally, 42% of surveyed firms claimed to eco-innovate to generate less waste during the production process. We can see that the main driver of eco-innovation of surveyed firms is the reduction of energy consumption, probably because energy savings tend to reduce production costs during the production phase as well as during the use phase. Indeed, displaying highly energy efficient LED products is a source of comparative advantage for LED manufacturers.

The scope of eco-innovations developed in-house is an important aspect to examine, since the market potential of these eco-innovations will not be the same if they are new to the firm only or if they are new to the whole world. Our results reveal that 24% of surveyed firms consider that their eco-innovation activities are a novelty for the world and 24% a novelty for Europe, which suggests that these firms have a robust innovation potential.

It is also interesting to identify the reasons for which firms eco-innovate. They are shown in the table below, in which the answer "N/A" means that the question was deemed by the respondent not applicable to his/her company. There were cases in which no answer was provided by the respondent: they are placed in the column "V" ("Void").

Table 1. Reasons to eco-innovate

	HIGH	MEDIUM	LOW	N/A	V	SUM
To increase sales on existing markets	58%	11%	11%	8%	12%	**100%**
To reduce cost	53%	18%	11%	5%	13%	**100%**
To enter new markets	45%	24%	11%	8%	12%	**100%**
To improve product quality	45%	24%	11%	8%	12%	**100%**
To increase product range	39%	29%	5%	13%	14%	**100%**
To meet standards and labelling requirements	32%	18%	18%	18%	14%	**100%**
To outperform regulatory requirements	18%	32%	18%	18%	14%	**100%**
To comply legal obligation	26%	29%	16%	16%	13%	**100%**
To improve compatibility with other products on the market	23%	11%	37%	15%	14%	**100%**
To improve reputation	21%	11%	8%	47%	13%	**100%**

We can see that for 58% of surveyed firms (first black cell), the most important reason to eco-innovate is to **increase sales on existing markets**. Other strong motivations to eco-innovate are to reduce costs (53%), to enter new markets or to improve product quality (45%), to increase product range (39%), and to meet standards and labelling requirements (32%). Another motivation to eco-innovate (grey cell) is the concern to outperform regulatory requirements (32%).

Two main categories of barriers to ecodesign were collected with the online survey. They include financial barriers and knowledge barriers. The following table shows the ranking in terms of importance of the financial barriers to eco-innovation faced by surveyed firms. It confirms the finding of the first phase of WP8, since like 28% of the online surveyed firms (black cell) agree with cycLED SMEs on the fact that the

main barrier to LED eco-innovation is the **lack of in-house sources of funding**. Other important barriers also corroborate the findings of phase I, since the high costs of eco-innovation, the lack of public and private eco-innovation funds as well as the lack of financial support to SMEs are listed as important barriers by about one third of the surveyed firms (grey cells).

Table 2. Financial barriers to eco-innovate

	HIGH	MEDIUM	LOW	N/A	V	SUM
Lack of funds within your enterprise or group	28%	33%	22%	8%	9%	**100%**
Eco-innovation costs are too high	24%	32%	24%	18%	2%	**100%**
Lack of public funding sources to support eco-innovation	24%	29%	21%	23%	3%	**100%**
Lack of financial support for SMEs	21%	29%	18%	29%	3%	**100%**
Lack of private funding sources to support eco-innovation	15%	29%	29%	24%	3%	**100%**
Educational institutions do not provide enough people well trained to develop eco-innovation	15%	18%	35%	29%	3%	**100%**
The gross intrinsic value of your products is not high enough	3%	29%	26%	38%	4%	**100%**

The next table shows the ranking of knowledge barriers to eco-innovation faced by surveyed firms by order of importance. The removal of these barriers is crucial for the success of any eco-innovation since knowledge lies at the heart of any innovation process. It appears that the **lack of qualified personnel** to eco-innovate is the most important knowledge barrier, for 29% of the respondents (black cell). Other important knowledge-related barriers include for one third of surveyed firms the lack of eco-innovation information and of external eco-innovation expertise, as well as the lack of information about eco-innovation markets (grey cells).

Table 3. Knowledge barriers to eco-innovate

	HIGH	MEDIUM	LOW	N/A	V	SUM
Lack of qualified personnel to eco-innovate	29%	21%	32%	15%	3%	**100%**
Difficulty to find complementary expertise to eco-innovate	18%	32%	18%	29%	3%	**100%**
Our established competences made it too costly to eco-innovate	12%	24%	29%	32%	3%	**100%**
Cost to shift to LEDs due to our established competences	12%	12%	38%	35%	3%	**100%**
Lack of information on markets for eco-innovations	9%	32%	38%	18%	3%	**100%**
Lack of skilled people to repair used products	6%	3%	41%	47%	3%	**100%**
Lack of information on recent technological developments related to eco-innovation	3%	32%	44%	18%	3%	**100%**

3.3. Women's participation to eco-innovation

The lack of participation of women to eco-innovation can weaken firms' eco-innovation strategies. Therefore, an assessment of women's participation to eco-innovation has been conducted on two cycLED partners. Key findings in order to ensure a better participation of women to eco-innovation include:

- Promoting environmental technology and design amongst children and young people;
- Positive discrimination measures in favour of women to increase the number of female engineers;
- Gender-blind job recruiting;
- In-house training courses to increase the number of female engineers and technicians;
- Improving working conditions to achieve a better work-life balance.

The entire report on the participation of women to eco-innovation can be found in the Appendix n°2 of this deliverable.

4. BENEFITS TO THE INDUSTRIAL PARTNERS

In this section we summarise the benefits of the work carried out in WP8 for both cycLED partners and other industrial firms.

4.1. Benefits to cycLED partners

For all cycLED partners this WP8 has pushed them to think outside of their business as usual box, and enabled them to identify their own barriers and to help other cycLED partners to identify their own. Four ad hoc reports have been prepared for each cycLED SME in charge of developing a demonstrator.[6] By stimulating thinking about barriers to eco-innovation, partners could discover new concepts that could help them in the design of their demonstrator, as in the case of DfR for one of the SMEs. During formal interactions such as cycLED WP8 workshops or more informal exchanges during consortium meetings lunch breaks or social events, ideas about new barriers and solutions emerged as in the case of the only barrier that scored a level 5 ("Lack of certification mechanisms", which was brought up by a cycLED expert during a consortium meeting organised by SIRRIS in Belgium. The idea of considering patents as barriers to eco-innovation also came up during a consortium meeting, organised by ONA in Spain. This is to mention but a few of the stimulating environment provided by the work conducted within WP8. Positive externalities also arose from this work since during several workshops on barriers and their solutions cycLED partners had

[6] Since these reports are confidential, they cannot be made available in this public deliverable.

the opportunity to interact and exchange ideas about their eco-innovation practices and difficulties, which directly contributed to the successful development of cycLED demonstrators.

