Prototype of improved refrigerators

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Revised after rewiew

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Technical References

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Executive Summary

This deliverable aims to illustrate the activities performed by Electrolux targeted to the analysis and to the identification of potential areas of improvements for the design of a new prototype of refrigerator in some aspects, such as the materials selection, the combination of joining methods, the recycling process and solutions for increasing the recyclability of PU foam which is the core of the CIRCULAR FOAM project. The document presents a comparison of the recyclability indexes between a baseline refrigerator and the new refrigerator platform called 'Genesi', recently industrialized in the Electrolux Susegana Plant (Italy) as a starting point for the new design. The Genesi range already presents a higher recyclability index due to the replacement of non-recyclable materials, but some recommendation for the new prototype has provided to obtained higher levels of recyclability.

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1 Introduction

The home appliance industry uses large quantities of materials, energy and resources that have a significant impact on the environment at every stage of products life cycle: from the extraction of materials to production, transport, up to the use phase. For instance, to produce washing machines, fridges and dishwashers, the European industry uses every year about 500 kt of steel, 200 kt of plastics, 60 kt of copper and 40 kt of aluminium; during usage, the total energy and water EU consumption sums up to 25 TWh and almost 2 km³ of water per year.

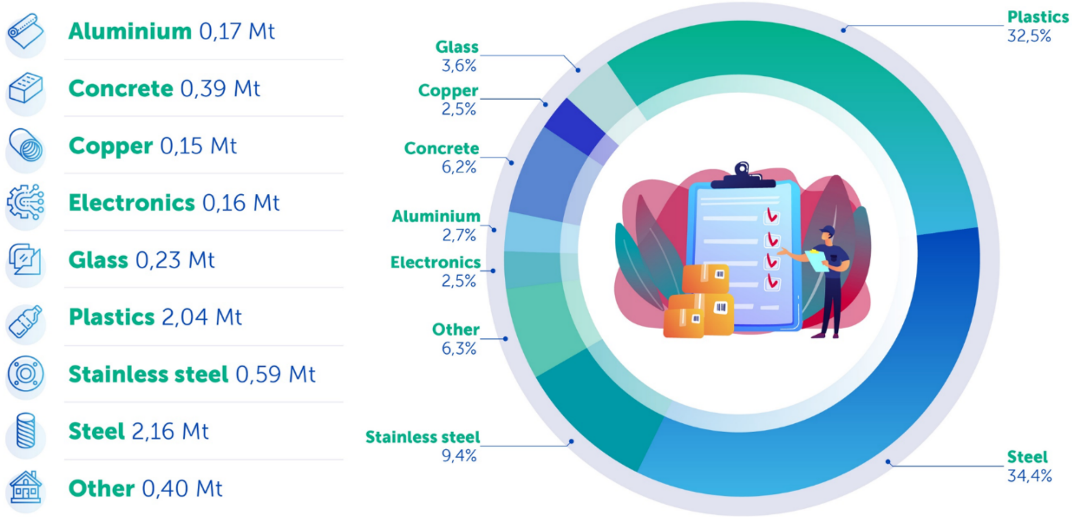

Fig 1: Quantity of single material used by home appliance sector

Over the years, home appliances manufacturers have increased the efficiency standards at the user phase, but also with raw materials sourcing, the design and production of appliances. in the recyclability there still some gaps to close; 90% of the materials coming from the officially collected appliances, when they have reached their end of life, are recovered, recycled and ready to enter again into manufacturing loops; however only 35% of appliances are collected and recycled in the EU each year. The sector is now committed to do more. Beside the new energy labelling regulation, for saving energy consumption, in March 2022, the European Commission, with the Sustainable Product Policy initiative (SPI), presented a first package of proposals to accelerate the transition to a circular economy, pushing the industry towards a market of devices with a longer life cycle. The Ecodesign for Sustainable Products Regulation (ESPR), in fact, outlines new requirements for device manufacturers to make their products more durable, reliable, reusable, repairable and recyclable, as well as more energy efficient.

