FROM THE CONCEPT OF BUILDINGS AS MATERIALS BANKS TO ESTABLISHING LOCAL MATERIALS' PROCESSING CENTERS AT NEIGHBORHOOD SCALE: THE EXAMPLE OF THE WESTERN GARDEN CITIES POST-WAR AREA

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ABSTRACT:

Large amounts of material waste resulting from the renovation of post-war housings pose a great challenge for managing waste through destruction. Applying the concept of the circular economy may allow the opportunity to reuse these materials that would otherwise be thrown away due to renovation. The article explores the possibility of embedding Buildings as Material Banks (BAMB), a circular economy concept, at the neighborhood scale. Through holistic macro planning, BAMB will be embedded in the renovation process of the post-war neighborhood in a step-by-step manner to realize the reuse of materials. Although the article investigates some cases of reuse of old materials, due to the limitation of length, the study did not make detailed adjustments and adaptations to the site, Western Garden Cities. Specific materials from the Western Garden Cities will be studied in future studies.

KEYWORDS: *Circular economy, post-war housing, renovation, Buildings as Material Banks*

I. INTRODUCTION:

Many post-war social housings in the Netherlands await renovation (Havinga et al., 2020).[1] In the last century, the construction of these low-technology post-war estates helped alleviate the housing shortage in the Netherlands for a short period (Argiolu et al., 2008). However, because of small living areas, poor insulation, these dwellings no longer meet the needs of contemporary use. Besides, the Amsterdam authorities have also recognized some social problems that can result from overly dense housing patterns, such as high crime rates, high mobility, and low communication (Olsson et al., 2021). To control that, Amsterdam released a document called "Richting Parkstad 2015" in 2001, which presented a plan to renovate post-war housings (Havinga et al., 2020). The plan specifically identifies the Western Garden Cities[2] area of Amsterdam.

The renovation of many post-war housings poses a great challenge to manage the waste produced by demolition. According to the Dutch Material Flows Report, a large proportion of construction waste in 2014 comes from post-war housings between 1945 and 1970 (EIB and

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1 **Stock of post-war housing:** Western Garden Cities has 142 complexes with about 21.700 dwellings in need of renovation ("Garden City", 2021) and 1941 homes renovated in 2018 in Amsterdam (City of Amsterdam, 2020: p.15).

2. **Western Garden Cities:** The area Western Garden Cities is the most famous elaboration of the Algemeen Uitbreidingsplan AUP (General Expansion Plan) of Amsterdam. The urban development plan was developed between 1934 and 1958. Including "Slotermeer, Geuzenveld, Slotervaart, Overtoomse Veld and Osdorp" five districts ("Garden Cities", 2021).

Metabolic, 2020). Furthermore, many new materials are needed for the renovations.

Circular principles in the construction industry advocate reusing materials via the R strategies. [3]Some of the materials that have been discarded due to building renovation still had the potential for secondary use. Examples are wooden window frames and brick facades. Therefore, introducing reuse practices into post-war neighborhoods presents a great opportunity for controlling waste flows especially today when there is still a large circularity gap (Haigh et al., 2021).

This paper explores the potential of transitioning to a circular built environment and in particular, the concept of Buildings as Material Banks (BAMB) in post-war housings areas. And based on this, the paper further looks for the potential of establishing a materials processing facility at the neighborhood scale. The literature review will develop around circularity, the notion of BAMB, and the use of Materials Passports. After that, practical examples of secondary use of materials will be discussed. In the last part of the paper, the article will discuss the specific steps and obstacles encountered in the implementation of BAMB in the Western Garden Cities, thereby exploring the possibility of a circular flow of materials in the renovation of post-war housings.

II. METHODOLOGY

Through the literature review, the basic definition of circular economy and its main principles will be presented. In particular, the notion of Buildings as Material Banks and the basic guidelines for its implementation will be discussed.

A case study analysis based on the secondary use of materials will also be studied. By studying the characteristics of comparing different materials for reuse, different treatment methods can be targeted for different materials.

