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CIRCULAR FOAM

Demonstration of the design for recycling

Deliverable 6.4

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Technical References

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Executive Summary

CIRCULAR FOAM work package 6 revolves around the demonstration of the developed technologies for the polyurethane value chain. In this context, task 6.4 aims to demonstrate the practical implementation of design-for-recycling principles building on information gained from all relevant workpackages, including, but not limited to WP2, 3 and 4. More specifically, three products have been redesigned in this task to improve their recyclability, without compromising on their performance.

Electrolux improved the recyclability index of their Genesi type refrigerator from 81% to 86% by using harmonized materials and elimination of adhesive types.

Kingspan developed a new panel design based on customer feedback and the principles of lean design. This lower embodied carbon panel range has a 21% reduction in embodied carbon (A1-A3) and a 15% reduction over the full life cycle (A-C) compared to standard panels. Additionally, QR-coded side tapes were also included for the integration of a digital product passport, aiding recyclability and stakeholder transparency.

Unilin developed a new insulation board called UTherm Next, which utilizes a mono-material aluminium facer and a PU coating to replace the traditional multilayer facer. Additionally, the fossil-based polyol is substituted by a circular polyol containing 30% recycled and 70% biobased raw materials.

The results described here highlight that design for recycling can be implemented across different polyurethane-based products and provide a strong first step for the upscaling of product development along the principles of design for recycling and integration digital tools to aid end-of-life waste management and recycling.

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1 Introduction

The transition towards a circular economy requires not only the development of recycling technologies but also the rethinking of product design. Products with complex or unknown material compositions or difficult dismantling steps hinder effective recycling steps, notwithstanding how good a recycling process is. The Circular Foam project also addressed this challenge by utilizing knowledge gained from all relevant work packages to innovate the design of polyurethane-based products to facilitate their recyclability.

This deliverable highlights the innovative steps taking by three manufacturing companies, namely Electrolux, Kingspan and Unilin, to integrate circularity principles into their product development processes preparing making them fit for the future. The following section describes in detail the approach taken by each company to not only improve the recyclability of their products but also to contribute to improved sustainability and resource efficiency.

2 Company specific design for recycling

2.1 Electrolux

Genesi is the name of the new Built-In (BI) range of refrigerators and freezers by Electrolux, Figure 1, produced in Susegana, Italy. The main characteristics of this new range are the cabinet structure in metal, to be compliant with the safety regulation on flammability 2 years in advance of the release of this global norm, and the easy installation into wooden furniture's.

Genesi is also the name of the factory where this new range is produced. The level of automation of this plant is probably the highest in the manufacturing of domestic refrigerators and freezers; more than 50% of the operations are performed by robot, providing accuracy and high repeatability in the parts assembly.

In the new Genesi BI range the recyclability index increased from 81% up to 86% thanks to harmonization in material usage and the consequent elimination of some material types, and the elimination of adhesive tapes. Further improvements could come from PU foam recycling and from redesigning some electronic components.

In the Genesi factory, Electrolux already uses the **QR code** on the components produced for internal use, which enables full traceability. For example, if you consider a plastic inner liner or a metal door panel, through the QR code Electrolux is able to identify the batch of raw material used to produce that part, and the batch of the internal components including the machine/line where they were produced. This information is very useful for a digital product passport of the finished product and could be included in the future as an opportunity to facilitate recycling.

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FIGURE 1: EXAMPLE OF QR CODE ON A REFRIGERATOR DOOR

2.2 Kingspan

Kingspan have developed a number of initiatives to improve the use of recycled material in panels, reduced input energies, and facilitate easier recovery and recycling. In terms of design for circularity, Kingspan drew upon the results from Deliverable 2.4 (Customer Experience Report), specifically the customer and stakeholder responses to the original prototype specification presented under Deliverable 2.2 (Improved Panel Design) and also from other work packages (specifically the recycling trial outcomes under WP3).

