Value Retention Options in Circular Economy
: Issues and Challenges of LED Lamp Preprocessing

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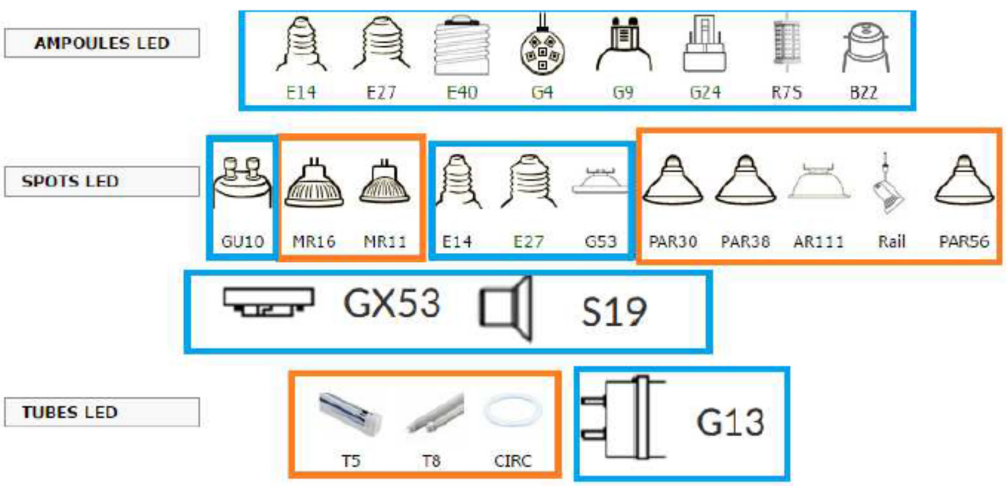

Figure S1 : Various type of LED lamp and Tube. AMPOULES LED = , SPOTS LED = , TUBE LED = , Yellow boundary denotes the shape based category while green boundary denotes base type category.

There are different types of Bulb in the market. However not all of them usually returns at the market. With researcher experiences from the sampling of five big bag, a general composition of lamp is made.