III. LITERATURE REVIEW

3.1 The circular economy

Circular Economy (CE) decouples economic activity from the consumption of finite resources (Ellen MacArthur Foundation, 2013). CE attempts to eliminate the notion of waste by maintaining the efficiency and value of products (Dokter, Thuvander and Rahe, 2020). Some of the challenges in achieving CE lie in the change of business models and the diffusion of specific knowledge, but more importantly, a change in the mindset of recognizing waste as a resource (Piscicelli and Luddena, 2016). More waste added to the resource flow means less raw material is needed, which removes the link between economic growth and resource extraction. In this way, CE would be a possible way to alleviate resource shortages (Copeland and Bilec, 2020).

Architecture, Engineering, and Construction (AEC) play an important role in the movement towards CE. The annual waste generated by the demolition of buildings accounts for about 40%

3 **R strategies**: Circularity strategies towards circular economy. According to PBL Netherlands Environmental Assessment Agency, this concept has currently expanded to 10R strategies: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover (Potting, Hekkert, Worrell and Hanemaaijer, 2017).

of the total national waste (Ministerie van I&M & Ministerie van EZ, 2016).[4] In addition to this, today the construction industry is still the largest consumer of raw materials (BERGE, 2017). This is why reusing materials that have been discarded as buildings come to the end of their lives can significantly reduce waste.

3.2 Buildings as Material Banks

Buildings as Material Banks (BAMB) can be seen as an approach to achieve a circular economy in the construction industry. According to the notion of BAMB, materials can be seen as only temporarily stored in the building and can be reused in the long term (Leising, Quist and Bocken, 2018). This means that the built environment moves away from the linear "take-make-waste"5 process to considering buildings as temporary configurations of materials that can be used and reused many times over. The design and maintenance of recyclable building components in the BAMB project enables the maintenance of material values (Rose and Stegemann, 2019). BAMB contributes to the systematic integration of buildings into CE. It strives to create system-level shifts through CE while aiming to increase the value of used building components and materials (BAMB. BAMB 2020). BAMB is now more than a concept and has become an experimental and practical project funded by the European Union.[6]

3.3 Materials Passport

One of the most important tools of the BAMB is the use of Material Passports (MP). MPs are electronic and actionable datasets that collect material properties (Brussels Environment, 2019). All information about the material is recorded, such as life expectancy, dimensions, and production information. Reliable and standardized databases can help bridge information gaps and communication between relevant stakeholders in the construction industry (Heinrich and Lang, 2019). The MADASTER platform, for example, offers online registration of materials and products. On this digital platform, all materials used in the process of construction are recorded. The reason why MPs are so important is that materials information in the digital platform can help to assess and optimize recycling potential at the early stages of design, thus maintaining material value as well as reducing raw material use (Honic, Kovacic and Rechberger, 2019).

IV. CASE STUDIES

Putting waste materials back into use is no longer just an ideal under the paradigm of a circular built environment, but is already being used in some cases. Following table (Table 1) lists a number of case studies built with the use of secondary materials and reversible design. The table shows that the reuse of waste materials is not limited to the local part of the building. The whole

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4 **Waste from Construction:** In 2018 alone, Amsterdam produced 670 kt of materials for the built environment, while at the same time disposing of 6,817 kt of built environment waste (City of Amsterdam, 2020: p.15).

5 **"Take-make-waste":** A linear economy traditional paradigm, which means that raw materials are collected, then transformed into products that are used until they are finally discarded as waste and generally not to their full potential. (Ellen MacArthur Foundation, 2013)

6 **BAMB program:** This is an experiment funded by European Union. To test BAMB to its maximum potential, six pilot projects were tested in different environments. Architects and other stakeholders of the pilot projects optimize the life cycle of building materials by incorporating the end-of-life phase at the beginning of the design. The pilot projects of the BAMB program tested whether the building components were successfully reversible through repetitive assembly and disassembly and whether they could be assembled in different ways to fulfill various functions (Brussels Environment, 2019).

building is made up of old materials, and also reversible buildings that will be made up of new materials can help maintain the value of the materials.