As a global leader in household appliances and in sustainability, Electrolux has set a series of ambitious targets to reduce its own footprint, to achieve climate neutrality in operations in 2030 and throughout the value chain by 2050.

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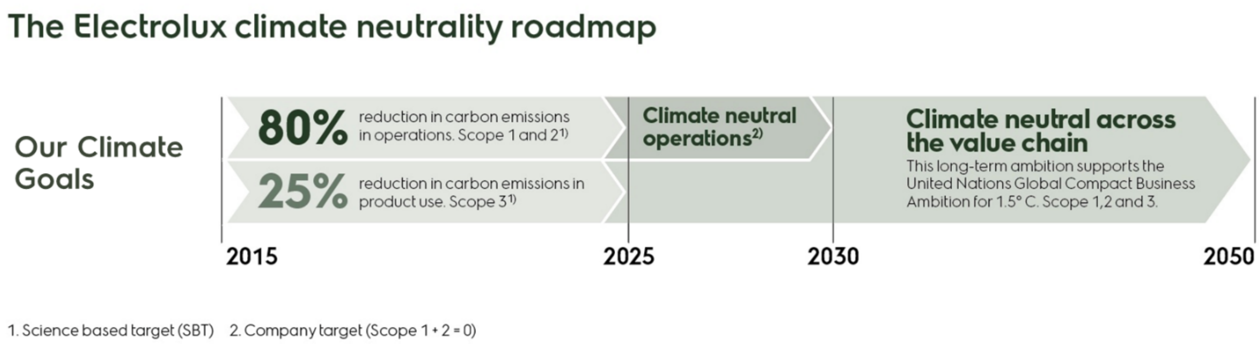

Fig 2: Electrolux sustainability goals

One of the aims of this Program is to contribute to the adoption of a circular economy by integrating recycled materials into product platforms, promoting recyclability, using more sustainable packaging solutions, increasing the availability of spare parts to repair our products, design products that can be more easily repaired and recycled and, in general, developing circular business solutions.

In the specific segment of refrigerators, analysis on recyclability and circularity have been conducted by Electrolux to identify key areas and design strategies to be applied to the next generation of refrigerators starting from a comparison between the ultimate product platform called 'Genesi' and previous platform as a baseline highlighting the progresses already achieved in this direction but also the gaps to be covered for a complete refrigerators' circularity.

2 The recycling process for domestic refrigerators

The waste stream of refrigerators and freezers is a rapidly growing and a specialized recycling process is required. It is designed for high throughput and efficiency which limits the room for customization and inevitably leads to losses of recyclable materials at the tail-end, e.g., small volumes of specialized plastics. The key precondition to perform an effective and clean recycling process is the quality of the "raw material" and, within the specific scope of CIRCULAR FOAM, the case of PU foam fluffs and powder, against the risk of contamination by other materials used in the appliance. Moreover, the manufacturing process of domestic refrigerators and freezers is based on the injection of PU foam into the insulation cavity and on its capability to get a good adhesion to both plastic and metal liners. This implies that during the end-of-life treatment of the appliance the separation of PU foam from liners may be critical and metal and plastic particles could be present.

The starting point for increasing the purity level is a better understanding of the parameters affecting recyclability and what dimensions to measure and set goals for when it comes to recyclability.

Typically, there are six output fractions (see Figure 1); mixed plastics, mostly polystyrene (PS), ferrous metals, non-ferrous metals, glass, polyurethane foam (PU) and compressors. All fractions are further refined downstream of the cools process. In particular, the plastic and the PU fractions are seen as a residual with significant impurities that needs additional treatment.

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Appliances ranging over 30 years in age are treated in the same process. A small snapshot sampling reveals that almost half are discarded too early (before the nominal service-life of 14 years). Others reach the recycling facility long after they have stopped functioning (or should be discontinued due to the ODS ban) as they are used as e.g. storage furniture in a second use cycle.

