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ARC6115 - Critical Study

How can ‘waste’ be used within architecture and how is its value as a resource determined?

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Introduction

This essay will analyse the use of 'waste' in architecture and examine the role of humans in determining its value as a resource. The term 'waste' was defined in Old and Middle English as something "outside an economy of human values" (Locke, 1960) that "had not… been used for the benefit of humankind." (Cairns & Jacobs, 2014). A similar definition was outlined by Kevin Lynch in Wasting Away, a book in which he began to answer a question posed a hundred years prior by an early scholar in the study of waste; "When one considers the numerous arts and sciences that the professional man must have at least some acquaintance with… is it to be wondered at, that dilapidations are not more studied?" (Fletcher, 1872). Before his untimely death – halting any major progress in the field of waste studies – Lynch set out his definition of waste as; "what is worthless or unused for human purpose. It is a lessoning of something without an apparently useful result; it is loss and abandonment, decline, separation, and death. It is the spent and valueless material left after some act of production or consumption, but can also refer to any used thing: garbage, trash, litter, junk, impurity and dirt. As we have seen, there are waste things, waste lands, waste time, and wasted lives" (Lynch, 1990). The similarities between Lynch's definition and that from Old English lie in human valuation and usefulness; but where Lynch's definition becomes more refined is in its acknowledgement of 'death'. "Death, destruction, and deterioration represent the negative, anxiety-inducing flip side to a range of… assumptions about built architecture's defining attributes" (Cairns & Jacobs, 2014); inevitably, "as built form, architecture will… start to decay and deform" (Cairns & Jacobs, 2014). The most common 'cause of death' in architecture is a lack of stakeholder investment – for a building "sickens… when it is not maintained" (Filarete, 1965). The "buildings that we value do not depreciate" (Cheshire, 2016) - evident in the increasing number of listed buildings, showing how "buildings that are really valued and loved are retained over their contemporaries." (Cheshire, 2016). The questions that arise are who determines when we value something or not? Who has to 'love' a building for it to be retained? Whilst there are no straightforward answers to these, we can begin to examine what gives something value.

In today's society we have a linear model of consumerism; we take, make, and then dispose. Within this industrial infrastructure, products are made for the consumer "quickly and cheaply without considering much else" (Braungart & McDonough, 2009). This way of thinking can be traced back to the 18th century,

starting with the Age of Enlightenment. This period - argued by the garbage philosopher John Scanlan to have been just as equally an age of "rejecting waste" (Scanlan, 2005) – was the earliest sign of architecture being linked to the creation of value. The importance of 'orderly' design - leaving behind "the mess of designing and building, and (denying) future states of decay" (Cairns & Jacobs, 2014) - created a sense of "alienation from the life and death of matter" (Scanlan, 2005). Later in the 18th century came the Industrial Revolution; a period of rapid change where the production of goods and economic growth became valued above all else – largely at the expense of the environment and our own well-being. The Revolution, "like all paradigm shifts, encountered resistance" (Braungart & McDonough, 2009). Romanticist poets, artists, and aesthetes such as John Clare, John Ruskin and William Morris spoke about their fears for a world where "aesthetic sensibility and physical structures were being reshaped by materialistic designs" (Braungart & McDonough, 2009). The industrial design agenda had no regard for the natural world, nor any understanding of how delicate, complex, and intertwined it was with our own prosperity. As was the case in the Age of Enlightenment – processes were expected to be streamlined and waste was considered as just that. For the most part, we continue to operate in a way that places the consumer need above all else; we take, make, and dispose… but then what? If we continue down that same route of cradle-to-grave consumption, soon enough there will be nothing more to 'take'.

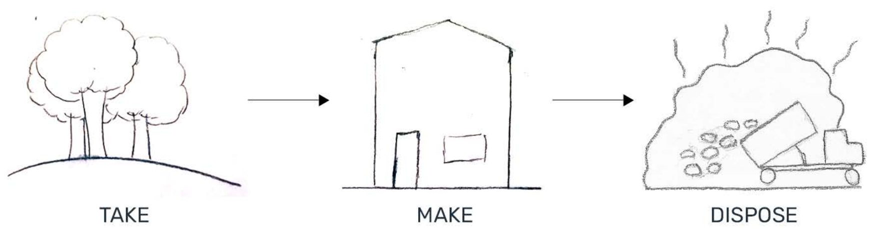


Fig. 1: the linear economy model

To elicit real change, “the consumerist society needs to reinvent itself” (Sessi, 2016). The biggest hope we have now is in “moving away from our current linear economy towards one where our products, and the materials they contain, are valued differently” (Environmental Audit Committee, 2014). This is the intention of a circular economy, starting with a shift from cradle-to-grave consumption to cradle-to-cradle nurture. One of the earliest advocates for the circular economy, Swiss architect Walter R. Stahel, proposed “an economy based on a spiral-loop system that minimizes matter, energy-flow and environmental deterioration without restricting economic growth or social and technical progress” (Stahel, 1982). This idea took into consideration cradle-to-cradle ideology, biomimicry and industrial symbiosis - inspired by “biological cycles where nothing is wasted and waste is food” (Cheshire, 2016). Stahel’s economic model can be seen in figure 2, based on a system of reusing (loop I), repairing (loop 2), reconditioning (loop 3) and recycling (loop 4). Evidence of this shift in thinking was seen in the 1970s, when archaeologist and professor William Rathje founded the study of garbology; an idea that we can study and analyse a community or culture through its waste.