Bold = more prominent

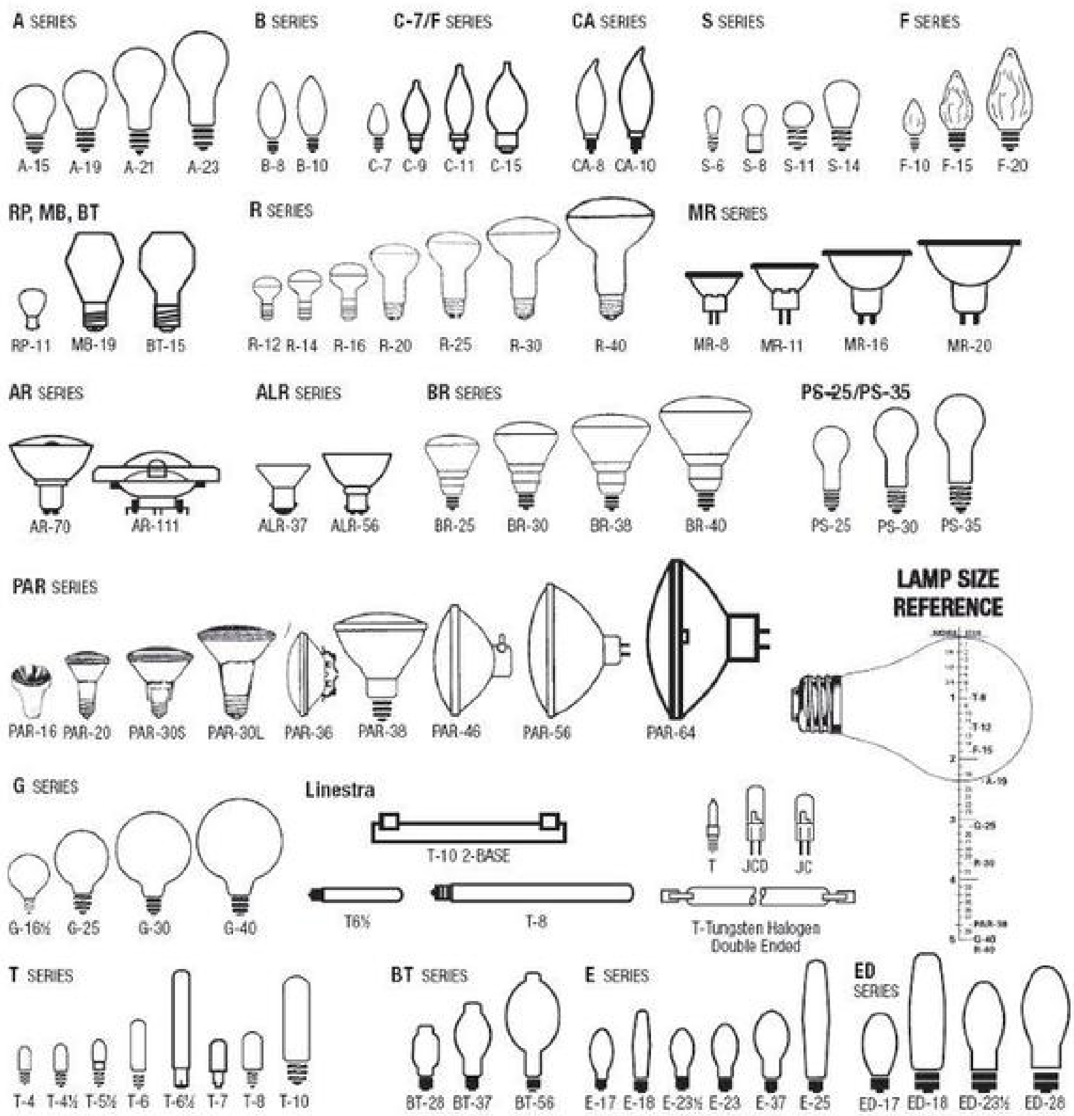

Figure S2: different shapes and sizes of LED lamp in the market taken from thelighitingfactory.com (2019), available at [https://thelightingfactory.com/pages/bulb-shapes-and-sizes accessed at 09/02/2019](https://thelightingfactory.com/pages/bulb-shapes-and-sizes).

Recycled fraction comparison between LED and CFL:

Figure S3 shows that LED lamp does not almost contain any glass, replaced mostly by plastic in the lamp cover, while CFL lamp does not contain any LED chip and package while contains small quantity of ferrous and non-ferrous metals. While CFL recycling generates fluorescent powder, LED recycling fraction does not tend to produce any such powder fraction. The LED bulb, on the other hand, produces metal fraction and other electronic output rich in precious and rare earth metal.

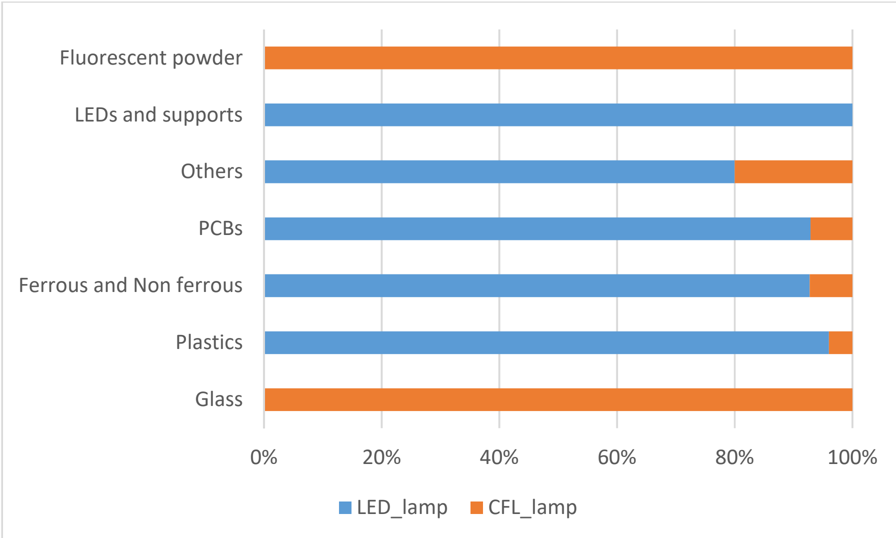

Figure S3. Type of recycled fragments in LED lamp and CFL lamp. (Source: Recylum 2015)

Inconsistency of material composition even at the same model:

When we disassembled lamps of the same model, we found that they have similar weight, with little variation among the weight of the constituent material (Figure S4). However, we still found that they do not have the same composition material. For example, in model 1, one lamp had resin attached to PCBs. Similarly, in model 3, one lamp contained no resin in contrast to the other two that contain resin. It is quite surprising that even within a model, there is no consistency in design. This fact is partially addressed in Seidle (2015) blog post: he dismantled the same brand model with different price tags and argued that it is the quality of PCBs that differs in different product, leading to cost differences of the otherwise similar LED lamps. Seidle (2015) contends that the lack of standardization may well be intended by manufacturer to win a price advantage and to reach a wider set of customers.