Name	Year	Architect	Area	Function	Recycle Part	Use Method	Detachable
The Resource Rows	2015	Lendager	9148 m^2	Dwelling	Facade	Cut the abandoned brick wall into larger modules for the facade	No
People's Pavilion	2017	bureau SLA + Overtreders W	250 m^2	Pavilion	All	All materials used in the project are old. The materials not only come from the suppliers but also from the garbage of the local residents.	Yes
Afvalbrengstation	2017	SuperUse Studio	2700 m^2	Garbage transfer station	Except for the steel structure	The facade is made of an industrial remnant material. Supplemented by second-hand Azobé sheet piles	No
The Circle	2017	Cie Architect		Pavilion	Floor and roof	Discarded wooden frames are made into wooden floors, and jeans are used as insulation material	No
Tijdelijke rechtbank amsterdam	2016	cepezed	5400 m^2	law court	None	Because of special attachment system, this building can be reassembled completely in at a different location	Yes
Triodos bank Netherlands	2019	RAU Architect	12994 m^2	Bank office	None	All materials used in the building are accurately recorded, which facilitates the reuse of materials if user needs change or the house is not in use.	Yes
Villa Welpeloo	2009	Superuse	400 m^2	Housing	Load-bearing structure and façade cladding	The structure is made of steel girders from a paternoster, formerly used in the textile industry. The wooden façade cladding is made of redundant cable reels	No

Table 1 Case studies built with the use of secondary materials and reversible design. Made by author.

Waste materials can now be used not only for façade or interior decoration, but also for load-bearing structures after special treatment (Hebel, Wisniewska and Heisel, 2014). In addition, there is a growing interest in the disassembly of building components. Some buildings do not use recycled materials, but the materials used can be simply disassembled and reused. This is also a means to promote material reuse. While these examples are only a partial reference, they also offer the possibility of embedding BAMB in post-war communities. Reusing materials is the core means by which BAMB maintains its value, and reversible building design provides the technical support to implement BAMB over long periods.

V. Findings

5.1 BAMB applied to post-war building stocks

This chapter explores how the Buildings as Material Banks can be applied specifically to the post-war community to promote a circular economy within the area. BAMB currently does not have a clear and unified implementation standard, and the only practical BAMB projects funded by the EU are only attempts based on building scale. This paper, based on the combination of the BAMB project and Urban Mining[7], proposes to divide the implementation into five phases: inventorying, harvesting, processing, distributing, and reusing.

5.1.1 Inventorying

After identifying the post-war housings that need to be renovated, a detailed inventory should be conducted (Rose and Stegemann, 2019). The purpose of the inventory is to clarify the reusability of components in the building. The components that still have the potential to be reused in the building are counted, and their quality, quantity, and characteristics are generally identified. In addition, the connections of the components need to be documented so that the professionals have a preliminary judgement of how to recycle these materials.

The creation of the inventory requires the participation of stakeholders from different fields. People from different fields of work will have different concerns, thus making the inventory more comprehensive. The inventory will help to reduce construction waste by recycling as much usable material as possible. In addition, the inventory can initially help to determine the general types of materials (Figure 1) and how they will be used in the future.