Under its Planet Passionate programme, Kingspan has developed the LIFECycle Product Circularity Framework which aims to enhance the circularity of our products. The Planet Passionate programme has also resulted in the recycling of over 1.1 billion PET bottles into our manufacturing processes [1], over 30% reduction in waste to landfill since 2020 and the launch of 19 products with improved environmental performance. The LIFECycle Product Circularity Framework seeks to develop and incorporate lean design principles, recycled input materials, improved factory processes, and opportunities for reuse and recycling at product end-of-life. This has led to the

[1] Sustainable business magazine, (https://sustainablebusinessmagazine.net/circulareconomy/kingspan-meets-milestone-one-billion-pet-bottles-recycled-into-manufacturing/)

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development of our Lower Embodied Carbon (LEC) range, including the QuadCore KS1000RW LEC Roof Panel, QuadCore KS1000RW LEC Wall Panel and QuadCore AWP LEC Wall Panel. Aesthetically, the QuadCore LEC insulated panel variants are indistinguishable from the standard QuadCore insulated panel products. Using comparative LCA data, the QuadCore LEC panels demonstrate a reduction of 21% in embodied carbon over lifecycle stages A1-A3 (cradle-to-gate) and a 15% reduction over A-C (full lifecycle) when compared with the standard QuadCore AWP Wall Panels in a 100mm thickness (in accordance with EN15804-A2:2019) [2]. This reduction was achieved with the use of steel manufactured by an electric arc furnace process, with increased recycled content [3]. As noted above, our focus to date has been on polyols derived from recycled material and one of our key interests in the Circular Foam project is the possibility of developing and incorporating increased levels of recycled MDI which makes up the bulk mass of PIR-based formulations.

In terms of flatter and less complex panel designs, we had originally favoured this option to facilitate easier steel removal (either via a mechanical ripper or possibly a wire saw). However, from outcomes presented in WP3, shredding the entire panel (steel and foam) at the recycling plant and separating the steel magnetically was also a viable option. Under D2.4, some respondents had some concerns the flatter designs could suffer from reduced structural strength as the crowns that provided reinforcement were absent. Separately, some respondents viewed the flatter designs favourably in terms of transportation and storage – particularly at end-of-life. To this end, future designs options will include those with minimised crowns while not eliminating them altogether to ensure structural strength is maintained. Additionally, recycled and bio-based alternatives are being considered for sealants to improve the circularity of these components also. Another aspect considered under D2.2 was the removal of side tapes to minimise waste from this source. However, this will likely introduce issues during production and replacement of current PP / PE side tapes with more recyclable options seems a more viable path to reducing non-recyclable waste overall.

The demonstration of digital product passports is presented and discussed under D6.2, however some points relevant to D6.4, specifically around the panel design and stakeholder feedback, are discussed below. Aside from regulatory requirements, stakeholders saw great value in being able to access digital product passport information via QR code. In particular, the ability to access information is of high importance to respondents as evidence of the sustainability credentials as well as to contain (dis)assembly instructions, safety data sheets, certifications, etc. From a Kingspan point of view, DPPs allow for comprehensive tracking of inputs and products throughout the supply chain and the ability to easily provide the above information to the customer in a rapid manner, minimising delays due to queries, follow-ups, etc.

Consideration also must be given to where the QR codes could be deployed on the panel. Ideally, they will be out-of-sight when installed for aesthetic reasons and also to protect the printed codes from climate and other factors that may rend them unreadable and unusable over the lifetime of the panel. In this instance, the obvious choice is to have the codes incorporated within the side-tape of the panel. Side tapes already commonly carry branding and other information and QR codes could easily be added. One aspect that will need to be resolved however is that the codes

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[2] Kingspan Planet Passionate Report 2024, p. 40 (https://viewer.ipaper.io/kingspan/c2410164-planet-passionate-report-2024/planet-passionate-report-2024/?page=81)
[3] The EPDs for QuadCore AWP LEC, QuadCore KS1000RW LEC and QuadCore Coldstore LEC are verified by a third party and available for download on EPD Hub's website (https://www.epdhub.com/).

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would need to be printed or affixed to the tape during manufacture to allow for the codes to be attributed to batch or individual panels accordingly. Figure 2 shows and example of the DPP QR code (demonstrated in D6.2) as it may appear when deployed, affixed to the side tape in this case (a). The code is readily visible at all times prior to installation (or post deconstruction) and can be rapidly scanned via smartphone or tablet (b).