Fig. 3: Output fractions from recycling process of domestic refrigerators and freezers

3 Comparison of recyclability index

3.1 Baseline refrigerator

Electrolux has developed a new range of refrigerators internally called 'Genesi' and produced in Susegana's new plant in Italy, which has shown an improved design for higher recyclability in relation to the previous range. A recyclability assessment was initially performed on the baseline Electrolux fridge sample and has provide an index of ~81% (by material weight), a similar propensity as the average product in the cooling process. However, for newer products the secondary material value is dropping as plastics have replaced metals during the past decades. This poses a risk in the mid-to long-term if it leads to less drive from recyclers to properly treat these products. In case glass fibre used for insulation, it ends up as landfill.

Half of the material types in products are not recycled. Even if a material is recyclable in theory, it does not mean that it is in practice since the recycling process is adopted to recycle bulk materials with a value on the secondary market. Materials used in small quantities and/or which are difficult to remove and isolate will therefore not be recycled. When it comes to plastics as Polystyrene (PS), acrylonitrile butadiene styrene (ABS), polypropylene (PP) and Polyethylene (PE). they are generally incinerated. The incineration process allows to recover energy. Findings are based on a detailed disassembly and analysis of the baseline sample. Six parameters were used to evaluate the recyclability (material choice, material combination, joining methods, recycling process and recycling system). Material choice (PU-foam and glass fibre) is the main parameter limiting the recyclability. Ferrous metals are easily separated and recycled in a mechanical process due to their magnetic properties. Glass has a pure fraction thanks to ease of manual separation. Among material combinations and joining methods, glued parts and composite panel are key obstacles for recycling, while snap fits promote

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recyclability. Copper and aluminium (otherwise valuable materials) risk ending up in plastic stream when surrounded by foam.