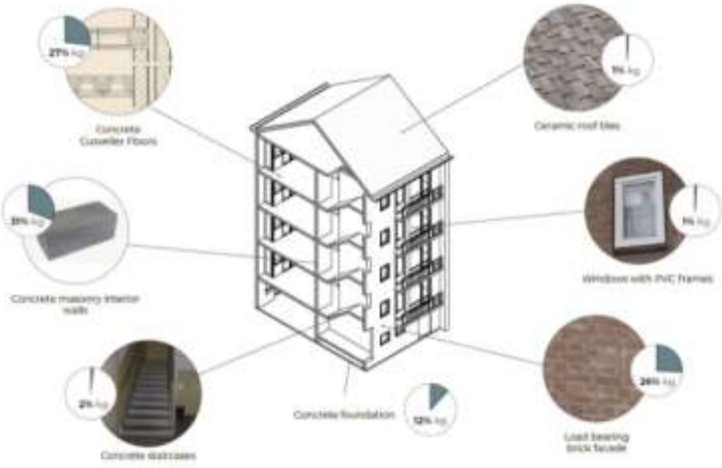

Figure 1 Materials that had the opportunity to be reused in post-war housing (Braam, 2021).

7 Urban mining is a term, which regards a city as a huge repository of raw materials. (Hillebrandt et al., 2019)

5.1.2 Harvesting

After the inventory is created, professionals will manage the materials on site. This is not only removing the components that were renovated from the post-war housings, but also separating the parts that are still usable in a way that maintains as much value as possible. This requires knowledge of assembly and disassembly among the demolition workers, and perhaps even training in advance of the formal demolition (Copeland and Bilec, 2020).

Inventories need to be made again after the components have been successfully separated from the buildings. The contents of the inventory may change before and after the harvesting process due to inspection or technical reasons. Separated building components also need to be stored properly to prevent damage to their quality. Following figure (Figure 2) brings together the things that need to be done before and after the transformation and the corresponding stakeholders.

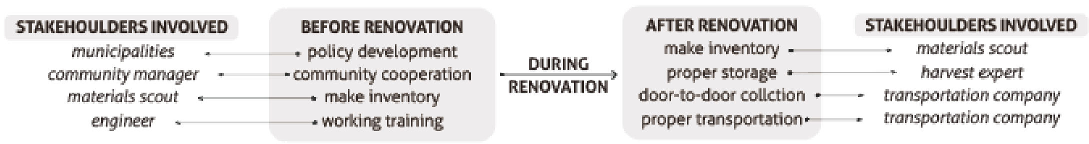

Figure 2 Things need to be done before and after renovation. Drawn by the author.

5.1.3 Processing

Materials separated from the post-war buildings will be transported to a local material processing center, where they will be initially sorted, processed, documented, and stored. This phase is divided into two steps: choosing what strategy to apply for each product and second, issuing Materials Passport

a) R strategy

The collected waste materials need to be initially sorted to ensure a more targeted treatment for the following process (Figure 3). Second, the sorted materials will be treated using various circularity strategies (10R strategies) depending on the quality and condition of the materials.[8] Third, properly processed materials will be temporarily stored in a third-party material process center until they have a chance to be used again (Figure 4).

Figure 3 Classification of materials. Refer to the Amsterdam Cycle Monitor. Drawn by the author.

8 For example, discarded windows and window frames can be combined for interior partitions – Repurpose, external walls with poor insulation can be cut down and planned to be reused in the future with new insulation -Remanufacture.

Figure 4 Waste material disposal process. Drawn by the author.

b) Materials Passport

All building components or materials collected from post-war housings should be documented by the Material Passport. The Material Passport should include basic information about the type of material, size, color, and production information. In addition, the material's properties of water and fire resistance, life expectancy and usage history, all information that would affect the reuse of the material should be recorded (Figure 5). Information about the material will be recorded digitally on an online platform, so that all interested stakeholders can access the relevant information without any barriers.

Figure 5 Information about the material that will be recorded on the MPs. Drawn by the author.

5.1.4 Distributing

After processing, the harvested components will be reuse. In some cases, the discarded materials can be used directly on-site, which requires interaction between the designer and the demolition company. In most cases, however, recycled materials require multiple distribution channels to put them to proper use. Diversified distribution channels can break down information barriers and allow all kinds of people to have access to recycled materials (Copeland and Bilec, 2020).