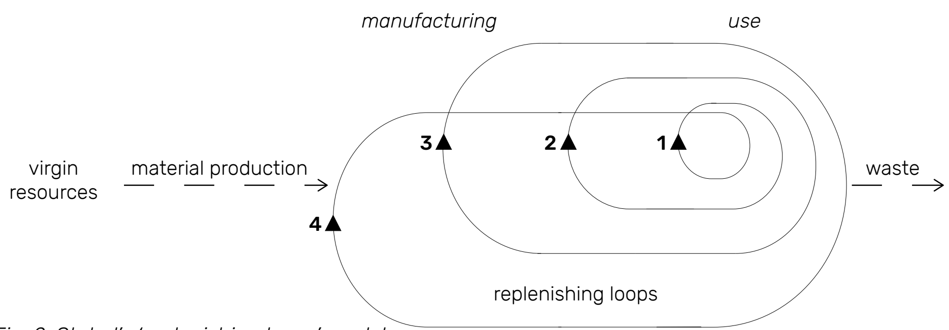


Fig. 2: Stahel’s ‘replenishing loops’ model

Though it was discussed much earlier, the idea of cradle-to-cradle design was not founded until 2002, when Michael Braungart and William McDonough released their book Cradle to cradle: Re-making the Way We Make Things. One of their main acknowledgments within their work was the idea of guilt language; talking about zero emissions, zero footprint - reducing, avoiding and minimising our impact where possible. We put so much emphasis on the feeling of guilt that we almost forget we can enact change. This is one of the points discussed in Cradle to Cradle; as well as outlining design strategies and technical thinking about material classification, they emphasise the fact that “cradle to cradle is a support strategy” (Braungart & McDonough, 2009) – meaning it can only truly work when all people involved in the process are invested in its success. Just like Stahel, they recognise the importance of learning from nature – a concept that challenges the anthropocentric view that “nature exists for the benefit of humans” (Sessi, 2006). In opposition, the non-anthropocentric view sees “humans as part of nature and dependant upon nature” (Sessi, 2006). Braungart and McDonough believed that in order to prosper, humans need to imitate the processes of nutrient flow seen in nature – a process where waste from one system becomes food for another. The suggestion that we can only succeed by imitating nature solidifies our reliance upon it.

From the perspective of modern values, it can seem that success and sustainability are contradictory terms; “successful buildings make money, sell quickly, command more rent, have long lives or help induce the regeneration of an area” (Sessi, 2006), whereas a sustainable building “replenishes, restores, and nourishes the rest of the world” (Braungart & McDonough, 2009). The former serves to benefit the economy, the latter benefits the living. Georges Bataille, a French philosopher of decay and degradation, was particularly interested in reviving a society that “characterized by the logic of productivity and fully subscribed to a market economy, seemed to have lost the sense of what gives value to existence” (Kendall, 2016). Bataille, interested in the ‘market economy’, distinguished between two kinds of consumption; “one in which resources are consumed to meet basic needs, and another in which resources are squandered.” (Cairns & Jacobs, 2014). In successful buildings, resources are squandered. By rethinking our relationship with waste, we can design sustainable buildings that will “be an asset for many years to come” (Sessi, 2006) – once again questioning the idea of longevity in architecture.

It is known in economics that buildings have lifespans, less understood is the fact that “durability is not an intrinsic attribute of architecture” (Cairns & Jacobs, 2014), rather it is an attribute placed upon it by society. In modern society, “the fate of a materialised object is unavoidably linked to processes of valuation” (Cairns & Jacobs, 2014) – be that economic, social, or cultural. This manifests itself in architecture when a building ‘outlives’ its intended use - being “torn down well short of (its) design life with hardly any products or materials being reclaimed for reuse” (Cheshire, 2016). This reflects our attitude towards products – condemning something to waste when we no longer see the original value in it. Without addressing the flaw in our way of thinking, we will continue to misuse material resources which could prove “catastrophic for the future of life” (Braungart & McDonough, 2009). One of the most important changes that needs to take place is in current society’s view of architecture – where economic value overrules all others. Demolition costs and real estate cashflows are the first things to be considered, and the material value of a building becomes irrelevant – “because (buildings) are not designed to be material banks” (Zachariasse, 2014). This begs the question; what if they were designed to be exactly that? Rather than designing with the intention to resist time, in a circular economy, the construction industry would approach “the built environment as an interim stage of material storage” (Pranger & O’Donnell, 2021).

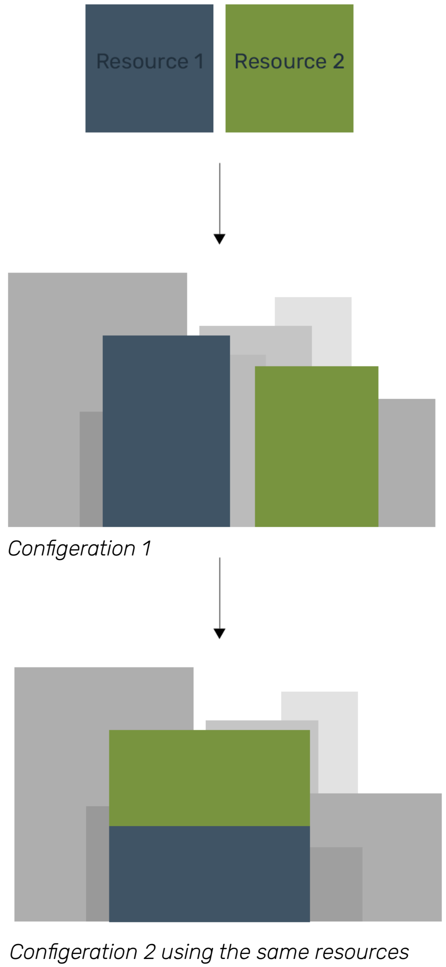


Fig. 3: thinking of the built environment as material storage

Case Study 1: Brighton Waste House

In this section two case studies will be examined – both of which approach the idea of waste in innovative ways. Striving to create sustainable architecture, they both adopt principles of the circular economy; however, with many alternative definitions of what a 'circular economy' is, they approach this in very different ways. The first case study, the Brighton Waste House, works closely to the definition set out by the European Commission in 2014:

"Re-using, repairing, refurbishing and recycling existing materials and products. What used to be regarded as 'waste' can be turned into a resource. All resources need to be managed more efficiently throughout their life-cycle."