But the main benefits of WP8 went to the four SMEs in charge of developing a demonstrator, who received multiple direct benefits from the work carried out in WP8:

- Identification of their barriers to eco-innovation;
- Categorisation of their barriers to eco-innovation (regulatory barriers, barriers to ecodesign);
- Ranking of their barriers to eco-innovation (major barriers, relevant barriers, …);
- Prioritisation of their barriers to eco-innovation (which ones can be solved in-house?);
- Solutions to their barriers to eco-innovation.

Many solutions to overcome these barriers to ecodesign can be found by firms themselves. However, in several cases the complexity of the barrier will require external support to be overcome. In order to provide additional benefit to our industry partners, we have also helped them analyse the potential sources of this support. External sources of support that industrial partners can find to overcome their barriers to ecodesign can be divided into three main categories:

1. Financial external help to overcome barriers to ecodesign (subsidies, vouchers, ...);
2. Knowledge supports (training, partnerships, IPR management, ...);
3. Normative support (standards, regulations, ...).

These solutions are explored in greater detail in D8.3, a deliverable which will be publicly available from an ad hoc webpage (http://gossart.wp.mines-telecom.fr/cycled).

All cycLED partners also benefit from indirect advantages of the work carried out in WP8, since for example the solutions suggested to policy makers and industry representatives will eventually support eco-innovative LED firms in the forms of improved standards and product quality checks, or of public supports to eco-innovation.

A greater awareness about the obstacles to LED eco-innovation can also motivate cycLED industrial partners to launch or to take part in cross-industry actions, such as the ones led by the industry association Lighting Europe.[7] Finally, the self-assessment tool provided in the Appendix n°1 of D8.3 will enable cycLED partners to regularly monitor their progress in terms of their capacity to overcome barriers to eco-innovation. This tool can also be used by any lighting company. Indeed, if they fill in the questionnaire on a regular basis and if their eco-innovation performance improves, over time they should be facing fewer

[7] See their “Compliant Lighting Initiative”, http://www.lightingeurope.org/uploads/files/LightingEurope_Press_Release_Compliant_Lighting_Initiative_March_2015.pdf.

barriers to eco-innovation especially in-house, since they would have overcome a number of them. This made easy by the fact that the tool is available in several European languages besides English such as German or French. The website of the survey (http://cycled-survey.eu/) will remain online until the end of 2016, so companies filling in the survey can benefit from their own results but can also receive the latest results of the survey by leaving contact details if they wish to. Passed this date all publicly available document related to WP8 will be archived on an ad hoc webpage (http://gossart.wp.mines-telecom.fr/cycled).

In several occasions, we have mentioned examples of activities carried out within the cycLED project which have helped overcome barriers to LED eco-innovation. Besides the successful development of four demonstrators, this suggests that European research projects such as cycLED can significantly contribute to the development of eco-innovations. Indeed, the niche or protective space that they provide enables a stable and multidisciplinary collaboration over several years between a variety of stakeholders from industry, academia, or policy makers. We trust that the results of WP8 on regulatory barriers and on barriers to ecodesign can contribute to further improve the capacity of the European Union to shift to more sustainable lighting systems.

In order to exemplify the benefits of the work conducted in WP8, we reproduce below the explanations of two cycLED SMEs about how this work has helped them improve their eco-innovation. The barriers referred to below were presented in individual reports sent to each SME. These reports are attached in Appendix n°2 of D8.3, but they had to be anonymised because the interviews carried out during the Phase I of WP8 are confidential.

ETAP's benefits from WP8 (by Greet Verhoeven)

ETAP is at the end of the implementation of a PLM-ERP system which will help them with version management and quick handling of fast evolving technologies. Better performing LEDs and drivers could be changed in the complete product range in a very quick way. This barrier will be solved with a couple of months. We have further investigated the robustness of different drivers and we have started collaborating with a reliable qualitative supplier. For the range out of the demonstrator we have chosen two types of drivers depending on the application. ETAP starts the ETAP academy in 2016 to educate (potential) customers about LEDs and Lighting in order to take away the perception that LEDs are risky and fragile. Next to that Emergency Lighting and Light Management will be instructed. By Light Management the emphasis will be on reduction of the energy consumption. Also out of the demonstrator Light and Daylight Controls are foreseen in our new standard range.

ONA's benefits from WP8 (by Ana Blay)

Following the work conducted for WP8, ONA has been able to overcome several of its most important barriers to eco-innovation identified in WP8. For example, ONA had problems with its LED drivers. Realising that LED drivers could substantially reduce the eco-innovativeness of its LED products, ONA changed the requirements it imposes on the subcontractor in charge of ordering drivers for its LED products. It now only takes drivers with a reliability rate of at least 60%, meaning that according to the experience of this trusted external technician when sold to clients only one out of three could fail in the short run. Prior to this decision, the main criterion was only cost-based, namely driver durability was less important than driver price. Another important obstacle for ONA to start new eco-innovation activities was related with financial resources. Thanks to the cycLED project this small company of four people could develop and ecodesign LED product. But there were several financial risks that could have undermine this new product development, which are related with the identified barrier "Eco-innovation costs are too difficult to control". As a consequence, additional measures to control eco-innovation costs were taken, such as the ones related to the maintenance of the ecodesign LED product. Indeed, because one of the promises it has to deliver is the long lifetime. The choice of long-lasting LED drivers contributed to fulfil this promise, but another measure helped a lot as well. ONA decided to only sell the product in Spain, and free maintenance has been limited to hotels, in order to limit the number of travels needed to service ONA's ecodesign lamps (bring new parts of take back lamps to repair them).