Firstly, materials that are difficult to handle and have high value can be returned directly to their manufacturers. After treatment, these materials can be sold almost as new products again. Secondly, architects can also preview all materials waiting to be used on the online platform. Those selected materials will be delivered directly to the site during the construction phase. In addition, small quantities of materials in various shapes and sizes can be sold locally as thrifted goods or exchanged by residents with still valuable materials, which can catalyze research in the concept of reusing by creating a market (Bocken, de Pauw, Bakker and van der Grinten, 2016) (Figure 6).

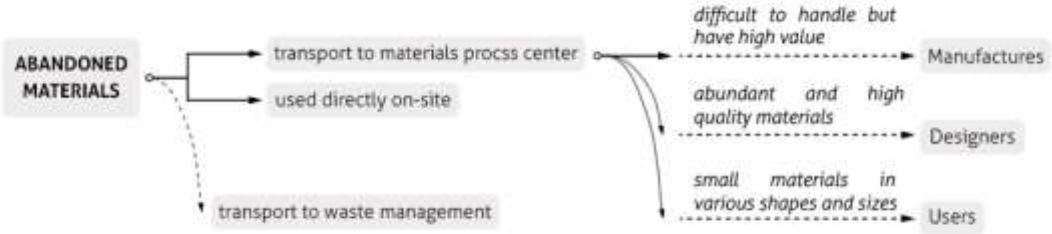

Figure 6 The different destinations of waste materials in post-war housing. Drawn by the author.

5.1.5 Reusing

For the realization of BAMB, it is not enough to focus only on the process from harvesting to distribution of materials. BAMB is concerned with the approach of using and maintaining the value of materials over time (Brussels Environment, 2019). The long-term value of materials that enter the BAMB recycling system should be given more attention than their use in the present. To keep building components in as high a quality condition as possible in the long term, easily separable structures and connections that do not destroy the value of the material will be central (Hillebrandt et al., 2019).

Therefore, for those materials that are brought back into the value chain, regular tracking of the Material Passport is a necessity (Copeland and Bilec, 2020). When they are no longer in demand in the future, a new round of recycling programs will be initiated: the process of inventorying, harvesting, processing, and distributing will be repeated (Figure 7).

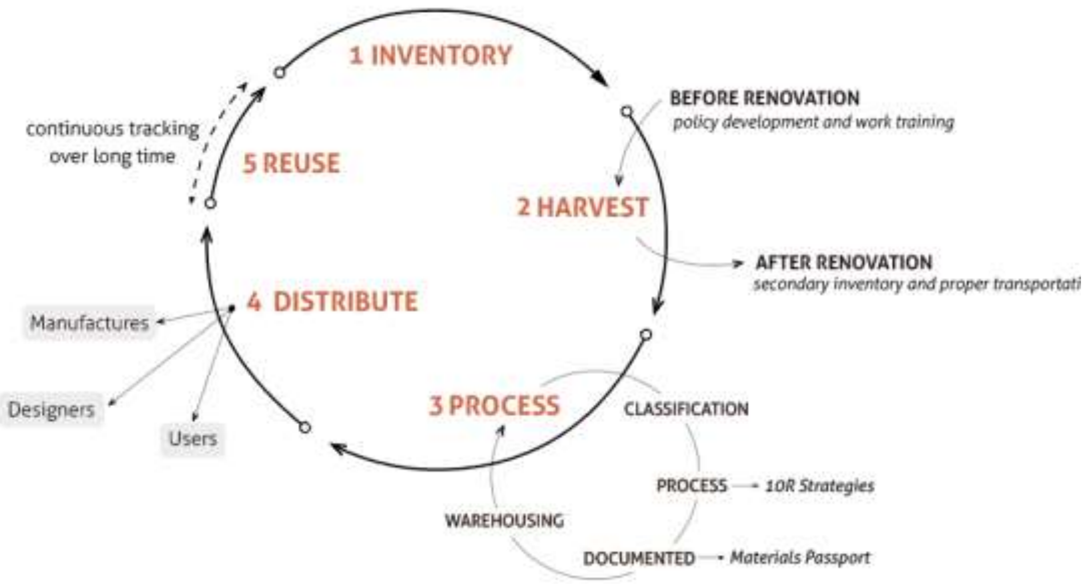

Figure 7 Flow chart for implementing BAMB in post-war residential areas. Drawn by the author.