The Waste House was designed by Duncan Baker-Brown and built in 2014. The architect and senior lecturer was inspired by a 2008 project by Kevin McCloud – 'Man Made Home'. McCloud's project (figures 4&5), which was presented at that year's Grand Designs Live, was a shed built from oak that had been felled at the site of its construction; praised for its efficient processes and use of materials. Baker-Brown developed his concept for 'waste house' in response, intending to create a living research project to address the cultural shift needed within both the construction industry and the everyday behaviour of man. As well as approaching the design with component renewal and replacement at the forefront, it demanded a transformation in the attitude of the consumer – valuing the reused over the new. The house was constructed using "90% discarded materials… (diverting) an estimated 44 tons of waste from landfill" (Pranger & O;Donnell, 2021), Waste House proves that "what one considers junk, another takes as inspiration" (Cairns & Jacobs, 2014). Amongst its many accomplishments, it became the UKs first "permanent structure with full planning permission" (Pranger & O'Donnell, 2021) to be made from waste – also meeting all local building regulations – showing that waste can be made useful again.

Whilst the concept of the design lead to the use of waste materials, it was the use of materials that influenced many of the functional qualities of the building. Situated on the University of Brighton's campus, the building acts as a live educational research lab for students and staff. As well as hosting public workshops to teach people about sustainability, the building plays a significant role for Masters' students studying Sustainable Design; allowing them to

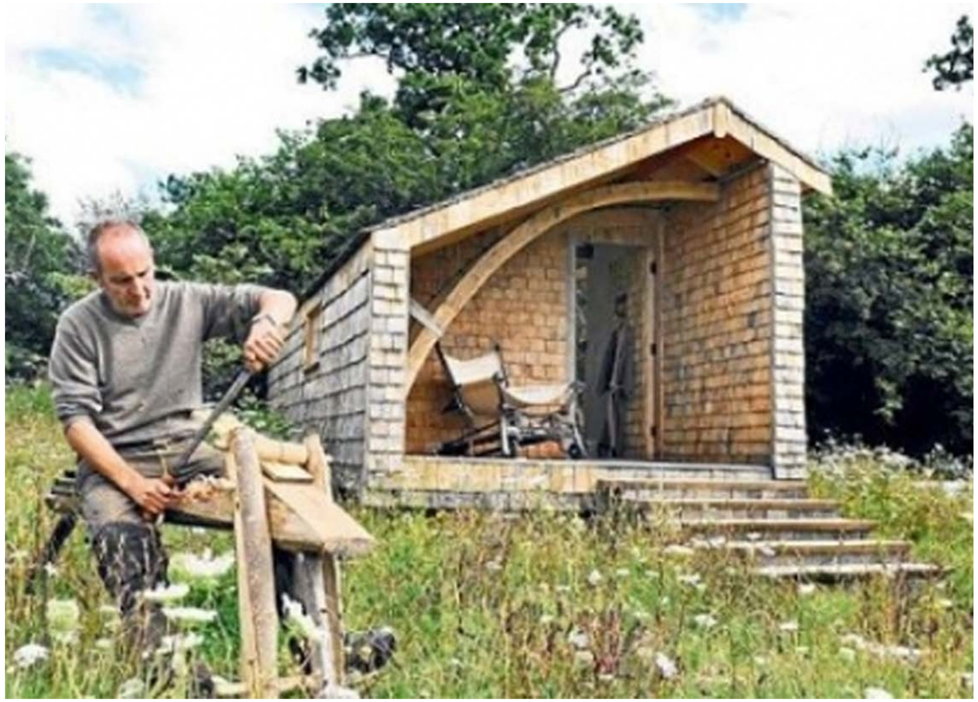
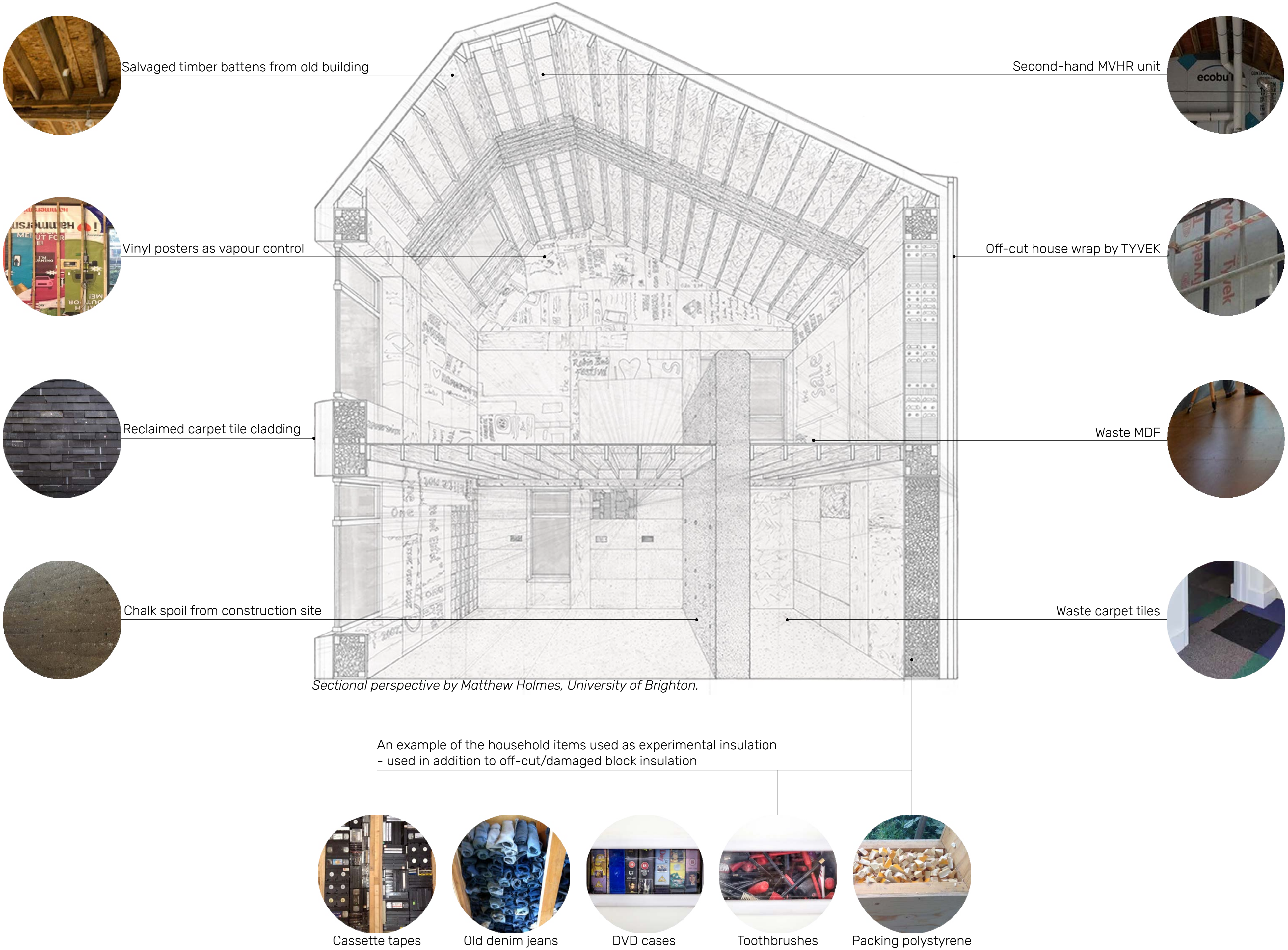