Regarding the human resources barrier about the "Lack of technical personnel to ecoinnovate", with the support of the cycLED project one of the four staff members has been trained on eco-innovation and gained knowledge about its obstacles and gotten ideas about how to overcome them. Given the small size of the company, which is seen as an advantage by ONA, information could circulate easily to other staff members who could upgrade their knowledge about eco-innovation and the major obstacles that are to be avoided to successfully develop eco-innovative LED products. Regarding eco-innovation training in Spain, following the work conducted for WP8, ONA has searched for training programme on ecodesign and eco-innovation, and found one in Barcelona but it does not do distant learning. This Masters is nevertheless a potential place to hire new recruits in the future, and to find expertise for future projects.

Regarding relevant barriers (level 1) to ecodesign which have been addressed by ONA, we can give the example of barriers related to human resources. The "Lack of skilled sales personnel in eco-innovation" has been overcome by an increased circulation of information about eco-innovation between the four employees of the company, and by encouraging the online self-training of the sales persons who are subcontracted by ONA, notably on the environmental benefits of LED products and services. This all the more relevant since customers ask an increasing number of questions in this respect.

4.2. Benefits to other European LED firms

Besides helping cycLED demonstrators, the work carried out in WP8 will also benefit to other European LED firms, especially SMEs, who would like to develop eco-innovations. Indeed, the solutions to barriers to LED ecodesign might also be useful to these firms, who can use freely the self-assessment tool made available on an ad hoc webpage (http://gossart.wp.mines-telecom.fr/cycled). This tool being available in six European languages, many European firms will be able to benefit from it. It can also be used by any lighting company.

For the firms that answered our online survey, they first learn a lot about their eco-innovation potential and how to improve it by overcoming eco-innovation obstacles. This eco-innovation thinking also supports the integration of eco-innovation objectives into the firm's strategy, and enables it to formulate solutions to improve its eco-innovation performance. Besides, all the firms which have been interviewed have requested to receive the results from our survey by filling it their contact details. During the interviews, enabling them to have access to these results was a clear motivation for them to answer our questions. Also, many of them did not know about European research projects, and many underlined that they would look into European sources of eco-innovation research funding in the future. Thanks to the questionnaire, they have also gained awareness about eco-innovation regulatory issues, which gave them incentives to support existing actions such as the ones led by Lighting Europe. Furthermore, the policy solutions to overcome regulatory barriers to eco-innovation, which are brought forward in D8.3, will reinforce the supports for and sources of pressures on companies of the European lighting sector to accelerate its transition to sustainable development.

Last but not least, the results from our survey will enable European LED firms to engage in a benchmarking exercise with their competitors, which could trigger a positive move to setting up an ambitious eco-innovation strategy free of major obstacles to eco-innovation. The responses provided by cycLED partners will also be useful to them to invent their own solutions to overcome their barriers to eco-innovation.

5. APPENDICES

5.1. Appendix n°1: Phase I list of all relevant barriers to ecodesign (Level 1)

Global score per barrier	Category	Barrier	Firm A	Firm B	Firm C	Firm D	Number of Level 1 evaluations per barrier
3	FINANCE	The pay-off period of eco-innovation is too long	1	1	1	0	3
3	FINANCE	Economies of scale are too small to reduce costs	0	1	1	1	3
4	TECHNOLOGY	LED drivers are barriers to eco-innovation	1	2	0	1	2
4	FINANCE	The gross intrinsic value is too low, which discourages innovation in recycling technologies	0	1	2	1	2
2	HUMAN RESOURCES	Staff lacks information on technologies and markets	0	1	0	1	2
2	HUMAN RESOURCES	Lack of access to the knowledge of other firms through strategic alliances	0	1	0	1	2
2	HUMAN RESOURCES	Difficulties in allocating staff to new eco-innovation missions due to on-going projects	0	1	0	1	2
2	HUMAN RESOURCES	Lack of skilled sales personnel in eco-innovation	0	1	0	1	2
2	FINANCE	Difficulty to calculate future benefits	0	1	0	1	2
2	FINANCE	High cost of eco-innovation development	0	0	1	1	2
2	RESOURCES & CAPABILITIES	Marketing and sales channels have not been developed yet	0	0	1	1	2
2	RESOURCES & CAPABILITIES	Lack of ecodesign tools	0	1	0	1	2
1	FINANCE	Excessive perceived risk of eco-innovation investments	-1	1	1	0	2
3	FINANCE	Eco-innovation costs are too difficult to control	0	2	0	1	1
3	RESOURCES & CAPABILITIES	Information systems are sources of rigidity that discourage eco-innovation	2	1	0	0	1
1	INNOVATION & DESIGN MANAGEMENT	Too much uncertainty in the timing of innovation	1	0	0	0	1
1	INNOVATION & DESIGN MANAGEMENT	Sticky Knowledge: some people are reluctant to share their knowledge	0	0	0	1	1
1	TECHNOLOGY	LED products are not recyclable enough	0	1	0	0	1
1	TECHNOLOGY	The hazardousness of LEDs is an obstacle to eco-innovation	0	0	0	1	1
1	HUMAN RESOURCES	Lack of access to information about the needs of different markets	0	0	0	1	1
1	HUMAN RESOURCES	Lack of training for eco-innovation	0	1	0	0	1
1	FINANCE	Lack of networks to access external financial resources	0	0	1	0	1
1	FINANCE	High cost of knowledge acquisition	0	0	0	1	1
1	RESOURCES & CAPABILITIES	Difficulties in training skilled people on eco-innovation	0	1	0	0	1
1	RESOURCES & CAPABILITIES	Lack of access to the technical knowledge of research labs and universities through alliances	0	0	0	1	1
0	VISION & STRATEGY	Environmental commitments are not realised	-1	1	0	0	1
0	TECHNOLOGY	LED glare is an obstacle to eco-innovation	-1	0	1	0	1
-1	RESOURCES & CAPABILITIES	The size of your organisation is too small to ecoinnovate	0	-1	-1	1	1

NB: In grey: the Level 1 barriers to ecodesign that obtained a global score of at least two or that got at least two Level 1 evaluations.