5.2 Consideration in the implement of BAMB

5.2.1 **Integrated collaboration among stakeholders**

The implementation of BAMB requires the close cooperation of the stakeholders. There are many steps required to implement BAMB in the neighborhood, and often these steps involve people from various fields (Figure 8). In addition, the implementation of BAMB will have a long-time span. Without a clear and systematic operation, it would be difficult to have a direct connection even for those involved who are upstream and downstream of the material handover.

BUILDIND LIFE PHASE	ACTION WITH MATERIALS	RELEVANT STAKEHOULDERS
Project conception phase	initial selection of materials	manufacturers / designers
Structure design phase	specific materials information	engineers / designers / contractors
Construction phase	record and update materials passport	constractors / builders
Maintenance phase	materials remove and collection	users / designers / recyclers

Figure 8 The different stakeholders and their responsibilities for materials at different stages of design. Drawn by the author.

5.2.2 **Awareness raising and staff training**

The realization of BAMB requires not only policy support but also a bottom-up awakening of awareness. This includes, on the one hand, the need for post-war neighborhoods to become aware of the possibility of reusing old materials. Only with a full understanding of circularity will community residents take the initiative to use these materials and stakeholders involved will be better engaged. On the other hand, it requires training for practitioners (Copeland and Bilec, 2020). For example, demolition workers need to be professionally trained to understand how to remove building components without undermining their future use.

VI. CONCLUSION

The renovation of historic post-war housings is essential to achieve the Dutch no-waste target for 2050 (BPIE, 2011). The massive renovation of buildings leads to many waste materials, and this waste needs to be brought back into the value chain through a circular material flow. "Buildings as Material Banks" not only helps to systematically harvest waste materials and properly reuse them in the short term but also influences the flow of materials towards the circular way in the long term (Honic, Kovacic and Rechberger, 2019).

BAMB implementation needs to focus on the amount and type of available materials in the neighborhood (inventorying): how to remove unneeded building components from post-war housings with as little loss of value as possible (harvesting); how the collected materials should be processed for reuse (processing); and in what way these materials will be returned to the value chain (distributing).

The implementation of BAMB relies on collaboration which requires timely and direct information sharing between different stages (Gorgolewski, 2008). The use of Material Passport allows the stakeholders to visualize the history of materials via an online materials database.

The realization of a circular flow of building materials in the renovation of Dutch post-war housings cannot be achieved by the success of individual projects alone. A systematic transformation strategy must be established (Kirchherr, Reike, and Hekkert, 2017). This is a comprehensive issue, involving various stakeholders and a long-time span. In this way, upfront intervention for participants who would originally be at the rear end of the value chain in a linear economy can be allowed. In addition, the center will also serve as a local educational platform, showing residents the value of secondary use of materials through practical examples.

VII. DISCUSSION & LIMITATION

Although this research proposed that the application of BAMB to the neighborhood scale to be a feasible means to move towards a circular built environment, there are still some problems and reflections in the process of the research.

Firstly, due to limited space, the article does not expand in-depth on the specific materials discarded due to renovation in Western Garden Cities. The type and condition of materials will affect the approach and quality of materials collected in the community, and thus the reuse of these materials (McDonald, 2004). These details will affect the practical implementation of BAMB. The Western Garden City is a typical post-war housing area and the implementation of BAMB in this area will not only contribute to the circular built environment in Amsterdam, but will also provide a circular model for post-war housings all over the Netherlands.

Second, the notion of BAMB does not yet have many practical cases of application at the community scale. This leads to the fact that the difficulties that will be encountered in the implementation of BAMB for material circular flow are inaccurate and not fully predictable. Although some buildings have been designed with the BAMB concept in mind and material data is recorded in the form of Materials Passport. However, it is only limited to the scope of a single building.