Fig. 4: Photograph of 'Man Made Home', made from salvaged materials and local timber

Fig. 5: Photograph of 'Man Made Home's interior, showing a safe repurposed as a fridge



Sectional perspective by Matthew Holmes, University of Brighton.

Fig. 6: Materials of the Waste House

experiment with the use of waste and organic material in product design. Figure 6 shows the application of waste materials throughout the building - focusing on those that were reclaimed or repurposed. The exterior cladding of the building is made from 2000 recycled carpet tiles – showcasing the innovative thinking behind the repurposing of materials. The use of "second-hand plastics as low-grade insulation" (Pranger & O'Donnell, 2021) throughout the building is of particular interest across the University's faculties – with students from science and engineering courses monitoring the heat-retaining properties of the different materials through sensors in the walls. One of the objects used within the insulation are toothbrushes – of which almost 20000 single-use products were retained from an airport. Whilst the effectiveness of this is still under review by the University, the prospect of being able to insulate inhabited buildings in this way speaks to a utopian future where there is value in everything. If the project succeeds in the coming years, it would prove that "organic low-carbon materials can perform as effectively as their high-energy, high-carbon counterparts" (Testado, 2014), reducing the cost of constructing low-carbon buildings, the time spent on site, and the amount of waste produced.

Unlike most designs, the aesthetics of this building were largely determined by the waste materials that were available rather than the vision of the architect. For example, instead of measuring the desired window sizes and ordering them, they looked at the sizes they had on hand and adjusted the design to suit. Duncan Baker-Brown commented on this unique approach, saying; "there's something beautiful about doing it that way round, responding to what's possible and what's available rather than forging ahead with mass-produced components." The ability to adapt to what resources were available embraces what it means to live in a circular economy – encouraging a system where people share the responsibility of and investment in building components.

Fig. 7: Resource cycle within waste house

Case Study 2: Urban Mining And Recycling Unit

The second case study is the Urban Mining And Recycling (UMAR) unit, whose innovative technical design resonates deeply with the Ellen MacArthur Foundation's 2014 definition of a circular economy:

"An industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models."

The UMAR unit was inspired by a pavilion at New York City's IDEAS Festival in 2015; Dirk E. Hebel's EHT Zurich Pavilion (figures 8&9), made from recycled drink cartons. Hebel, a professor at the Karlsruhe Institut für Technologie (KIT), developed this concept from his research at the time, looking at ways to "leave the age of mining behind and describe a path of harvesting" (Hebel, Wisniewska & Heisel, 2014). It was also a manifestation of the book he wrote alongside Felix Heisel and Marta Wisniewska: 'Building from Waste: Recovering Materials in Architecture and Construction', calling attention to recycled construction and materials. The UMAR unit is a more technical adaptation of the pavilion, designed by Werner Sobek in collaboration with Hebel and Heisel. The prefabricated unit is one of many temporary installations within EMPA's NEST research building in Switzerland, which provides a space to explore the future of buildings through testing, researching, developing, and validating new materials, technologies and building systems. Underpinning the design of UMAR was the ideology that "all resources required to construct a building must be fully reusable, recyclable, or compostable" (Pranger & O'Donnell, 2021).