5.2. Appendix n°2: Report on the participation of women to eco-innovation

When preparing the DoW, cycLED partners did their best to ensure a high participation of women partners. The following table shows the distribution of males and females in the teams of the 13 active partners, who have been included in the latest version of the DoW (version date 2013-10-11), plus additional active members Greet Verhoeven (ETAP) and Altay Özaygen (IMT/TEM):

Table 4. Gender distribution of cycLED's team members

#	Name of the partner	Country	Number of team members	Number of females	% of females	Number of males	% of males
1	FRAUNHOFER	Germany	7	2	29%	5	71%
3	ONA	Spain	3	2	67%	1	33%
4	ELPRO	Germany	2	1	50%	1	50%
5	BRAUN	Germany	2	0	0%	2	100%
6	UMICORE	Belgium	3	1	33%	2	67%
7	ETAP	Belgium	4	1	25%	3	75%
8	PHILIPS	Netherlands	3	0	0%	3	100%
9	NTU	UK	2	0	0%	2	100%
10	OUT	Germany	2	0	0%	2	100%
11	EDCW	UK	3	0	0%	3	100%
12	SIRRIS	Belgium	6	1	17%	5	83%
13	IMT/TEM	France	5	3	60%	2	40%
14	RIVA	Germany	2	0	0%	2	100%
TOTAL	-	-	**44**	**11**	**39%**	**33**	**61%**

1) Aims

Besides a mere statistical description of the gender distribution of cycLED project partners, our gender and technology experts have conducted a specific evaluation of gender issues in the LED sector. As explained below, this has been done by conducting in-depth face-to-face interviews with several members of two (anonymised) cycLED partners. The rationale, method and results of this gender-related research are presented below. We also provide in the next section an overview of the analysis of gender issues in the lighting sector.

The objective of the cycLED project gender mainstreaming work is to investigate possible developments in the cultural association of technology and masculinity within sustainable development, which could impact (positively or negatively) women's participation in eco-innovation. We have carried out two case studies, one in an industrial company, and the other in a research institute. Both organisations are involved in eco-innovation and more specifically in the field of lighting technologies. We first provide a brief overview of gender and sustainable development research. We then describe the research methodology, the theoretical framework used for the case study analysis, and results for each case.

2) Rationale

In the literature on gender and sustainable development two major themes have particular bearing on the cycLED project environment. Firstly, the gender, environment and development debate (GED-debate) and secondly the feminist critique of science and technology. Historically in Europe, the former is reflected in an eco-feminist position. Although there are different theoretical lines within the eco-feminist approach, all forms of eco-feminism emphasize women's privileged bond with nature/environment. For some this is due to a gendered cultural development of "women as care-takers" (Shiva, 1988). For others it is seen to be the result of societal, historical developments binding women to nature due to their capacity to give birth (Mies & Shiva, 1993). In recent years, particularly in Europe, there has been much criticism of the eco-feminist position (Badinter, 2010), its failure to reflect diversity (Wichterich, 2012), and in particular the fact that it draws upon an essentialist view of men and women.

Regarding the second theme − a feminist critique of science and technology − the environmental movement, from its beginnings, integrated a critical reflection on scientific technological development. Today many scientists recognise that the environmental movement of the 1960s began with the action of the U.S. biologist Rachel Carson, who described the danger of pesticides used in agriculture both for human beings and the environment. This eventually paved the way for a law forbidding the use of DDT in the United States (European Commission, 2001). Concerning technology, the cultural association between technology and masculinity in Western societies is largely agreed upon, "not only as a popular assumption – from which much sexist humour about 'women's technical incompetence' has been generated – but also as an academic 'truth'" (Gill & Grint, 1995). A feminist perspective shifts our understanding of what technology is, broadening our understanding to include not only artefacts but also the cultures and practices associated with technologies (Wajcman, 2010). There are three major positions on gender and technology to-date: eco-feminism, liberal feminism and the more historical perspective which sees technology as masculine culture. The years 1985 – 1995 saw the emergence of a powerful critique of both the liberal and eco-feminist positions. It argued that women's alienation from technology is a result of the historical and cultural construction of technology as masculine (Cockburn & Ormrod, 1993; Wajcman, 1991). "Empirical research on everything from the microwave oven (Cockburn & Ormrod, 1993), the telephone (Martin, 1991) and the contraceptive pill (Oudshoorn, 1994), to robotics and software agents (Suchman, 2008) has clearly demonstrated that **the marginalisation of women from the technological community has a profound influence on the design, technical content and use of artefacts**" (Wacjman, 2009; our emphasis). Feminist STS (science, technology studies) scholars have now widely adopted a social constructivist framework (Berg & Lie, 1995; Faulkner, 2001). In common with techno-feminist theory, it conceives of technology as both a source and a consequence of gender relations (Wajcman, 2004).

Besides these theoretical considerations, research on gender and sustainable development has documented men and women's attitudes, presence and engagement in the protection of the environment,

in both the public and private spheres. The majority of studies across countries have generally shown that women have stronger pro-environmental attitudes than men (OECD 2008; Lee, Park, Han, 2013) and have also revealed women's higher participation in private environmental behaviours. However, most studies consistently showed no gender differences in community/society-oriented behaviours. A recent US study (Lee, Park, & Han 2013) on gender difference in environmental attitude and behaviours in adoption of energy-efficient lighting (fluorescent lighting and CFL) in private homes indicated that **women were more likely to engage in energy-saving practices and were more willing to pay a higher price for energy-efficient light sources**. However, no gender differences emerged in the purchase of energy-efficient light sources and support for policies banning inefficient incandescent light sources. In addition, compared to men, women scored higher on subjective norms in the adoption of energy-efficient lighting. Finally, women were more likely to perceive lighting as an important factor in their everyday lives, prefer incandescent lighting, and perceive fluorescent lighting as having negative effects on human health. The authors see these results as significant given that women can play a critical role in the adoption of energy-efficient lighting for their home, as they are generally responsible for buying about 80% of household goods. However, they call for caution in applying these results as "gender roles and values differ from society to society", and recommend future research to focus on the adoption of LED lighting as it is currently considered the most promising lighting technology (Lee, Park & Han, 2013).

In the public sphere, the recycling industry is a rapidly expanding sector (in France, +36% employment over 10 years) that has become highly industrialized. In 2010, 34,000 people were employed in France in the recycling industry, 79% male and 21% female. Executives and decision-makers are for the most part men and one third of women employed are unskilled (Recycling, 2010). Furthermore, professional women working in environmental professions in industry or research are often biologists, biochemists, physicists, geologists, physicians, or they have studied environmental professions in the field of engineering. In general, the professional situation of these women is dominated by men in quantitative as well as in qualitative aspects (European Commission, 2001). Even if women are not under-represented in professional education (e.g. in geology and biology), they seldom reach the top level of professional hierarchies. Nevertheless, since the 1970s networks of women in natural sciences and technology, for example the WITEC (European Association for Women in Science and Technology), have been set up in many European countries. Amongst other topics, WITEC-studies investigate the development of new professional profiles which incorporate social questions in general and women's experiences in particular, including women's views on technological development and gender-differentiated views on the quality of life (European Commission 2001).