Finally, it is important to note that in the transition to CE, the most important thing is not top-down policymaking and business model changes, but bottom-up awareness (Brussels Environment, 2019). Only when every individual involved in the material circular flow realizes that waste is not just waste, but another form of resource can CE move forward more smoothly.

REFERENCES:

1. Akhimien, N., Latif, E. and Hou, S., 2021. Application of circular economy principles in buildings: A systematic review. *Journal of Building Engineering*, 38, p.102041.

2. Argiolu, R., K. van Dijken, J. Koffijberg, G. Bolt, R. van Kempen, E. van Beckhoven, R. Engbersen en G. Engbersen (2008). *Bloei en verval van vroeg-naoorlogse wijken*. Den Haag: Nicis Institute. (18) (PDF) Social reconquest as a new policy paradigm. Changing urban policies in the city of

Rotterdam.

3. Babbitt, C., Gaustad, G., Fisher, A., Chen, W. and Liu, G., 2018. Closing the loop on circular economy research: From theory to practice and back again. *Resources, Conservation and Recycling*, 135, p.1.

4. BAMB. 2021. *BAMB - Buildings as Material Banks (BAMB2020) - BAMB*. [online] Available at: <https://www.bamb2020.eu/> [Accessed 7 December 2021].

5. Bell, S., 2020. *The 5 R's: Refuse, Reduce, Reuse, Repurpose, Recycle.* [online] Roadrunnerwm.com. Available at: <https://www.roadrunnerwm.com/blog/the-5-rs-of-waste-recycling>.

6. BERGE, B., 2017. *ECOLOGY OF BUILDING MATERIALS*. [Place of publication not identified]: ROUTLEDGE, p.10.

7. Braam, M., 2021. *Nieuwenhuysenbuurt/future proof.* [ebook] p.20. Available at: <https://repository.tudelft.nl/islandora/object/uuid%3A7c7c7a99-892d-4326-9b89-50391f6fa0bd?collection=education>.

8. Brussels Environment. (2019). *BUILDINGS AS MATERIAL BANKS* (p. 9). TUM Technische Universität München.

9. Bocken, N., de Pauw, I., Bakker, C. and van der Grinten, B., 2016. Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, 33(5), pp.308-320.

10. Buildings Performance Institute Europe (BPIE). (2011). Europe's buildings under the microscope: A country-by-country review of the energy performance of buildings. *Buildings Performance Institute Europe* (BPIE).

11. Copeland, S. and Bilec, M., 2020. Buildings as material banks using RFID and building information modeling in a circular economy. *Procedia CIRP*, 90, p.143.

12. *Circular Dutch economy by 2050*. Government.nl. (2021). Retrieved from https://www.government.nl/topics/circular-economy/circular-dutch-economy-by-2050?utm_medium=website&utm_source=archdaily.com.

13. City of Amsterdam. (2020). *Amsterdam Circular Monitor* (p. 15). Amsterdam: City of Amsterdam.

14. CityzenEU, 2021. *How to make a monumental post war building futureproof? Housing cooperation Eigen Haard took up the challenge successfully*. [online] City-zen. Available at: <http://www.cityzen-smartcity.eu/how-to-make-a-monumental-post-war-building-futureproof-housing-cooperation-eigen-haard-took-up-the-challenge-successfully/>.

15. Dokter, G., Thuvander, L. and Rahe, U., 2020. How circular is current design practice? Investigating perspectives across industrial design and architecture in the transition towards a circular economy. *Sustainable Production and Consumption*, 26, pp.692-708.

16. Ellen MacArthur Foundation, 2013. *Towards the Circular Economy*. Economic and Business Rationale for an Accelerated Transition. [online] Seacourt. Available at: <http://https: //www.ellenmacarthurfoundation.org/assets/downloads/publications/ Ellen- MacArthur- Foundation-

Towards- the- Circular- Economy->.