By "(placing) life-cycle thinking at the forefront of the design" (Pranger & O'Donnell, 2021) Sobek was able to implement a range of circular principles within the unit. The implementation of these principles often determined the aesthetic and spatial qualities of the design – particularly through designing for disassembly. Modern buildings often boast about the use of recycled materials without acknowledging that "through their installation, they have become unrecyclable" (Pranger & O'Donnell, 2021). The UMAR unit addresses this shortfall by applying the five principles of designing for disassembly;

Fig. 8: Hebel's EHT pavilion, made from used drink cartons

Fig. 9: Inside the pavilion, showing recycled seats

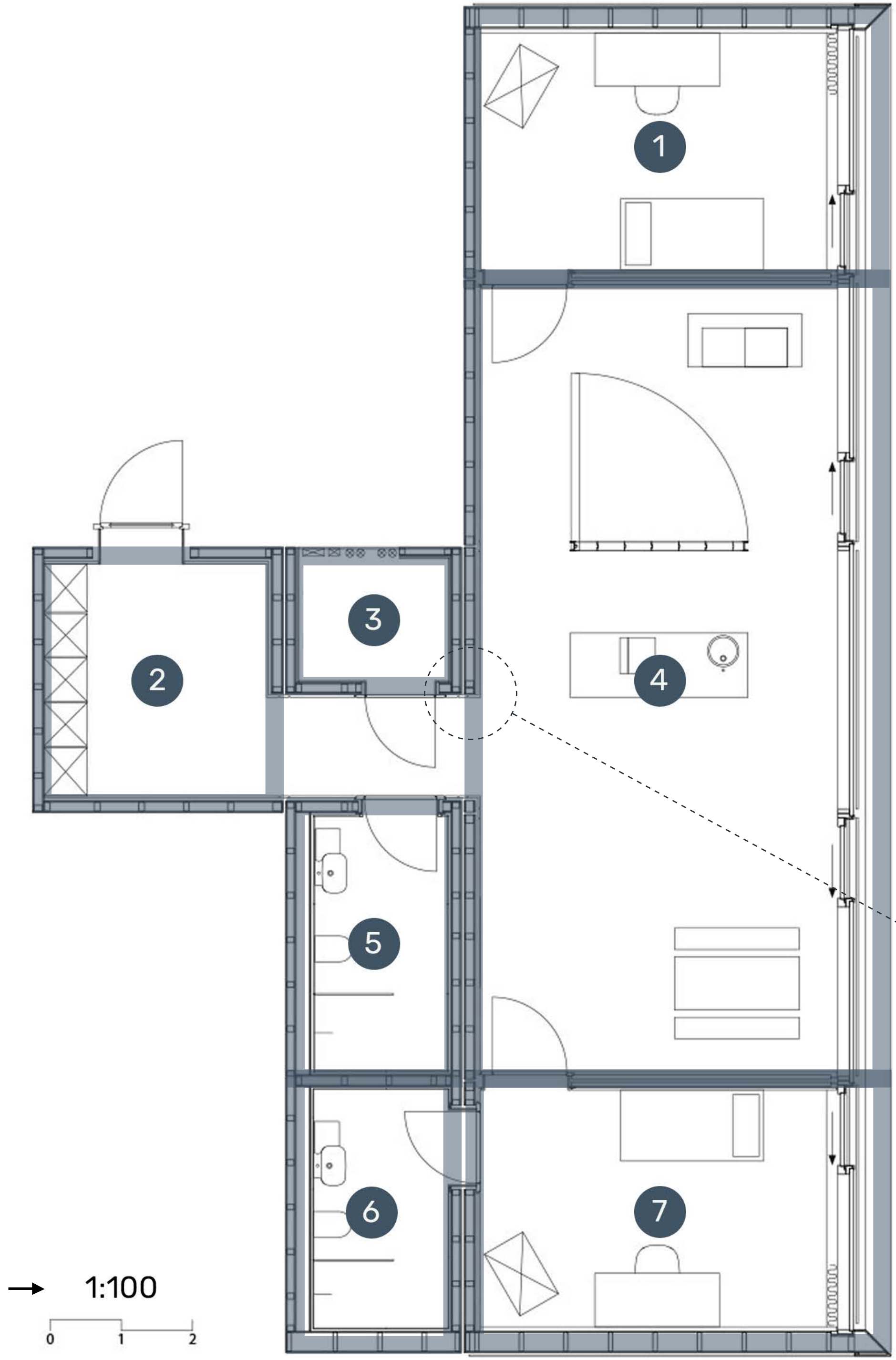


Fig. 10: prefabricated elements of the UMAR Unit

Fig. 11: photograph showing the construction process, with elements positioned by cranes and rails

Fig. 12: photograph showing exposed structural elements

1) Materials: materials should withstand multiple life-cycles, be non-toxic, and have properties that make them recyclable.

2) Service life: the building should be designed with the whole lifetime in mind; long-lasting elements should be flexible; buildings should be designed to adapt to future changes in function; consider the building as a temporary arrangement of materials, with value preservation in mind.

3) Standards: employ modular systems where elements can be easily replaced; use prefabricated elements for quicker and easier assembly/disassembly.

4) Connections: design reversible connections that can tolerate repeated assembly and disassembly; make sure connections are easily accessible; use mechanical joints and if binders cannot be avoided, make sure they are dissolvable.

5) Deconstruction: create a simple plan for deconstruction that is respectful to nearby buildings, people and nature.