From the above synthesis we could envisage environmental engineering as being more inclusive than other engineering fields, and also expect to observe an evolution in the cultural association of technology and gender. In order to investigate these hypotheses, we decided to carry out a field study within organisations involved in the eco-innovative LED industry.

3) Method

Our research is based on an interpretive field study. We have used a qualitative approach − semi-structured interviews – to collect data. Given that all cycLED partners are committed to gender equality of opportunity in recruitment, they are considered appropriate organisations for studying the gender-technology relation within eco-innovation activities.

We have carried out case studies in two of the thirteen cycLED project partner organisations. The first case study is an industrial company located in Belgium (Company A), and the second a large research organization located in Germany (Institute B). Data was collected on the premises of the two participating organisations. We conducted two series of five one-hour interviews, with three women and two men in both organisations. Questions were phrased to elicit information on interviewees' views concerning gender diversity in environmental engineering and gendered relations to technology and, in particular, to LED technology in research and industry. All the interviews were recorded for future transcription, and transcripts were checked by the interviewees. The data has then been coded using the data analysis software NVivo10. Transcripts have been coded twice − firstly a descriptive coding and then a more conceptual one.

Our analysis is based on a constructionist and structurationist approach, elaborated from previous work (McDonnell & Morley, 2015). Particular attention has been paid to investigating the existence of a potential, emerging shift in the gender/technology relation. **A key question will be whether eco-design contributes to reinforcing or undoing the gendered division between the conception of technology and its use.**

The theoretical approach used for analysing the corpus focuses on both structural and individual practices. For social constructivists, common-sense knowledge of the world is constructed through social interaction, and day-to-day conversation is the most important vehicle for maintaining a stable view of reality within a social group (Berger & Luckmann, 1966). Social order, namely gender order, is based on and maintained through actors sharing a vision of reality. This "reality-maintenance" process not only includes what is being said, but also what is silently taken for granted and left unquestioned. At the same time, conversational interaction can modify reality: some rules are no longer mentioned, others are challenged. Most social movements aim to change how reality is interpreted, and casual conversations play a background role in such evolutions. Giddens's structuration theory (1984) also refers to the conditions governing the continuity or transformation of social structures. According to Giddens, the structure of a social system is produced, reproduced or changed through the interactions of actors, along three dimensions: signification, domination and legitimation. On the signification dimension, actors draw on schemes of meaning to understand reality. Gender stereotypes claiming women's incompetence in technology are an example of such interpretive schemes if they are taken as a lens to bring into focus why so few women work in technological fields. On the domination dimension, sources of power (material, authority, influence) are

diversely allocated to actors, who use them to influence others, make them cooperate, or even to constrain. The legitimation dimension is what legitimises actions, i.e. social norms and associated sanctions for those who defy the norms. Female executives and researchers may be criticised or even dismissed for being more assertive, self-reliant, decisive, etc., than is considered acceptable for a woman according to gender stereotypes in a given society. In return, sanctions contribute to confirming the rule.

Our analysis aims at studying how the association of technology and masculinity is reproduced or changed in a particular setting. Subtle mechanisms in daily conversation or working practices contribute either to undermine or to consolidate this association. Drawing on earlier work (McDonnell & Morley, 2015), we have used the word 'move' to refer to any interaction or practice that could impact the gendering of technology. 'Inclusion moves' contribute to include women into technology, and 'exclusion moves' to preserve the status quo. Moves are identified by studying statements (about men and women, technology, gendered characteristics, etc.), attitudes (concerning men and women in technology), behaviour (communication and collaboration within working groups, work/life balance issues, etc.) and practices (concerning diversity, recruitment, promotion, part-time work, and so on). Certain statements, attitudes or decisions regarding relations between the sexes are not discussed or commented on because they rely on knowledge that is taken for granted. This knowledge can conform to gender stereotypes and/or draw on issues related to discrimination against women.

4) Results

CASE STUDY A

A is a private Belgian lighting company founded in 1949. It provides high-end lighting solutions to professionals, offices, shops, hotels, factories, hospitals, schools, etc. It develops end-to-end lighting solutions, i.e., from the early stages of creating lighting concepts and designs to the manufacture, delivery and final stages of studies and consultancy. It has played a pioneering role in the development of LED lighting, in terms of both research and manufacturing, and has subsidiaries in 11 countries. Annual turnover is around €60 million, 6% to 7 % of which is invested in research and development. It employs approximately 600 people worldwide, approximately 43% male and 57% female. In the Belgian plant about 150 employees work in the assembly department. This is exclusively female apart from the male manager. It should be noted that the vast majority of these female employees work part-time. On the other hand, 83% of management are men and 17% are women. Furthermore, figures for 2010, 2011 and 2012 show that out of a total of 16 executives only one is female. This, however, has not always been the case. "*Actually, things were more balanced than this, let's say ten years ago. Today, XXXX is the only female person on our management staff. So, out of a group of more than 20 people, she is the only female" (AM1).* The company prides itself on being socially responsible. It has an excellent track record for environmental sustainability and is involved in a variety of projects that promote sustainable development within the

company as well as abroad, in particular in developing economies. However, the company admits in its "Sustainability report" (Sustainability report 2011-2012, October 2013) that more effort is required in the field of social and racial diversity. Nevertheless, no mention is made of the male/female equality question.

Inclusion moves

In our analysis three main types of practices or interactions can be considered to further women's inclusion in the company. 1) Product design is no longer seen as a male-dominated process. 2) The company has expressed growing concern about diversity. 3) The integration of highly qualified women is perceived as something to strive for.

Open design process

In line with market trends, Company A has made a strategic shift away from a technical approach to product design and towards a more market-oriented approach. Discourse on products includes terms such as '*atmosphere*', '*aesthetics*', and '*architecture*'. Product design is '*challenged*' by multiple points of views, and this is seen as positive by all engineers: "*It's always a combination of the technological point of view and the aesthetic point of view... and also, where you want to go. For each product you see a market, so it's a complete mix of different inputs" (AF1).* This may explain why no one believes that including more women would change product design, as women are already involved in the process of developing new products. Open design however can have an impact on female inclusion because people from different backgrounds, including women, have to cooperate and work together.

