Rethinking recurring waste flows: Creating material cycles by identifying new use cases for idle materials

Johannes Scholz 1, Isabel Ordóñez 1,2 and Susanne Rotter 1

1 Department of Environmental Technology, Chair of Circular Economy and Recycling Technology, Technische Universität Berlin, Strasse des 17. Juni 135, 10623 Berlin, Germany
2 ELISAVA, Barcelona School of Design and Engineering, La Rambla, 30, 32, 08002 Barcelona, Spain

J.Scholz@tu-berlin.de, isabel.ordonez@tu-berlin.de

Abstract. This article presents Collaborative Material Workshops (CMW), aimed at identifying new use cases for commercial waste materials waste materials, which are continuously being generated and have valuable technical properties. With the assumption that such materials have a high re-use potential, they are defined here as idle material streams. The objective of CMW is to identify scalable and feasible applications for the re-use of idle material streams and to communicate those results to commercial adopters. In cooperation with a local secondary material initiative and a project-related NGO, TU Berlin researchers have investigated the idle materials “printing blankets” and “aluminium composite panels” in two CMWs. Both materials combine valuable technical properties, a short use phase, and poor recyclability. The resulting two CMWs included 1) detailed background research, 2) physical material testing and 3) experimental CMW with material-related experts. With a special focus on the construction industry, the article discusses the barriers of identifying scalable and feasible new use cases for idle materials through the method of CMW.

Keywords: Recurring waste flows, Idle material streams, Collaborative Material Workshops, Use cases, Local material cycles

1. Introduction

Cities do not only account for more than half of the world’s population, but also for 60% of global resource use at a private and a commercial level. SDG 11 “Sustainable Cities and Communities” lists as a target the “reduction of the environmental impact of cities by paying special attention (…) to municipal and other waste management” [1]. In addition to 50 643 Gg of municipal waste produced in 2019, Germany also produced 50 698 Gg of waste from manufacturing and other economic activities [2] making the manufacturing and commercial sector as big a waste generator as the private sector. The reduction of commercial waste streams by the optimization and modernization of processes is an important aspect of the transformation to a more environmentally conscious business culture and is part of environmental management systems like EMAS or ISO 14.001. Nevertheless, various commercial processes require the consumption of supplies and materials and thus generate commercial waste. In these cases, the amount of generated waste is defined by the process and are only preventable by
optimization and modernization to a certain limit. Due to these limitations, other approaches may be required to prevent remaining waste streams from being generated. Several examples of commercial waste were identified where the discarded materials still contain valuable technical properties for new potential re-use cases and are at the same time poorly recyclable. This study presents and applies the methodology of “Collaborative Material Workshops” (CMW) as a tool for the identification of new use cases for idle commercial material streams as an enabler for potential waste prevention strategies in this sector.

According to the DIRECTIVE 2008/98/EC on waste, “prevention means measures taken before a substance, material or product has become waste, that reduce: (a) the quantity of waste, including through the re-use of products or the extension of the life span of products” [3]. As long as the owner of a material is not required to discard it as waste, it is possible to use said material as input for new production processes. By cascading materials across different product categories and production systems, the extension of the lifespan of material is also possible [4] enabling waste prevention. Figure 1 is a description of the differences between waste prevention measures and the other measures of the waste hierarchy in the context of the described actions.

Commercial processes generally use a large variety of technical materials with specific requirements on their technical properties. High expectations regarding material properties such as resistance, flexibility, and weight among others, have driven materials to be tailored to specific use situations, as can be seen in the proliferation of different types of plastics, specific metal alloys, technical textiles and composite materials. Examples can be seen in the printing, construction, transportation and advertising sector. These specific properties create the value of the material, which, after being used for its purpose, reaches its end-of-use phase (EoU) and is commonly disposed of as commercial waste, reaching its end-of-life (EoL).

Even if the EoU phase is usually directly followed by the EoL of the material, there are cases where the EoU would be more correctly defined as the end of a primary use. The material might still have most of its technical properties intact, making it suitable for a potential re-use in similar applications or even outside of the business practices of the initial user. Recurrent commercial processes, which generate consistent waste streams in a predictable manner are very interesting to investigate for possible re-use scenarios. These recurring commercial waste streams, that have a interesting potential for re-use applications, given the valuable technical properties they were designed with, are defined in this article as idle material streams.