(Merrild, Jensen & Sommer, 2016)

The principles of design for disassembly are evident throughout the whole unit, from the prefabricated structure down to the heating-cooling ceiling and how its pipes are fixed to the panels. As shown in figure 10 the unit was constructed as seven prefabricated elements, not only speeding up the time spent on the construction site but also ensuring a "circular use of material resources through precise planning and the controlled environment" (Pranger & O'Donnell, 2021) of the factory setting. The prefabricated nature of the design ended up determining the unit's form, with a series of rectangular elements arranged to create the floor plan. The simplicity of the layout allows for easier assembly, disassembly, and maintenance and reuse of parts – since 'box' forms are commonly used in architecture. As well as the spatial influence, the prefabrication approach meant that the joinery of elements was typically left exposed – once again making them more accessible for maintenance purposes, as well as reflecting NEST's function as a "laboratory and… public repository of information" (Pranger & O'Donnell, 2021) – showcasing the innovations of the design. The maintenance of elements is also considered in its fixings and connections of the unit – where "materials are tucked, folded

Fig. 13: heating/cooling pipes

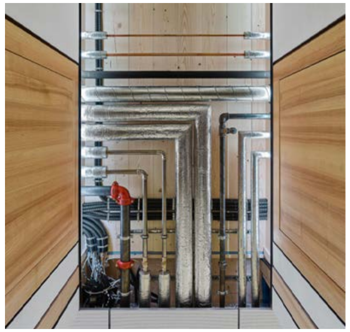


Fig. 14: exposed pipework

Fig. 15: pressed window front

Fig. 16: 'pluggable' bed

or screwed" (Pranger & O'Donnell, 2021) rather than the irreversible method of gluing. One of the most prominent examples of this is seen in the exposed pipework – with pipes attached to panels with plates and screws, as seen in figure (INSERT NUMBER). Nevertheless, the biggest innovation in this design is undoubtedly its use of materials and its dedication to preserving their value. Almost all materials within the unit were "borrowed from their technical or biological cycles... (to be) put back into circulation again at the highest possible quality and quantity" (Pranger & O'Donnell). This means that "type-sorted recycling or pure biological composting of all elements is feasible at the end of the unit's lifetime" (Pranger & O'Donnell, 2021). Like in the Waste House, the insulation within the unit is of particular interest. As well as using standard biological insulating materials such as rock wool, the unit also uses insulation made from hemp fibres and denim – the first of which can be composted after its use and the second of which creates a resource out of waste from the textile industry. Whilst both of these materials are certified for indoor use, the unit provides the opportunity to test the quality of living they provide – with two students having moved in to give feedback on their experiences. As well as the technical processes within the unit, it incorporates another crucial aspect of the circular economy: resource investment. For example, the carpet used within the bedrooms is rented and can be fully recycled once returned to the manufacturer. The idea of the user buying a service rather than buying the product means manufacturers are invested in the whole life of the product – therefore "incentivised to design products that can be repaired, upgraded and disassembled at end-of-life" (Cheshire, 2016).