Diversity discourse and practices

Company A is a family-owned business, and the president is the daughter of the founder. The company has a clear anti-discriminatory discourse. All the interviewees explicitly say that no distinction is made between women and men in hiring and promotion. All of them declare that they would prefer to work in a mixed-gender team, and to have more female colleagues. However, diversity practices at the workplace are limited. Two female interviewees report participating in promoting girls' and women's interest in technology, but the company appears to have been involved in such activity only once. Some years ago, an interesting experiment to counter gender imbalance in the production department was carried out with unskilled female employees. They were offered technical training in order to be able to read technical diagrams and plans and to set up the machines. A plan to include non-EU employees was also successfully implemented, and there appears to have been no criticism of this policy. However, all interviewees explicitly disagreed with positive discrimination to achieve greater gender balance. Nevertheless, even if the situation as regards male/female equality remains unchallenged, anti-discrimination discourse as well as a first experience in diversity inclusion can be considered as inclusion moves because they pave the way towards greater gender balance in technical environments.

Integrating women

There are few female managers or product developers. Nevertheless their integration does not seem to be an issue. Several interviewees recall a young, female engineer hired just after graduation, and who left the company four years later to go back to her country of origin. The only woman in a managerial position describes her relationship with her team in very positive terms, such as mutual understanding, respect, and shared commitment to the job. She seems to adopt a gendered "care" attitude, but interestingly, a male colleague at the same level, explains his own shift from a mere technical focus to a broader people-oriented approach. The successful integration of women can be categorised as an inclusion move, because positive experiences strengthen men's open attitude towards hiring women and at the same time develop women's self confidence in a male environment.

Exclusion moves

The interviewees seemed to be aware of gender stereotyping issues and did not refer to common sense assertions concerning men and women. However, one of them started the interview with a 'Men are from Mars & Women are from Venus' discourse about gendered abilities, and this was a first clue that certain exchanges within the company can convey negative messages about women's inclusion. We identified three exclusion moves: 1) Female teams are undervalued compared to male teams; 2) Casual exchanges between men and women can be unpleasant for women; and, 3) Family life is often seen as a major disadvantage for women in the workplace.

Undervaluing female teams

Interviewees unanimously approved of mixed male/female work teams. However, working in an all-female or female-dominated environment was less valued than working in a male-dominated environment, and this was even true of interviewees who had never experienced a female-dominated environment. For example, in referring to a department within the company where there are many unskilled female employees, one interviewee says: "*Men working with men, there could be problems, but it's much more limited than when women are working with women. If you look here in the company, in the production department, women behave in another way, I think. I don't really know, but, there is some jealousy*" (AM2). Another engineer in speaking about unskilled female employees recounts: *'I had two women in my department and there is a difference in talking with them about a mistake they have made or something else. You talk with them about it and the day after, they are still in a bad mood or they start to cry and so on (...). But it depends also on the level at which they are working, if they are engineers or not and so on' (AF1). Even when making a distinction between different grades, the general attitude seems to be: 'I find it very pleasant to work in a male environment; anyway more pleasant than if there were a lot of women involved,' (AF1).* Women at work are perceived as creating more conflict than men: "*I think maybe because of the*

character of females, I don't know, but I prefer to work with a male team, or a mixed team, than an all-female team. I think it makes things more difficult, because we have our own characters……and I think that, only females, I think that's difficult' (AF2). Women causing conflict are observed not only at the unskilled employee level, but also in positions of power*: 'Women, as soon as they move up the ladder in a company and it is all-woman environment, you get this sort of "'playground atmosphere"', she laughs, 'where everybody is very sweet towards each other, but behind one's back, it's war!*' (AF3).

Nevertheless, the few women in top management are accepted and even valued. All interviewees expressed, as mentioned above, a positive opinion about mixed teams. But we noted that in the discourse of most interviewees women are seen to contribute in terms of empathy and 'care' and of their ability to coordinate. Finally, as certain behaviour contradicted this idealised view of the female character, the interviewees seem inclined to conclude that women, as a category, can be a source of conflict and thus their number should remain limited.

Gender in humour and discussions in the workplace

As one interviewee stated, '*Humour is always a good barometer for measuring how well people work together'* (AF3), and it seems that jokes about gender differences are part of male-female interactions within the company. Another interviewee spontaneously mentioned: '*The department that I work with the most is the development department, and its all-male. There are typical conversations between males and females, jokes and things like that but I don't have a problem with that'* (AF2), and she later explained that she and her female engineer colleague could cope with that sort of interaction: '*There are the typical conversations between male and female, but I think my colleague and I, we are strong enough to cope with that. So, I don't have any problems with that'* (AF2). The following extract from one of our interviews may be an example of this kind of joke incident: '*You know the story, if you give a woman a car and she has to drive to, let's say, Italy, and you take 100 women, 5 women will reach the destination, and the other 95 will end up in Spain!*' (AM2). Discussions on topics other than work seem to contribute to creating an environment where women are not fully included. At the moment*, 'there are more males, they have their own discussions and I think if there were more females, the mixture would be better I think*' (AF2). Speaking of a female engineer, her male boss says that '*she is lonely because she is the only female technical manager*', but he immediately adds that '*she is not really lonely, because she likes to work with men. She is very assertive. And, you know, she has brothers as well I believe, and she has always had men in her environment'* (AM1). She herself mentioned that she was '*lonely at the top*', and it seems she sometimes would like other kinds of exchanges: '*I had a very good relationship with the commercial director. However, she left, I think, about five years ago. We often got together at noon for a chat; we went to have lunch outside, especially in summer. And, it was nice to discuss certain topics with another woman because on some issues we have completely other thoughts, and it was nice that we could talk like that and sometimes I miss that'* (AF1). However, no female interviewee mentioned having encountered explicit exclusion: '*I think*

*the women who work here, are accepted, apart from the typical male/female jokes… '(*AF2), and as noted before, they all prefer not to work in all-female environment.