**Figure 1:** Description of the differences between waste prevention measures and the other measures of the waste hierarchy[3]
Creating material cycles to transition into a more circular economy (CE) faces several barriers. Barriers can be categorized into the technological, market, regulatory, and cultural areas. E.g. technological barriers include the lack of data about secondary materials, market barriers address missing standardisation and low virgin material prices, while cultural barriers are seen for example in a hesitant company culture [5]. Even if the knowledge about material properties and plannability can partly address technological and market barriers, several other barriers are frequently blocking the implementation of material cycles as part of a CE. The research gap and barrier for CE addressed in this article is the lack of a methodology to identify scalable and feasible re-use applications for idle material streams.

The identification of re-use applications for idle materials in yet unknown field of application is an essential step to addressing technological, market, and cultural barriers for the CE. In many ways it wants to replicate the resource exchanges possible through industrial symbiosis, by helping the resource generating entity to find a suitable match for their potential discards [6]. Since in many cases companies lack the time, capacity, knowledge or even interest to identify possible re-use cases outside their business models, the engagement of external actors is necessary. For the development of new products or business applications based on idle materials, reliable material knowledge is needed to ensure a successful development [7]. Given that researchers as external actors are limited in their knowledge about specific materials, waste generating processes, design or crafting techniques, this study actively involves external actors from the manufacturing sector, local re-use scene and other material experts to complement each other's knowledge. This led to the development of the “Collaborative Material Workshops” (CMW). In a series of events focused on pre-selected potentially reusable idle material, external actors are provided with information and tools to create with the material and to elaborate potential use cases. This open approach combines academic research results with practitioner’s knowledge about the material to generate innovative crafting ideas that help to explore potential re-use possibilities. In order to communicate and disseminate the results achieved, an event is planned for September 2022 to present the material and activities to a wider range of stakeholders. The objective of the CMW is to identify scalable and feasible applications for the re-use of idle materials recurrently obtained from commercial activities. This article presents the experience of conducting two CMW, as part of the research project “Reallabor Zirkuläres Wirtschaften im urbanen Raum: Umweltkommunikation im Haus der Materialisierung” ¹, funded by the “Deutsche Bundesstiftung Umwelt” and that took place at the “Haus der Materialisierung” (HdM) during 2021. The HdM is a multidisciplinary city lab for sustainable material consumption in Berlin. The planning and the organisation of the CMWs was carried out in close cooperation with the secondary material initiative "Material Mafia” ²(MM) and the NGO “Circular Berlin”

2. Methodology
The methodology of CMWs as developed in this project was divided into four main process steps and several sub steps. Figure 2 indicates the methodical setup of: 1) Background research, 2) Physical testing, 3) Experimental CMW and 4) Dissemination of results to potential adopters.

1 Haus der Materialisierung: https://hausdermaterialisierung.org/
2 Material Mafia: https://www.material-mafia.net/
3 Circular Berlin: https://circular.berlin/de/
2.1. **Background research**

The background research was used to collect information about the material and the status of the material in the commercial system. Table 1 describes the information required in the five sub-process steps. The sources of information used were literature, local statistics, empirical studies, surveys, material manufacturers technical specifications and the Internet.

| Table 1. Information required as part of the background research for materials under examination |
| --- |
| **Description** | **Research activities** |
| **Local business processes and material origin** | Research on the origin of materials in the local context. | • Origin of the material  
• Estimation of mass flows  
• Overview of the local economic actors  
• Availability |
| **Production process** | Detailed knowledge about the material generating process. | • Production process of the material  
• Process where the material is used  
• Duration and intensity of use phase  
• Damages and loss of quality  
• Reasons for the end of primary use |
| **Material properties** | Detailed object characterization of the material and the material properties. | • Object characterization  
• Material properties  
• Material composition  
• Weight, Density, Size |
| **Toxicity and risk potential** | Research about a potential toxicity and risks. | • Substances of concern in the material or related processes  
• Contamination from use  
• Requirements for re-use |
| **Recyclability** | Research of potential recycling routes and the assessment of recyclability. | • EoL phase  
• Collection systems  
• Waste treatment technologies  
• Probability of re-use or recycling |
2.2. **Physical testing**

The physical testing of material properties supports the background research activities to obtain missing information. Physical tests of flammability, toxicity, or material resistance under certain influences may be required to evaluate the application in potential re-use cases. What physical tests should be performed may vary widely depending on the material that is studied, where it was obtained from and how much reliable information was obtained during the background research. Section 3 details what physical were done during the CMWs performed by the authors.