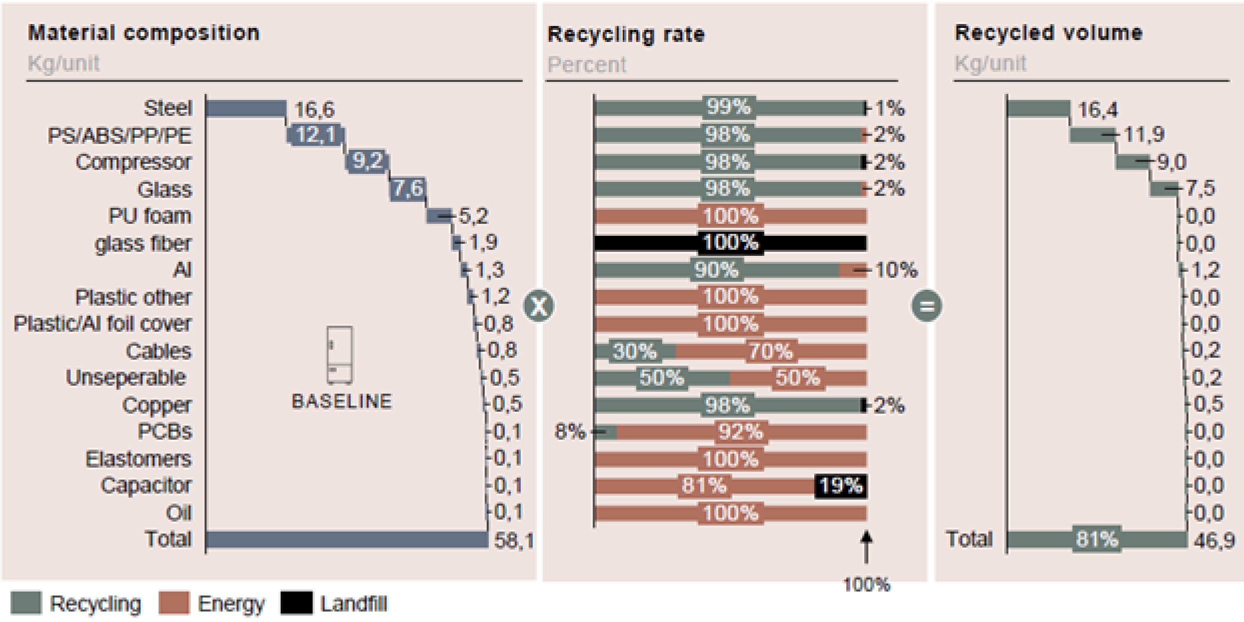

Fig. 4: The fridge baseline recyclability index

3.2 The Genesi range

The new Genesi range can release up to 20% less CO_2 emissions than their predecessors and over 80% of the fridge material is recyclable, making them the most sustainable fridges on the market. They can preserve vitamins for up to 95% longer, can help reduce food waste by up to 20% using precise electronic sensors, and keep food 60% juicier and more hydrated via a dual cooling system.

The Genesi Bill of Materials (BOM) has been analysed in relation to the Baseline model BOM to have an apples-to-apples comparison. The assessment has shown a similar result as the Baseline BOM, but Genesi has a slightly higher recyclability (86% vs. 81%) due to replacement of not recyclable materials but is consequently a heavier product. The absolute amount of material not recycled is roughly the same. The improvements achieved to optimize automation of assembling during production does not affect the recyclability since the recycling process is not a reverse assembling, but rather a mechanical fragmentation.

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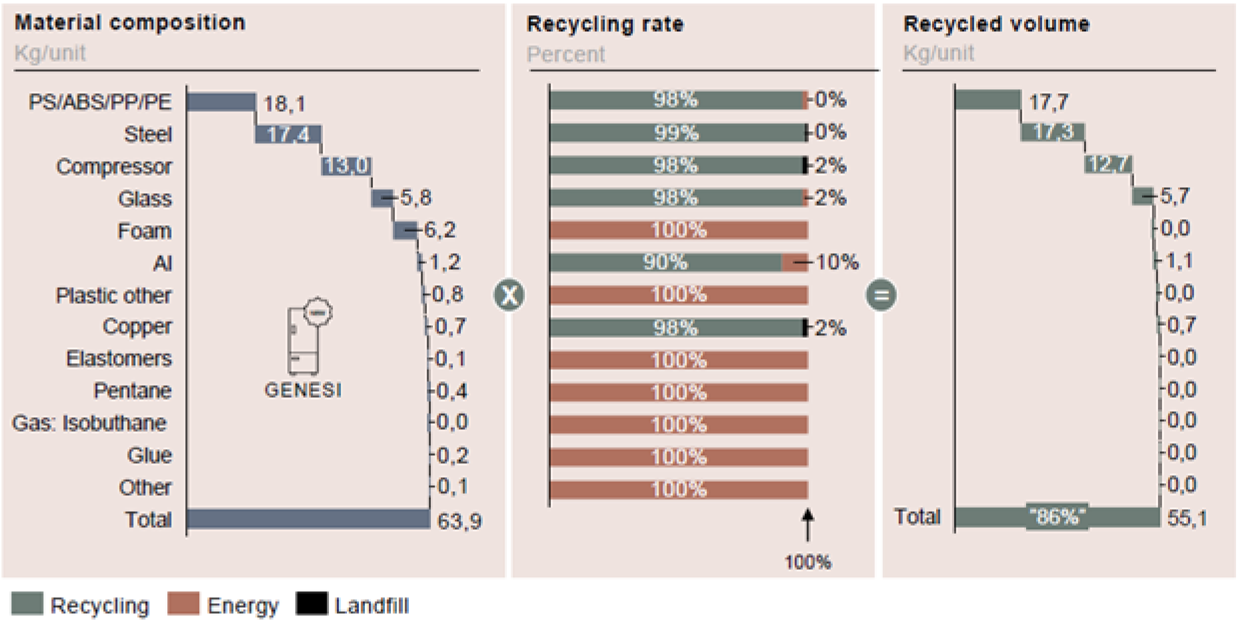

Fig. 5: Genesi recyclability index

4 Further potential improvements

In the next few years, it is likely that in Europe, more plastics will be recovered from the mixed scrap fractions which are mechanically treated today. New technologies will be introduced, and existing technologies will be improved. Looking ahead more manual steps are foreseen to be added to the recycling process of refrigerators and freezers, like manual removal of storage boxes in a mono stream of PS and removal of electronics to be able to capture precious metals.

