RESOURCE SALVATION

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The Architecture of Reuse

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FOREWORD

The notion of using the site and surrounding area as the first place to look for resources is unfamiliar and foreign to most current designers. But in the past, and in some parts of the world even today, discarding materials was not an option, as new materials were expensive or not easily available, and innovation included working creatively with materials that had a past life.

In any urban society there is a massive stock of available materials from demolition and industrial waste that is currently discarded but has potential value. Although the infrastructure to locate and use these resources is currently lacking, some industry leaders are establishing design strategies, material recovery processes, construction management approaches and manufacturing systems to create innovative new ways of using them in the built environment. This book explores the creative opportunities and practical aspects of this gradual move to a more circular way of thinking about material resources in the built environment. In particular, the focus is on reuse of materials and components, including both construction salvage and waste streams from other industries.

In *The Science of the Artificial*, Herbert Simon describes design as '*the process by which we devise courses of action aimed at changing existing situations into preferred ones*'. If we wish to create a more ecologically based built environment, we need not only to design more sustainable buildings but, more fundamentally, to devise a system and infrastructure that will achieve this. This is what this book is working towards.

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DEFINITIONS

Circular Economy refers to a closed-loop model of an economy where waste is eliminated and product are sold, consumed, collected and then reused, remade into new products, returned as nutrients to the environment or incorporated into global energy flows.

Cradle to Cradle (also referred to as C2C) models human industry on nature's processes viewing materials as nutrients circulating in healthy, safe metabolisms and separates these into technical and biological nutrients.

Deconstruction describes a process of selective disassembly of a building at the end of its life to recover materials and components or systems for potential reuse or recycling. It is an approach to building removal that can extract resources so they can be used for high value future uses.

Design for deconstruction (or disassembly) describes how a building is designed to be readily taken apart at the end of its useful life so that the components can have a second use. To facilitate this, a design team needs to consider how the major systems can be deconstructed during renovations and end-of-life.

Design for durability considers extending the life of a building and its individual components. This can mean choosing long-life components but also creating adaptability in a building as a means to extend its service life and its potential for repurposing.

Diversion (waste diversion, landfill diversion) is the process of diverting waste from landfills or incinerators through various means such as reuse, recycling, composting or gas production through anaerobic digestion. Waste diversion is a key component of effective and sustainable waste management and a major policy objective of many governments.

Embodied energy/carbon is the energy (and resultant carbon emission) used in all the processes necessary to produce a material or component.

Extended Producer Responsibility (EPR) is a policy approach in which a producer is held responsible (physically and/or financially) for a product in the post-consumer stage of a product's life cycle. EPR makes producers consider what will happen to their products after first use and incentivises them to use resources in a way that allows them to have second lives.

Life cycle analysis (LCA) is a comprehensive method for assessing a range of environmental impacts across the full life cycle of a product system, from materials acquisition to manufacturing, use and final disposition. The ISO standard ISO 14040 defines the processes for carrying out LCA calculations.

Linear Economy is a consumption model of an economy where a product is sold, consumed and discarded (take–make–waste).

Reclaim is to recover something of value from a waste stream.

Salvage is typically something extracted from the waste stream as valuable or useful.

Sustainable Materials Management (SMM) is an approach to promote sustainable materials use, integrating actions targeted at reducing negative environmental impacts and preserving natural capital throughout the life cycle of materials, taking into account economic efficiency and social equity.

Virgin materials (also known as primary materials) are resources extracted from nature in their raw form, such as stone, timber or metal ore that have not been previously used or consumed.

Zero Waste is a policy concept that focuses on creating a cyclical system, reducing waste, reusing products and recycling and composting/digesting the rest, with the ultimate goal of eliminating all waste and achieving zero waste to landfill.

1 INTRODUCTION

Our whole economy has become a waste economy, in which things must be almost as quickly devoured and discarded as they have appeared in the world, if the process itself is not to come to a sudden catastrophic end. (Hannah Arendt[1])

Today buildings are a graveyard for materials – once used they rarely have a further life. We hear that increasing percentages of demolition waste is 'recycled', but what value comes from this? Most recycling actually means crushing and use as road base or for other low value uses. Much of the usefulness and financial value is lost. Yet existing buildings and industrial waste streams are huge reservoirs of materials and components that can potentially be mined to provide much needed construction resources. There is increasing recognition that a building at the end of its life is an asset to be valued and that innovation and imaginative design can offer new opportunities for using discarded materials and components as valuable parts of buildings. In the developed world we can learn from ecological systems and from resource strategies in poorer parts of the world, where materials are more precious and salvaged items are more highly valued. This may help to create material systems for construction that replicate and integrate with the cyclical features of nature.