2.3. **Experimental collaborative material workshops**

The CMWs done consisted of two workshop parts. The first part was an information workshop followed by a physical workshop. Participants that were invited were researchers, material experts, manufacturers, designers and actors from the re-use scene, however no manufacturer of the specific materials could participate in the end.

2.3.1. **Information Workshop**

The information workshop presented the results of the background research and the physical testing to the audience. The workshop participants were invited to share their expertise and experience with the material in short presentations or through an active and open discussion. Speakers reported about potential re-use cases, challenges in the fabrication they had encountered and useful material properties. The information workshop aimed to generate a common basic understanding of material among the participants.

2.3.2. **Physical Workshop**

The physical workshops reported in this article were done in the workshop area of the HdM. The participants got access to a large range of materials, tools and space. In roughly 5 hours, the participants were open to follow their innovative ideas about how to use and test the provided material. During the workshop, no specific requirements or restrictions were set, avoiding to force any specific result. At the end of the workshop, the results were presented to the group and re-use applications, processing approaches and other ideas were documented.

2.4. **Dissemination of results to potential adopters**

The dissemination of the results requires documentating of the CMW. The product prototypes that may have been developed can be presented to potential adopters. Between the physical workshop and the dissemination of results, additional research activities might be necessary. Due to the Corona restrictions in 2021, step 2.4 has been postponed to September 2022, hence this step is not part of the results.

3. **Results**

The methodology of CMW was applied on two preselected idle materials displayed in table 2. The preselection of materials for the CMW was done in cooperation with MM, during the planning phase of the research project that financed these workshops. The decision for the materials was based on their local reoccurring material supply, material properties and a first estimation of potential re-use. The results of the CMWs are presented separately in the following sections.

**Table 2.** Selected idle material in the focus of the CMW

| No. | Name                        | Short | Origin                                           |
|-----|------------------------------|-------|--------------------------------------------------|
| 1.  | Printing blankets            | (PB)  | Industrial offset printing plants                |
| 2.  | Multilayer aluminium composite | (ACP) | Advertising, transportation, construction industry |
3.1. Printing blankets from industrial offset printers

PBs from industrial offset printers are a highly specific and expensive tool, which is required in the state-of-the-art offset printing industry. The robust and resistant material properties are still present at their EoU stage and contain a potential for re-use applications. Offset printing is a technique used for high-volume printing processes on materials such as paper, cardboard, metals or foils. The PB is necessary to transfer ink from the printing negative to the paper. Table 3 displays the results of the background research (step 1 of the CMW methodology).

Table 3. Background research results for PB

| Local business processes and material origin | Printing blankets |
|---------------------------------------------|--------------------|
| · Medium and large size printing companies  | Photos             |
| · 30 identified printers in the Berlin area (telephone inquiry). | Figure 3. Photo of a used PB |
| · Mass flow depending on the number and type of machines: 7.5 – 20 (PBs/machine * month). Estimation about 900 -1200 PB per medium-sized printing company in a year | Figure 4. Layers of selected PB[8] |
| · Offset printing plant                     | Production process |
| · Duration of use: 10.000 -18.000 rotations  | · Different types of PB with different material composition [9] |
| · End-of-Use: High demands on the quality of the printed products require a PB in damage-free condition. Small scratches or deforming cause the disposal, as well as the stop of a given product | · Size: 1072 mm x 800 mm x1.96 mm , Weight: 1700g – 2200g |
|                                             | · PB consists of a complex composite of plastics, cotton fabrics and a surface made of nitrile butadiene rubber (NBR) (Figure 3, 4) |
|                                             | · Two metal straps made of Fe-metal or Al fixed with re-hooks as tensioning rail |
|                                             | · Not UV- resistant (long term test results from MM). |
|                                             | · Eco-Costs: -4.56E+00 €/m² Carbon footprint: -1.07E+01 kgCO2eq /m²[10] |
| Material properties                          | Toxicity and risk potential |
| · Non-toxic, non-harmful material           | · Toxic if used with REACH registered ink or solvent |
|                                            | · Smells strongly of rubber in some cases |
Recyclability