For the design of an improved refrigerator (prototype) Electrolux is working on various areas; beside the recycled PU foam, current objective of CIRCULAR FOAM project, alternatives to glass fibre and electronics are under investigation to significantly improve the recyclability of the product and deal with the remaining ~19% of materials not recyclable.

In general, exploring possibilities of using more recycled material in the future prototype is an additional aspect of enhancing circularity and footprint. It can also send important signals to the recycling industry to improve their processes. With the increasing demand for recycled material, recyclers are incentivized to invest in research, process development and new technologies to further increase the capacity for, and quality of, producing recycled materials. In this context Electrolux (along with its peers) has a role to play both as market maker and market stakeholders.

4.1 PU foam and glass fibre

The most important area of improvement in the study of the new prototype has been identified as the Recycling or Reuse of PU-foam and glass fibre in vacuum insulation panels (VIP). If both PU foam and VIP core material were recyclable, this could raise the recycling index of the prototype by ~9% and ~3% respectively. It’s clear that the cleaner material is available in the beginning, the cleaner fraction is in the end. Electrolux, in its studies, has noticed that there

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are impurities in the plastic fraction and non-ferrous fraction coming out from the recycling facilities. This is partly because of the PU foam that is attached to all kinds of materials and hinders separation of those. The above is from a recycling perspective only, not considering the function or climate impact of the components.

4.2 Electronics

Another important area of improved design for the prototype is to secure the recycling of the electronics which could be done by separation before the fragmentation. A take-back system or an agreement with a service partner or a recycling company could be an option. To reach a higher recyclability for the electronic components it would be worth considering changing the plastic materials to any of the four types that are recycled today, if possible, from a functionality and safety point of view.

4.3 Recycled materials

Another aspect is looking into possibilities of using more % of recycled material in the prototype (plastics, metals, etc..). To increase the level of recycled content in the product would impact the overall sustainability of the product in a positive way. Not only by reducing the need for virgin raw material and saving the finite natural resources of this planet, but also because it reduces the carbon dioxide footprint of the product since recycled material require less energy to produce. By specifying a certain degree of recycled content in their products, a company can contribute to creating well-functioning markets for recycled material. Higher demand for recycled material, generates incentives for the recycling industry to invest in more research, process development and new technology to further increase the capacity for, and quality of, recycled materials.

5 Conclusion

The report provides recommendations for further improvement for the design of a new prototype of refrigerator, emphasizing the importance of material choice, their combination, the joining methods, the recycling process and system for increasing the recyclability of PU foam. In particular, the deliverable has highlighted the need to ensure the purity of raw materials to improve the utilization effectiveness as in the case of the separation of PU foam from metal and plastic liners. The recycling process of refrigerators has been described, with a focus on the output fractions and the limitations of the process. The report has also presented a comparison of the recyclability index of a traditional baseline refrigerator and the one obtained with the new Genesi range, as a starting point for the design of a new prototype.

The project work leading to this deliverable has investigated in close interaction with the recycling technology development, the influence of additives/ raw materials on the smart pyrolysis / chemolysis depolymerization. Based on these results and the insight from the recycling processes, new recipes and polyols were developed. The foams that were produced on the basis of the new developed formulations, will be tested in the frame of the recycling-related work. These results will show if these formulations can increase the recyclability. The results of these tests will be reported D4.3 “Procedure of the chemolysis and the separation of amines

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and polyols at 250 ml scale and pressure) for the chemolysis process including separation of amines from polyol at typical lab-scale eg. 250 mL" in M36. Then also results of the recycling of the new foams will be available.

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