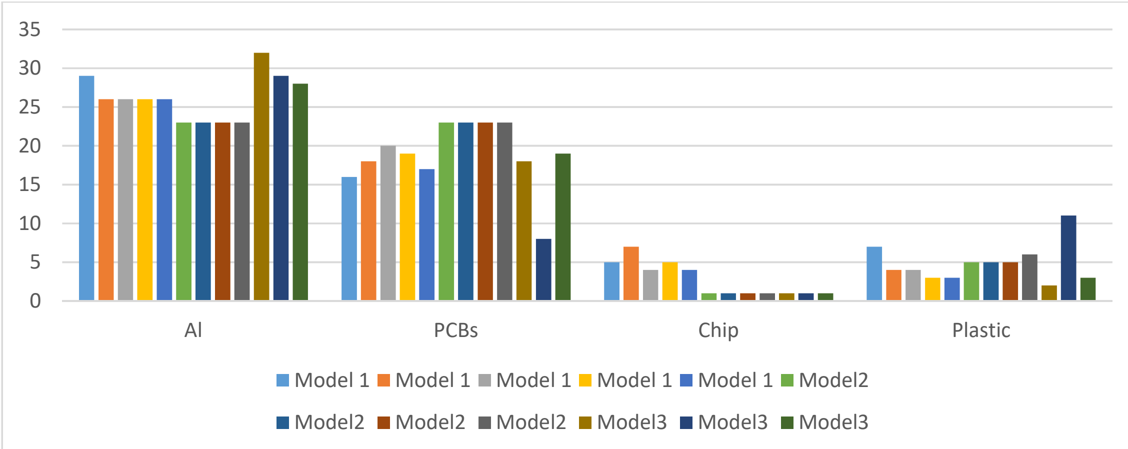

Figure S4. Inconsistent output fractions (unit: g) of model 1, model 2, and model 3

LED lamp failure:

LED lamp failure rate at the manufacturing facility is about three percent, while during usage, the failure rate is twenty percent (Jody Cloud 2016). The most frequent causes of failure of LED lamps are poor quality materials (poor driver, low thermal management, smaller LED chip, and gradual decay of lumens); lack of adequately rigorous testing (diligent manufacturers will test LED lamps by repeatedly turning them on and off, and by leaving them on for extended periods of time, usually ten days); and lamp operating temperature. Moreover, most technical failure of the LEDs is caused by the malfunctioning of drivers in dissipating heat from the LED chips. The reported cause of the reduction of light output is the degradation of the epoxy resin and the phosphor die due to excess heat. These losses may be avoided by encapsulating the semiconductor die in a new epoxy resin.

Defining Planned obsolescence:

Planned obsolescence (PO) is defined as creating 'in the buyer the desire to own something a little newer, a little better, a little sooner than is necessary'. According to the Oxford dictionary, PO is 'a policy of producing consumer goods that rapidly become obsolete and so require replacing, achieved by frequent changes in design, termination of the supply of spare-parts, and the use of non-durable materials. Three ways to stimulate PO are (1) limiting product durability, (2) lack of reparability - including restricting the availability of spare parts, not producing spare parts, creating incompatibilities of spare parts with new models - and preventing disassembly by gluing or other specific tools. Finally, (3) the psychological element of design includes aesthetic and technological superiority over the previous model, via advertising and seasonal sales promotion. Maitre-Ekern and Dalhammer (2016) state that a severe case of PO is the intentional introduction of a failure in the product design that ensures short life of a product. One example of the intentional PO is the reduction of life span of light bulb to 1000 hours, in 2000, when the average life span is 2500 hours. Sometimes companies that could not reduce the lifespan were fined for boosting economic growth. Present EU eco-design requirements set LED lamp durability at 6000 hours, whereas the optimal durability of the available LED lamps in the market is 25000 hours.

Benefits of longer life spans (hence eliminating PO) are not straightforward. For example, a shorter life time is desirable for a product that improves efficiency by 30% and reduces purchase price by 10% (Richter et al. 2018). In contrast, Tahkamo et al. (2013) found that the shorter life time poses higher environmental challenges, suggesting that the relative importance of manufacturing may potentially overturn the efficiency gain in the use phase. Richter et al. (2018) however suggest that the dilemma about lifetimes of lamps may depend on the type of energy mix used in the use phase. The more renewable the energy mix used in the lamp, the bigger would be the relative importance of the manufacturing impacts and hence the more desirable would a longer lifespan be.

Reference:

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