- Definition and collection as commercial waste[9]
- Not recyclable due to irreversible combination of mixed material.
- Treatment in waste incineration plant [9]

For the physical testing of the PBs, step 2 of the CMW method, different tools were used to try to separate the different layers of the PB what confirmed that the layers are not separable. Two different PBs as samples were examined. The surface of the PBs is waterproof. A calorimeter test in the TU Berlin laboratory have not found significant flammability or heating values.

The information workshop (CMW step 3.1) was held online on 03.06.2021 with 12 attendants. Participants presented experiences and examples of re-using PBs in books, seats bags and accessories. A recording of the session is available⁴. The physical workshop tested several crafting approaches. Results show that PBs are possible to be cut with scissors or sharp knives, they can be well glued to a rough surface, stretchable/compressible, sewable with strong sewing machines, robust/tear-resistant/durable, and could be sanded sandleable with a rotary tool. The material was tested in re-use applications such as floor tiles, bags, curtains/privacy screens, furnitures, modular toys, loops, hangers, hinges, irrigation systems or as artistic objects. Figure 5 shows the floor tiles. The tiles are placed in the HdM for long-term testing. Figure 6 shows the presentation of workshop results among the participants.

3.2. Aluminium composite panels
Aluminium composite panels are a sandwich material made out of different materials layers like described in figure 8. The combination of metal and plastics creates a relatively cheap product with low weight and high resistance. These valuable material properties makes ACPs to a more frequently used solution in several applications. The material is frequently offered to the MM in like-new condition in various forms from the advertising and construction sector, hence the material was selected for the CMW.

Figure 5. PBs processed into the new use case as floor coverings tiles. © Gomez
Figure 6. Presentation of workshop results to the workshop participants. © Gomez

⁴ Upcyclingseminar#1 Druckmatten https://www.youtube.com/watch?v=LCwVABH547o
### Table 4. Background research results for ACP

#### Aluminium composite panels

| Photo | Figure 7. Photo of ACP in Figure 8. Structure of ACP [11] the storage of MM |
|-------|---------------------------------------------------------------------|

| Local business processes and material origin | 
|-----------------------------------------------|
| - Frequently used in transient structures with a short use phase |
| - Used as signage indoors and outdoors, for exhibitions, fairs, temporary consitions such as road signs or banners |
| - Estimation of the quantity is not possible given the wide arry of possible uses. MM frequently receives ACP stacks in a variety of sizes, offcuts from the advertising industry and EoU panels |

| Production process | 
|--------------------|
| - Application of ACP in: Advertisement, construction, transportation, design, fairs, signs (long term and short term use) |
| - It has recently also been adopted as a backing material for mounting fine art photography, often applying an acrylic finish. Other uses include outer facades and signage, given its remarkable weather resistance |

| Material properties | 
|---------------------|
| - Size: 305cm x 205cm (full panel) Weight: 2.9 – 6.6 kg/m² |
| - Eco-Costs: -3.33E+00 - -7.65E+00 €/m²[10] |
| - Carbon footprint: -6.52E+00 –1.07E+01 kgCO₂eq /m²[10] |
| - Other sizes possible depending on the material origin |
| - Sandwich panel made of low-density PE, LDPE or PP core and a thin aluminium skin layer glued to each side (several alloy and plastic combinations in different thicknesses from several producers are available)[12] |
| - Thickness: (2mm, 3mm, 4mm, 5mm, 6mm)[12] |
| - Low weight and high strength, high formability, weather, temperature and chemical resistance |

| Toxicity and risk potential | 
|-----------------------------|
| - No toxicity potential |
| - Depending on the core material, they can have flame retardant properties as required in the construction sector or be deemed unsafe because of flammability issues. |

| Recyclability | 
|---------------|
| - Disposal as commercial waste |
| - Irreversible composite hence thermal waste treatment |
Not suitable for Al recycling due to high heat value of plastics
Not suitable for plastic recycling due to high separation effort
New scrap recycling in specific treatment [12]