17. Ellen Macarthur Foundation, 2021. [online] Ellenmacarthurfoundation.org. Available at: <https://ellenmacarthurfoundation.org/>.

18. EIB and Metabolic, 2020. *Materiaalstromen, milieu-impact en energieverbruik in de woning- en utiliteitsbouw.* Amsterdam, p.15.

19. Fouseki, K. and Cassar, M., 2014. Energy Efficiency in Heritage Buildings — Future Challenges and Research Needs. *The Historic Environment: Policy & Practice*, 5(2), pp.95-100.

20. *Garden Cities*. Vaneesterenmuseum.nl. (2021). Retrieved from https://vaneesterenmuseum.nl/en/garden-cities/western-city-gardens/.

21. Gorgolewski, M., 2008. Designing with reused building components: some challenges. *Building Research & Information*, 36(2), pp.175-188.

22. Havinga, L., Colenbrander, B., & Schellen, H. (2020). Heritage attributes of post-war housing in Amsterdam. *Frontiers Of Architectural Research*, *9*(1), 1-19. https://doi.org/10.1016/j.foar.2019.04.002

23. Haigh, L., de Wit, M., von Daniels, C., Colloricchio, A., & Hoogzaad, J. (2021). *THE CIRCULARITY GAP REPORT 2021* (p. 3). Ruparo, Amsterdam.

24. Hebel, D., Wisniewska, M. and Heisel, F., 2014. *Building from waste: Recovered Materials in Architecture and Construction*. Birkhäuser.

25. Heinrich, M. and Lang, W., 2019. *Materials passports - best practice*. München: Technische Universität München, p.5.

26. Honic, M., Kovacic, I. and Rechberger, H., 2019. Improving the recycling potential of buildings through Material Passports (MP): An Austrian case study. *Journal of Cleaner Production*, 217, pp.787-797.

27. Hillebrandt, A., Griese, M., Donhauser, R., Hauger, S. and McKenna, C., 2019. *Manual of recycling*. 1st ed. Munich: Detail Business Information GmbH, Munich, p.10.

28. Kirchherr, J., Reike, D. and Hekkert, M., 2017. Conceptualizing the Circular Economy: An Analysis of 114 Definitions. *SSRN Electronic Journal*.

29. Leising, E., Quist, J. and Bocken, N., 2018. Circular Economy in the building sector: Three cases and a collaboration tool. *Journal of Cleaner Production*, 176, pp.976-989.

30. McDonald, R., 2004. Recycled materials relational database. 1st ed. [Tampa, Fla.]: University of South Florida.

31. Ministerie van I&M, & Ministerie van EZ. (2016). Nederland circulair in 2050. Retrieved from https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/rapporten/2016/09/14/bijlage-1-nederland-circulair-in-2050/bijlage-1-nederland-circulair-in-2050.pdf

32. Olsson, L., Loerakker, J., Verlaan, T., Clemoes, C., & Mulvihill, D. (2021). *Revisioning Amsterdam Bijlmermeer - Failed Architecture. Failed Architecture*. Retrieved from https://failedarchitecture.com/the-story-behind-the-failure-revisioning-amsterdam-bijlmermeer/.

33. Piscicelli, L. and Luddena, G., 2016. The potential of Design for Behaviour Change to foster the transition to a circular economy. *Proceedings of DRS 2016, Design Research Society 50th Anniversary Conference*, p.2.

34. Potting, J., Hekkert, M., Worrell, E. and Hanemaaijer, A., 2017. *CIRCULAR ECONOMY: MEASURING INNOVATION IN THE PRODUCT CHAIN*. The Hague: PBL Publishers, p.5.

35. Rose, C. and Stegemann, J., 2019. Characterising existing buildings as material banks (E-BAMB) to enable component reuse. *Proceedings of the Institution of Civil Engineers - Engineering Sustainability*, 172(3), pp.129-140.

36. *The circular economy glossary*. Ellenmacarthurfoundation.org. (2021). Retrieved from https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/glossary.