Family life

Most interviewees expressed the belief that the gender imbalance in the company (and more widely in the industrial sector) was linked to the issue of family life and in particular having children. Firstly, working in industry is perceived as difficult for mothers: '*I think more women choose either an academic career or a career in education because it makes it easier to combine the responsibility for a family with the responsibility of a job. That's still the case"* (AM1). Company policy does not explicitly state anything about hiring or not hiring young women, but motherhood appears to be a problem. In speaking about the small number of women a female interviewee with no children explains: ''*I think a lot has to do with having children and the responsibility that a woman takes on to raise her children or when they are sick and so on'* (AF1). Another considers that maternity leave hinders the recruitment of women: "*that's a disadvantage with women… because you are at home for three months'.* Female interviewees remembered being asked during the hiring process about their future plans regarding family, etc., and being warned that it could be difficult to accommodate family life with a managerial position. In Company A, part-time arrangements are not available for people in highly qualified positions: '*We have certain layers in the company where a part-time is not allowed*' (AF3). An interesting exception is one of the female interviewees who is a mother of three and who has worked four days a week since she joined the company. She says she works as much as if she were full-time: '*I work four days but I think my days are longer. But it's my decision! I prefer to be at home one day a week, and then I do my job of five days in four days'* (AF2). But her situation was not mentioned by the others. For example, according to the company's human resources policy part-time contracts are only available in case of serious illness: '*As soon as you're in a management position, unless you are ill or something, we don't agree on part-time regimes'* (AF3). Full availability for the job is the rule for being promoted: '*What I do see is that as soon as you move up the ladder in a company, you work full time and you spend a lot of hours in the company* (AF3). And the same interviewee concludes that '*As soon as you adapt to that profile, then it doesn't matter anymore if you're a man or a woman'* (AF3). Most interviewees believe that men's involvement in family life is an increasing trend in today's society: '*More men are taking their family responsibilities seriously '*(AM1); and: '*Also a lot of men take care of the children when they are sick and so on, or work floating working hours and so on'* (AF1). However, from the interviewees' discourse, the company does not seem to have developed a concern for work-life balance, and women are still considered as the ones who are in charge of managing family life.

Case study A: Discussion

Company A appears to be open to diversity, but certain organisational practices assign women to a 'minority status'. A minority status means belonging to or being identified as a member of a group with lower power

than a dominant group (Butera and Levine, 2009: 2). In the present case, women can be identified as a 'minority group' in two ways. The structure of the company reveals several different gendered spheres. Certain spheres are considered a '*woman's world*' (AM2), but the manager is still a man: '*In our assembly department, there are only two men. One man is manager, and then, the rest are 150 or 140 women*' (AF1). In such an environment, women have minority status because they are unskilled; the only qualified employees are men. Other spheres are referred to by several interviewees as a '*man's world*'. This is the case for the technical departments. The women who work there are highly qualified, and they primarily define themselves in terms of their professional identity. But they are few, and they must cope with men's reminders concerning gender (jokes, male-female discussions, etc.). Other parts of the company are mixed-gender spheres; several have at one time or another been managed by a woman, but these women have all since left the company and were subsequently replaced by men (logistics, ICT, human resources, marketing, sales).

CASE STUDY B

Institute B is a research institute located in Germany and founded in 1993. The institute is part of a much larger research organisation. It is engaged in applied research for industry, in particular working on technologies and services to develop reliable electronics and integrate state-of-the-art technology into applications. Their customer base is wide and varied, ranging from international electronics corporations to SMEs seeking to integrate electronics into their products. It also works in close collaboration with several academic institutions. The institute's total turnover for 2013 was €29.4 million with external revenue representing 77% of the total. On the site we visited, staff numbered 389 in 2013, including 151 student assistants, masters' students and interns and eight apprentices. No gender breakdown is given in the annual report. As regards gender equality the Institute has an equal opportunity policy and has participated for several years in campaigns and projects to encourage young women and girls to engage with science and technology. All interviewees work in the environmental and reliability engineering department, more specifically in three of the working sub-groups within this department, namely technologies for resource-efficient electronic systems, environmental evaluation and eco-design, and environmental legislation. Currently LED technology represents an important research subject. The institute has a rather flat, non-hierarchical structure. As in Company A we interviewed five members of staff, three women and two men. We interviewed the person in charge of one of the three working sub-groups and two others responsible for a particular research project within the department.

Inclusion moves

Overall, Institute B appears more inclusive than Company A. We identified two main types of inclusion moves in the work practices described by the interviewees: 1) Making room for positive discourse,

exchanges and interactions concerning gender, 2) Creating a flexible workplace beneficial to both women and men.

Making room for gender

Collaboration between men and women appears effective, and conflict is not associated with gender but rather with individual behaviour. Different interviewees spoke of conflictual persons (both male and female) that they had encountered in certain projects. Male interviewees consider that the '*atmosphere*' is '*more relaxed in a mixed group'* (BM2) and sometimes '*more friendly'* (BM1). Women at work were not associated with stereotyped characteristics. For example, one male interviewee explained that '*Some women tend to keep things in the group more, preventing people from breaking away, or maybe stopping discussions that are going nowhere'*, and he added: *'I always do this, or at least I try to'* (BM2). Nobody mentioned any specifically male-female conversations in the department, or any problems of communication: *'We are very conflict free because we are able to talk with each other'* (BF1). One female interviewee from Spain experienced more gender equality in working relations within Institute B than in her previous work environment: *'I could feel how everybody was talking to me, and you see that they feel like we are equals'* (BF3). Another female interviewee remembered that when she first joined the Institute, her boss allowed her to lead a project that entailed a lot of responsibility: *'… to launch the proposal for a €4 million project… and it worked, it was accepted, that was the most fascinating thing! And, I'm well able to do that, to take decisions'* (BF1). Gender does not seem to be a problem in professional relations: *'I think that the fact that I was a woman was never a problem for the other party, and I was never made to feel uncomfortable' (BF2).*

Flexible work policies

Many employees in Institute B have a part-time work contract: *'The Institute is favourable if you want to work part-time'* (BM1). Part-time work is not associated with low-status positions: '*There is work flexibility, especially for those in highly qualified positions'* (BF1). Young mothers can benefit from part-time jobs: *'A lot of us here work only part-time, in particular in our department. It's mostly the women with small children right now who do that'* (BM1). One female interviewee who works part-time considers that she does as much work as if she were working full-time: *'I have the energy to work and I'm eager and I get this energy because I also have time for myself'* (BF1). She has set up a kind of job shadowing system: *'I'm putting efforts into being replaceable. Everyone within the group knows what I'm doing and what the issues are now. So, if I'm not there, my colleague is able to answer the phone, and knows more or less what it's about."* In such a context, maternity leave does not appear to disrupt the organisation of work: *'There was absolutely no problem when I told my boss that I would be away for a few months'* (BF2), one female interviewee said. However, managing a flexible workplace is not that easy from her male boss's point of view: '*You have to get the work organised, and it's a lot of stress. It's a lot of additional stress sometimes, but in the end, everything works out'*. And his position on working women is very inclusive: '*Two souls inhabit my chest… one of them sometimes says "oh no, not again… it's a disaster … How are we going to*

arrange everything?" And the other one says "Now okay," to put it bluntly, "do you want to be the typical asshole saying that women should just stop working and stay at home if they give birth? Is that what you want?" And so, I give preference to the other one (soul), because that is not what I want, definitely not. I don't want that here, and I don't want to have it at home either' (BM2).