No physical test (step 2.2) for ACPs were processed, since the required information were available in retailer information sheets. The information workshop (step 2.3.1) was held online on 07.10.2021, with 13 attendants. A recording of the session is available. The results of the physical workshop (step 2.3.2) show, that ACPs were mostly used in its intended function as a construction material. The material was adapted for interior furniture, artificial goods or as wall panelling. Figure 9 shows the processing of ACP as wall panelling. Figure 10 shows ACPs folded into an artificial bowl. The low weight and high resistance make the material suitable for mobile applications in bicycle construction and for the interior construction of caravans. The challenge of the material was to identify re-use cases, which are able to profit from smaller ACP cuttings.

4. Discussion
The background research of step 2.1 requires a holistic overview of the local economic activities, the addressed material and potential material experts. The cooperation with local actors helps to research the required information. Depending on the material, focussing on relevant topic is recommend.

The design of the physical testing of step 2.2 depends on the material and the already provided information by the manufacturer. Its purpose is to acquire additional information about the material to allow the succesful step 2.3. More physical testing of prototypes might be necessary after the workshop events.

Grouping several material experts for the information- and the physical workshop in step 2.3, to experiment with examined material creates a working environment, which enhances the ideation process and generates different perspectives. With this approach, knowledge about the material is generated, which is difficult to be obtained in regular research activities. At the same time, the results are highly dependent on the invited participants. It is important to invite selected experts from different branches.

The provided timeframe were partly not enough to acquire finished prototypes. Handcrafted prototypes made in a workshop are not a proof of concept, since additional tests in a professional production environment are necessary for a final evaluation. Additional activities to further develop CMW-results into processable re-use applications are necessary.The postponed dissemination of

5 Upcyclingseminar#2 Alu-Dibond https://www.youtube.com/watch?v=_ShAsbrxTpl
workshop results into September 2022 is intended to reach a larger audience of potential adopters. With the invitation of relevant workshop participants, workshop results are also communicated to potential adopters, since the participants are also working with the material and are able to implement the results into their processes. If relevant stakeholders like architects, civil engineers and product designers are not addressed the impact of the CMW will remain low. Hence it is important to present the results to architects and the scientific community at sbe22 to communicate the potential of the methodology and the researched idle material. The CMW for PB developed a potential application as floor covering tiles for the construction sector. The participants created a prototype that could theoretically replace virgin tile material. Advantages were identified in the technical properties and the availability of the materials. The long term behavior still needs to be tested. In addition, questions like production processes, logistics and surface treatment needs to be answered. ACPs are frequently used in the construction and the advertising sector. The ACPs researched in the CMW were, mostly available as large plates or smaller plate cuttings. The CMW results revealed that most of the developed re-use applications were similar to the original applications if ACP. This shows that idle ACP contain a potential to be led back in the same purpose, as long as the re-use application is able to use smaller cuttings. For both materials research regarding the standards for flammability, stability and long-term resistance are still to be carried out. The ideation process in the CMW is the first step in the product development process.

Potential use cases were identified in the construction sector. The construction sector and the built environment appear to be promising fields of application for re-use cases of idle material streams since these fields have a large demand for materials. In practice, it is still unclear, if the material meets the quality requirements and the certification standards for construction. Transferring poorly recyclable materials into a re-use application does not solve the problem of a lack of recyclability. If other non-recyclable materials are replaced and the generation of waste is avoided, the purpose of the activity is fulfilled, even if this does not create long-term material cycles.

5. Conclusion
The economic transformation toward a CE is confronted with several barriers. The creation of material cycles potentially prevents waste generation by re-using idle materials with technical properties. To have an impact on the waste balance with this approach, the re-use of idle material streams in similar quality and large quantity are required. The identification of re-use applications through CMV is just addressing one technological barrier. Several other barriers are still present. Transferring poorly recyclable materials into a re-use phase does not solve the problem of a lack of recyclability.