FIGURE 2: DIGITAL PRODUCT PASSPORT QR CODES DEPLOYED ON PANEL SIDE-TAPE (A). DPP INFORMATION IMMEDIATELY AVAILABLE ON-SITE THROUGH SCANNED QR CODE.

2.3 Unilin

UTherm Next, Figure 3, is a novel product range designed and produced by Unilin with design for recycling in mind. Insulation boards consist of a PIR foam core, obtained through the reaction between pMDI, polyol and additives, and a top and bottom facer. Typically, the facer material is a multilayer of very thin sheets of kraft, aluminum, and PE and is used to ensure dimensional stability and improved long-term thermal conductivity values through gas-tightness. Additionally, the multilayer contains a treated PE layer that ensures proper adhesion of the foam to the facer.

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However, due to its lightweight, the multilayer is challenging to separate from the foam during pre-sorting steps before chemical recycling (chemolysis).

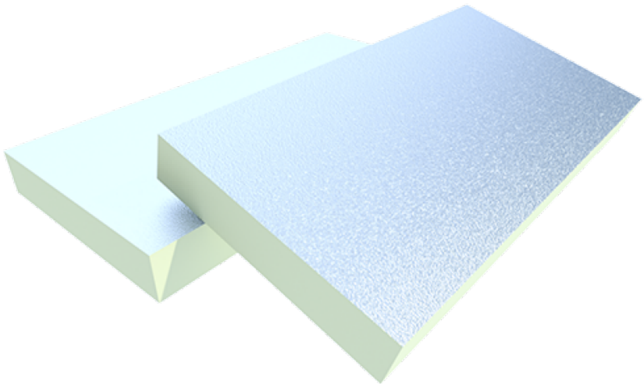

FIGURE 3: UTHERM NEXT A – NEW PRODUCT LAUNCHED BY UNILIN OF A RENEWED INSULATION BOARD WITH CIRCULAR CONTENT AND A MONOLAYER FACER MATERIAL

This issue has previously been tested and is well documented throughout WP3. Additionally, any traces of kraft paper can absorb significant amounts of solvent, hindering the chemical recycling process, by increasing the viscosity and absorbing chemicals making them unavailable for reaction. As a solution, Unilin has opted for a heavier 50µm thick aluminum monolayer, which increases separation yields and prevents potential obstructions in further recycling processes. The recyclability potential of the remaining facer fraction is also improved due to its mono-material composition. Moreover, the recycling of aluminum is already well established, further enhancing the recycling potential of the UTherm Next insulation boards. However, since the treated PE layer has been removed, an alternative solution to improve the foam-facer adhesion had to be found. Unilin addressed this by utilizing a PU coating on the aluminum monolayer that is compatible with chemical recycling of the foam and has great adhesion properties.

In the spirit of design for recycling Unilin did not stop at changing the facer material but also looked at the chemical building blocks of PIR. PIR insulation boards are primarily composed of MDI and polyol. For the launch of the UTherm Next portfolio, Unilin has transitioned their **polyol** from virgin to circular feedstock, comprising 30% recycled and 70% bio-based content. Although this development is not directly linked to the Circular Foam project, it aligns with Unilin's sustainability vision. The Circular Foam project, however, focuses on recycling rigid polyurethane waste into **pMDI**, which has a much higher impact than the polyol and plays a more significant role in the production of PIR insulation boards. With the efforts of the Circular Foam project comes a potential for drastically increasing the circular content of insulation boards, highlighting the importance of the project. The ability to convert PUR/PIR waste into pMDI will significantly enhance the sustainability and circularity of insulation board production. Nevertheless, by also utilizing a polyol from circular feedstock the UTherm Next insulation boards are Unilin's first insulation boards with a certified fixed share of circular raw materials.