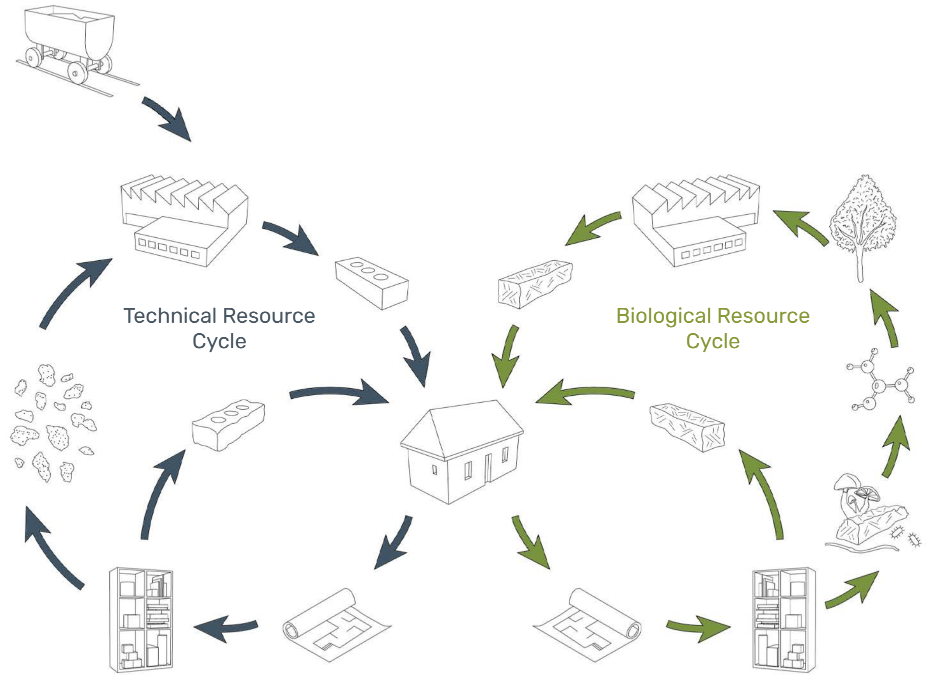


Fig. 17: Biological and technical Cycle by Dirk E. Hebel and Felix Heisel

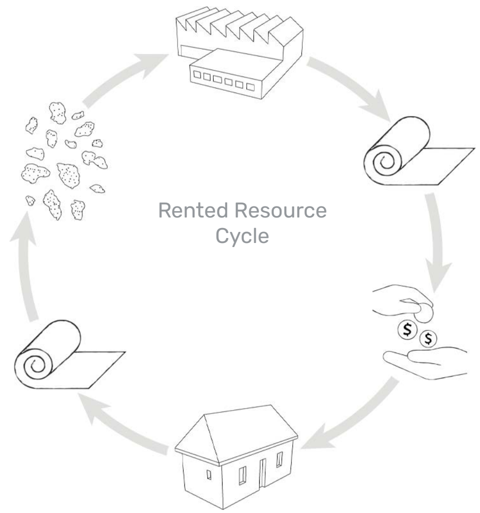


Fig. 18: Rented resource cycle

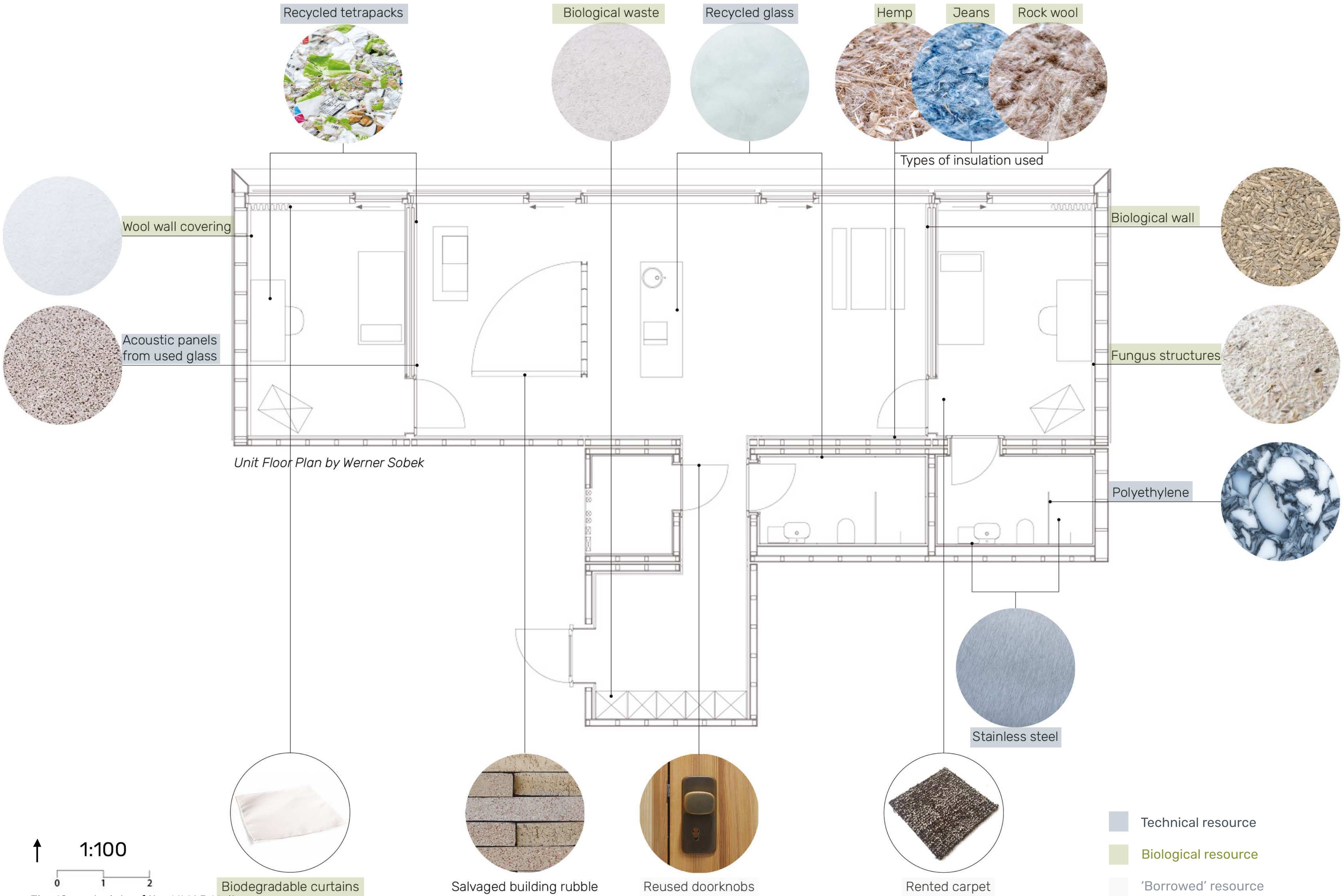


Fig. 19: materials of the UMAR Unit

Conclusion

Both the Brighton Waste House and the UMAR Unit present innovative thinking towards more sustainable design; applying circular strategies by taking waste and finding ways to make it useful – through recycling, reusing and repurposing resources. Not taking into consideration the more technical approach in the UMAR Unit, the biggest difference between the two designs lies in the attitudes of the stakeholders. Waste House become a community project – with 250 students of all ages, volunteers, and apprentices getting involved in its construction. The time and effort put into the building by the community creates a sense of emotional and social value; values that only loved buildings have. In contrast, the UMAR Unit was built with material preservation at its heart; resources are either borrowed from natural cycles or on loan from manufacturers – to be returned and reused at a later date. This means the same value placed upon the whole building of Waste House is placed upon the individual materials within the Unit; ultimately ensuring its success as a future asset.

Though both buildings are valued, they will only be valued as whole entities for as long as the architects or the builders live. Once they reach the end of their lifespan, and maintenance is no longer viable, they will be destroyed. This is where the downfall of Waste House becomes evident. Its ambitious "agenda to recycle has superseded other design considerations" (Braungart & McDonough, 2009). When we recycle a material that was not initially intended to be recycled, we often end up downcycling – which "reduces the quality of a material over time." (Braungart & McDonough, 2009). Despite recycling 44 tons of waste, it cannot be ignored that this only gives the waste one extra lifetime. Much like the "single reuse of popular 'recycling', when your plastic bottle becomes your parka… and in five years the parka goes to exactly the same dead-end cradle-to-grave" (Braungart & McDonough, 2009) as the bottle would have originally – the same will happen here. Waste House, as ground-breaking as it was at its conception, is only a temporary solution; it will "end up being landfilled itself… (erasing) the progress previously made… towards waste reduction." (Pranger & O'Donnell, 2021). On the contrary, the UMAR Unit – built with disassembly in mind – will have its resources sorted, distributed, and reused. In fact, "in a last, consequent step to validate, learn, and improve circular construction, the UMAR unit will be fully deconstructed and returned to its respective material cycles by 2023" (Pranger & O'Donnell, 2021). The whole-life thinking applied

to the UMAR Unit is the crucial element missing from Waste House. It also supports the concept of the future city; where "materials live through several states of formation and use over their entire life span, without ever being seen as a waste matter" (Pranger & O'Donnell, 2021). When comparing the two case studies, it is also important to consider their locations. Whilst it has not yet become part of UK legislation, "cradle to cradle is highly successful in the Netherlands because the Dutch have… a culture of support" (Braungart & McDonough, 2009), placing the UMAR Unit in a more advanced context.