Through the combination of background research and the active integration of material experts, the methodology of CMW presents a approach to address the barrier of missing re-use applications. Knowledge about the material and the related commercial processes is required, which can be successfully generated through the cooperation between scientist and material experts, to identify re-use applications and to support capacity building. Including stakeholders and providing space in this knowledge-building process increases the array of potential results. With PBs and ACP, two idle materials are investigated. PBs contain valuable material properties like stability, and resistance for re-use applications. Due to the quantity of the material, floor coverings tiles are a potentially scalable and feasible re-use case. Further research activities and tests are required to verify this result. ACPs are a frequently obtained material from the construction and advertising sector. ACPs were mostly re-used in the originally intended way as a construction material, by profiting from the valuable technical properties.

The construction industry and the built environment are potential fields of use for both discussed materials. The large material demand and a large field of potential applications create the possibility for a scalable application. Presenting detailed information and scalable re-use cases for idle material streams to stakeholders is required for the implementation of workshop results. With the presentation of the methodology of CMW and the obtained results at the conference sbe22, architects and civil engineers are provided with a valuable tool to adapt this approach into future projects.
6. **Outlook**

To finalize the series of CMW, the dissemination of the results to potential adopters is planned for September 2022. The dissemination of results got the additional focus on network and capacity building to enhance the creation of material cycles.

Further tests on long-term applications, resistance and treatment options are planned for both materials. The ability to cut PB with a hydraulic press would create the possibility to quickly produce a large number of standardized tiles. In addition, another floor prototype will be created and tested under controlled conditions.

**Acknowledgements**

The project "Reallabor Zirkuläres Wirtschaften im urbanen Raum: Kompetenzaufbau und Umweltkommunikation im "Haus der Materialisierung" in Berlin" is technically and financially supported by the Deutsche Bundesstiftung Umwelt. Thanks also go to the project partners Material Mafia, Circular Berlin and ZUsammenKUNFT Berlin (ZKB).

**References**

[1] United Nations, Sustainable Development Goals: Goal 11: Sustainable Cities and Communities, https://www.un.org/sustainabledevelopment/cities/.

[2] DeStatis, Brief overview waste balance. Waste management, 2019, https://www.destatis.de/EN/Themes/Society-Environment/Environment/Waste-Management/Tables/liste-brief-overview-waste-balance.html.

[3] THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, DIRECTIVE 2008/98/EC of 19 November 2008 on waste and repealing certain Directives.

[4] Towards the circular economy, 2013.

[5] J. Kirchherr, L. Piscicelli, R. Bour, E. Kostense-Smit, J. Muller, A. Huibrechtse-Truijens, M. Hekkert, Barriers to the Circular Economy: Evidence From the European Union (EU), Ecological Economics 150 (2018) 264–272.

[6] B. Baldassarre, M. Schepers, N. Bocken, E. Cuppen, G. Korevaar, G. Calabretta, Industrial Symbiosis: towards a design process for eco-industrial clusters by integrating Circular Economy and Industrial Ecology perspectives, Journal of Cleaner Production 216 (2019) 446–460.

[7] O. Rexfelt, I. Ordoñez, Designing from the dumpster: experiences of developing products using discards, IJSDES 3 (2017) 61.

[8] BIRKAN GmbH, BIRKAN 8894: Newspaper „no pack“ printing blanket - more flexibility in packing requirements, 2016, https://www.birkan.de/pdf/en/BIRKAN-8894_049500_en.pdf.

[9] BIRKAN GmbH, Product Catalogue Offset, 2018, https://www.birkan.de/pdf/en/BIRKAN_Product-Catalogue-Blankets_engl.pdf.

[10] Isabel Ordóñez, Susanne Rotter, Johannes Scholz, GMIT and the systematic environmental assessment of secondary materials (2022).

[11] H. Palkowski, A. Carradó, Three-layered sandwich material for lightweight applications, Emerging Materials Research 3 (2014) 130–135.

[12] 3A Composites GmbH, DIBOND. Catalog, 2010. https://pdf.joergkueper.de/dibondProduktinformationen.pdf.