As part of Circular Foam, QR codes that could be used to link to digital product passports (DPP) were also developed, Figure 4. Currently, a lot of different recycling methods are being developed,

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and it is not always clear which chemicals/products are allowed as input. The DPP could help recyclers by showing the composition of the foam and containing information on all relevant raw materials, making it easier for them to know if the foam can be recycled using their technology. It also would provide them with knowledge on any legacy chemicals, as the REACH regulations are constantly evolving, providing them with information whether the board can be recycled or needs to be destroyed. Moreover, the DPP could also include, among other things, dismantling instructions and date of production.

In parallel to the implementation of DPP regulations, specific methods to add such a QR code to products that also ensure its readability even on cutoffs will need to be developed.

The development of recycling technologies to obtain pMDI from insulation boards and appliances would be a necessary and major step forward in the design for recycling of insulation boards. The current design for recycling is focused on improving the separation of PIR foam and facer. Additional changes to the insulation board might be needed once new technologies have been developed to recycle both polyol and pMDI.

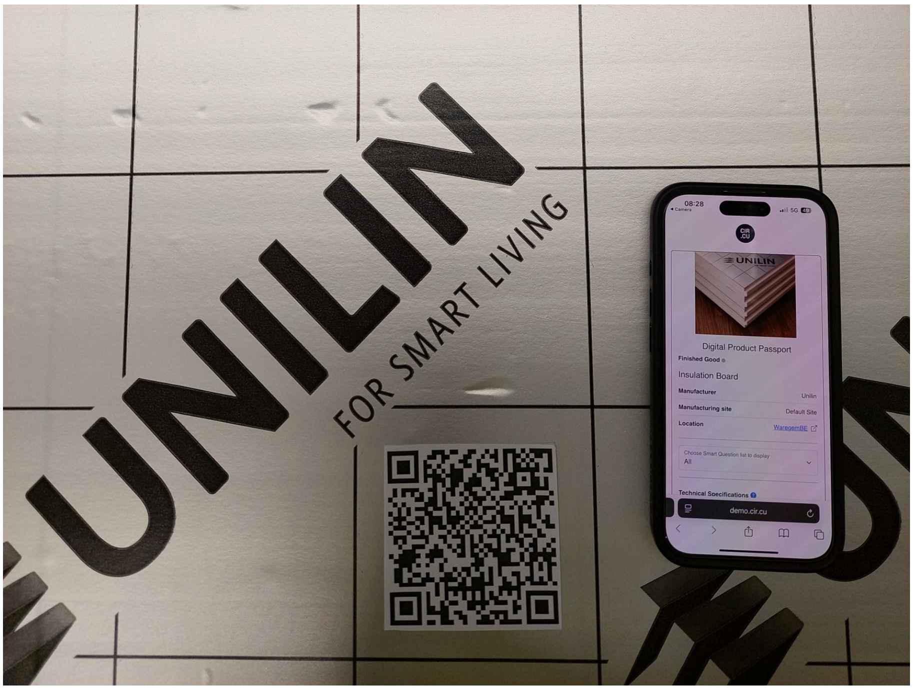

FIGURE 4: DIGITAL PRODUCT PASSPORT QR CODE DEPLOYED ON A UTHERM BOARD, WITH DPP INFORMATION IMMEDIATELY AVAILABLE ON-SITE THROUGH SCANNED QR CODE.

3 Conclusion

It is clear from the sections above that within the Circular Foam project significant progress is being made toward a more circular product design for a variety of different polyurethane containing products. Electrolux has further improved the recyclability index of their Genesi refrigerators from 81% to 86% and has innovated product traceability for components used in-house within their site by using QR-codes. Kingspan combined customer feedback with LCA data to develop lower embodied carbon panels with enhanced recycling features. Lastly, Unilin has designed a new type of Insulation board choosing to discard multi-material facer in favour for a recyclable mono-material facer in combination with using circular raw materials.

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Additionally, the first steps are being taking to determine methods to integrate a digital product passport as developed in WP2, which would ack as a key enabler for transparency, traceability and improved end-of-life waste management.

The aforementioned efforts demonstrate that leveraging information from the whole value chain starting from raw materials to dismantling and separation can lead to insights to further improve on and develop sustainable solutions for polyurethane containing products.

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