Exclusion moves

Institute B's environment is globally woman-friendly. Nevertheless, we identified two exclusion moves: The first is related to eligibility conditions for being promoted. The second is related to social exchanges and interactions outside working hours.

Eligibility conditions for being promoted

Part-time qualified jobs are easy to get in Institute B, but most interviewees believe that if someone is looking for promotion, he or she should work full-time, because part-time work *'is definitely not an advantage if you're looking for promotion'* (BM1). German law allows both parents to share a 14-month long parental leave after the birth of a child, and the father has to take at least two months leave. However, the policy at the Institute discriminates against men: *'Here in the institute, we are not replaced during parental leave. They accept when the guys stay at home for two months, because that's like the minimum you have to do when you want to get the full allowance from the State. So, they say "OK, they will do 2 months more or less." But if someone says "OK, I want to share the time equally with my wife, and stay at home longer and take care of the children", it's not really accepted'* (BF2). In the short term, women are favoured; but it is then difficult for women to move up the ladder, and to advance their careers: '*It's a lot easier for the women to stay at home than for the men. And I think if the situation were equal, it would be a lot easier for the women to come back. They could really choose, based on their family situation, who stays at home and for how long, but being at home for six months, or one or two years, that has a huge impact on your career.'* (BF2). Moreover, certain behaviour is expected in order to be promoted, i.e. a high commitment to the Institute and ambition: *'I don't think it would depend on the sex of the person, but the secondary effects, which are again the willingness to..., the fact that you have worked a lot and shown a lot of ambition and a lot of engagement for the institution, which also means going out for drinks in the evening'* (BF1). A male interviewee recognised that *'Once there are children, then it's sometimes difficult really to work in a higher level position, because you're expected to be at least 100% available for the job'* (BM2). As a matter of fact, *'Most Institute leaders are men'* (BF2), and *'There is no female head of department'* (BF1). One male interviewee introduced an intersectional perspective on how people get promoted in the Institute by linking gender and social background, *'If you look at who advances to high level positions, it's very often people whose parents are in high level positions, because they come from the same background - an environment which those in top positions already know very well, because it's their own.'* (BM2).

Social life in project teams

We have already mentioned that in order to be promoted, it was good to go out after work with colleagues for a drink. Only '*a few women*' (BF1) join those groups, thus conforming to social norms. It is *'quite unusual'* for a woman to go out in the evening after work for a beer; women are supposed to be more involved with child care. Another factor appears to impact the gendering of certain projects in the area of environmental engineering at the Institute. The dominant culture is that of the industrial engineering colleagues. One male interviewee reports: '*They are somehow in projects which are very technology-focused, which is OK, but you're slightly lost in the "small talk conversations". What also struck me at that time was that as soon as there is some break where you have some small talk, all of a sudden, you talk about cars! (...) I have a driving licence, but I don't have a car. But it was shocking also for me. If you're not really used to talking about cars, if you're not passionate about cars, you're really lost somehow in such kind of small talk.'* (BM2). Obviously, not all men are interested in cars, but cars are associated socially with masculinity. Talking cars regularly within a group has a symbolic meaning, and can be considered as 'doing gender' (West & Zimmermann, 1987). Such talk establishes a masculine zone, where insiders interact in a masculine competitive mode (who has the best car? whose is more powerful?, etc.) Outsiders are banned from this field of male expertise, be it real or imaginary.

Case study B: Discussion

In Institute B's environmental research activities, mixed-gender teams are frequent, and people collaborate on an equal basis. However, the work policy favours women's work/life balance, and men are not offered the same conditions as women when they have children. The reverse side of this is that early on in their careers, women do take responsibility professionally, but starting at a certain level the floor becomes "sticky", and no woman has yet become a member of top management. Furthermore, according to interviewees, environmental engineering is more open to gender diversity than industrial engineering: *'I think electronics engineering or electrical engineering is still very much ruled by men'* (BF2); *'Somehow, if it's for machinery building and so on, or civil engineering, it's very clearly dominated by men, 95% men at least. In environmental engineering, it was somewhat different: two thirds men, one third women'* (BM1). According to a female interviewee, *'on the topic of environmental questions, there are more women working, but the more electrical part and electronics, a lot of men work there'* (BF2). A male interviewee remembered that when attending courses with engineers not involved in environmental engineering the atmosphere was different: *'I felt it was more dominated by typical male topics of conversation, at least topics which are traditionally considered as such, like cars and how to go and come to work by car, and so on'* (BM2). However, people working in environmental engineering activities appear to develop their own culture, one that is less competitive and more socially concerned.

Concluding remarks

In both cases interviewees were asked how to improve the gender balance in the environmental field. Promoting environmental technology and design amongst children and young people was mentioned by most interviewees, whether from Case A or Case B. But they were sceptical about the effectiveness of actions such as "Girls' day". Positive discrimination was seen more negatively in the industrial setting, where gender is more an issue than in the research setting. Company A implemented affirmative action to hire non-EU employees, and this was evaluated positively by our interviewees; but surprisingly, concerning gender, they all think that actively looking for female engineers would lead to hiring a less competent person. Nevertheless, a male manager suggested that the company should set up an in-house training course to *'recycle'* (AM1), young, highly educated women into the technical lighting sector. Another interviewee wondered whether "gender-blind job recruiting" would not help to remove gender bias when hiring. In Institute B, all interviewees except one agreed that positive discrimination in favour of women would be necessary to increase the number of female engineers. Suggestions however, were also made to improve working conditions to achieve a better work-life balance, especially for men. This could increase gender equality between men and women with regard to career advancement.

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