Although there are numerous definitions of a circular economy – adapting over the years – they usually outline a system of changing values and cooperation. In order to fully transition to a “sustainable circular… building process, a change in policies, relationships and tools is necessary” (Torre, 2020). Despite many professionals in the construction industry applying the principles outlined within this essay, in the end the success comes down to the communities; the people who see a building through its whole life; the people who ultimately determine its value. In searching for cases where designing for disassembly succeeded, it became clear that there is still not enough being done. The Future Arena in Rio de Janeiro is just one example of the system’s failure. Built for the 2016 Olympics, it was designed to be disassembled and rebuilt as four primary schools, however, the changing state of the economy caused a recession in 2014 and the plan was never seen through. Is this building now a ‘waste’ building? In looking at a landfill you would find products “made from valuable materials that required effort and expense to extract and make” (Braungart & McDonough, 2009), but through discarding them in this way, “their value is wasted” (Braungart & McDonough, 2009). Surely then the same could be said for a building whose purpose has been served. If designing with material preservation is to ever succeed, it must become commonplace; “for ‘design for disassembly’ and the circular future of buildings to have any impact on society, it is critical that the availability of reused building materials reaches a certain mass” (Merrild, Jensen & Sommer, 2016). One successful example of designing for disassembly was the Cellophane House by Kieran Timberlake, which was built to be exhibited at New York City’s Museum of Modern Art. After being exhibited, the house was deglazed, un-stacked and disassembled using hand tools. The parts were organised and removed from the site within two days with very little waste being produced and 100 percent of the energy embodied in materials was recovered. All that was left in its place was a patch of gravel. Whilst this example gives hope to the future of cradle-to-cradle design, it still leaves questions unanswered. Even if we design for disassembly, can we guarantee the future use of the resources?

Buildings have to die; for a building to be permanent it would “have to be of very high quality and be greatly valued by future generations” (Cheshire, 2016). This does not mean, however, that resources have to die too. By designing a building to be a “fleeting, temporary structure… buildings can become disposable consumer goods” (Cheshire, 2016). In a society where buildings are seen as disposable, the question comes back to value and investment. Even if we change our values and successfully ‘preserve’ resources, will there ever be an ‘infinite’ resource? One that can live a thousand lifetimes and still be considered useful? Or are all materials destined to become waste? Whether a material lives one, ten or one hundred lifetimes, does it make any difference if everything is destined to be landfill in the end? Afterall, we throw things ‘away’ constantly, but “‘away’ does not really exist” (Braungart & McDonough, 2009) – ‘away’, in fact, merely means out of sight. Until we can guarantee that ‘waste’ can be preserved indefinitely, will waste not always be waste?

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References

Braungart, M & McDonough, W. (2009) *Cradle to Cradle: Re-making the way we make things*. Vintage.
Cairns, S. & Jacobs, J.M. (2014) *Buildings Must Die: A perverse View of Architecture*. Massachusetts: The MIT Press
Cheshire, D. (2016) *Building Revolutions: Applying the Circular Economy to the Built Environment*. London; RIBA Publishing.
Ellen MacArthur Foundation, (2014). *Towards the Circular Economy: Economic and Business Rationale for an Accellerated Transition*. Cowes, UK: Ellen MacArthur Foundation, 2013.
European Commission, (2014) *Moving towards a circular economy.*
Filarete, (1965) *Book 1,* folio 6r.
Fletcher, B., (1872) *Dilapidations.*
Hebel, D., Wisniewska, M. & Heisel, F. (2014) *Building from Waste: Recovered Materials in Architecture and Construction.* Berlin: Birkhäuser.
House of Commons Environmental Audit Committee, (2014) *Growing a circular economy: ending the throwaway society*, Third report of 2014-15, London: The Stationery Office, 2014.
Kendall, S., Nioche, C. et al (2016) *Georges Bataille: Key Concepts*. Routledge.
Locke, J. (1960) *The Second Treatise of Government and a Letter Concerning Toleration*. London: Courier Dover Productions.
Lynch, K. (1990) *Wasting Away*. San Francisco: Sierra Club Books.
Merrild, H., Jensen, K. & Sommer, J. (2016) *Building a Circular Future*. Denmark; GXN.
Pranger, D. & O'Donnell, C. (2021) *The Architecture of Waste: Design for a Circular Economy.* New York; Routledge.
Scanlan, J. (2005), *On Garbage*. London: Reaktion.
Sessi,P. (2006) *Strategies for Sustainable Architecture.*
Stahel, W. (1982) *The Product Life Factor.*
Testado, J. (2014) *Student Works: This house made of trash teaches a lesson in green housekeeping*. Archinect. Available at: https://archinect.com/features/article/103711909/student-works-this-house-made-of-trash-teaches-a-lesson-in-green-housekeeping
Torre, S., Cattaneo, S., Lenzi, C. & Zanelli, A. (2020) *Regeneration of the Built Environment from a Circular Economy Perspective.* Publisher Nature.
Zachariasse, C. (2014) *Interview with Coert Zachariasse*, in *Building Revolutions: Applying the Circular Economy to the Built Environment*, chapter 5.