But what would our cities look like if our buildings were to be built from locally available, renewable and salvaged resources? What sort of new urban vernacular may emerge if we focus on previously used materials and components that come from the local area and do not need large amounts of energy and other primary resources? How does value in old materials get transformed and reconceptualized into new value? How can we transfer heritage value in components and not just whole buildings? Will the process of designing and constructing buildings need to change if it is based on a harvest of local, salvaged materials? What infrastructure is required to make this happen?

Today there is increasing interest in exploring how buildings are made and un-made, and in finding new business models that make use of discarded materials, components, and buildings (Figure 1.1). The above questions are addressed in this book,

Resource Salvation: The Architecture of Reuse, First Edition. Mark Gorgolewski.

(a)

(b)

Figure 1.1 The TAXI building in Denver, CO, was entirely modernized by tres birds workshop using reclaimed materials, including a thermal exterior wall system fabricated from 21 000 recycled PET plastic water bottles.

which draws on the experience of practitioners and case study projects to explore the potential for a new type of architecture that places a high economic, social and ecological value on existing materials and treats the urban environment as a transient store of resources that should be redeployed once their initial use is complete. The book focuses on the experience of designers who have started to explore ways to close resource loops, attempting to create systems where less is wasted. Materials destined for landfill are put back to use, with positive effects on the economy, society and the environment. As architect Jeanne Gang put it, they have begun to explore an '*architecture originated in the material itself rather than in a formal language or design concept*'.[2]

Box 1.1 Venice Architecture Biennale 2016

For the 2016 Venice Architecture Biennale, Chilean architect Alejandro Aravena created two introductory rooms using over 90 tonnes of waste generated by the previous year's art biennale in Venice. Short lengths of previously used crumpled metal channelling were suspended vertically, creating a unique ceiling using waste. Also, the walls were covered by 10 000 m^2 (100 000 sq. ft.) of multicoloured leftover plasterboard (drywall) pieces which were stacked to create a moulded surface that included protruding display shelves.

1.1 BACKGROUND

Architecture in its traditional role is probably a dying profession. Today, architects must work with systems; they must design new ways of living and working in which buildings play a key role. We desperately need mediators between human need and the enduring cycles of nature. Architects can, and must inhabit this new role. (Paul Hawken[3])

Architecture is created from a fusion of concept and matter, what Louis Kahn called '*the measurable and the unmeasurable*', and throughout history architecture has been shaped by a dialogue between ideas and materials. Kieran and Timberlake in their book *Refabricating Architecture* state that '*architecture requires control, deep control, not merely of the idea, but also of the stuff we use to give form to the idea'*.[4] Traditionally this has led to a fascination with the newest and most innovative materials, and the evolution in architectural history has a strong association with new technology. Today the vast majority of materials used to create the built environment are new and pristine, and our consumer culture leads us to assume that new is best. At the same time, most materials are unrelated to place, and predominantly come from all over the world – aluminium may come from South America, steel from Russia, glass from China, timber from Canada and so on.

Material and component selection is a vital part of architecture because it holds such potential to communicate meaning in our built environment. In the developed world today we do not normally conceive of buildings as being made from local, salvaged, pre-used materials. We are used to the off-the-shelf method of choosing materials (and technologies). But up until the twentieth century many building components were custom designed by architects. Windows, columns and so on were not standardized. More recently, architects have come to rely on a readily available architectural palette of standardized components from catalogues or web sites. Information such as specifications, dimensions, and standard details for globally produced building components are readily available and their use is facilitated by digital technologies. Design and construction for most buildings is organized as a process of integration of appropriate components. This has isolated designers from a better understanding of materials and their tectonic potential and has removed some creative possibilities and discovery from design.

Furthermore, the quantity of these materials that we use has grown hugely. In the last 50 years the world population has doubled yet our use of some engineering materials has grown by 4–15 times.[5] This huge increase has enabled us to increase our living standards, creating and servicing a huge urban infrastructure connected by extensive transport networks. But, as architect Thomas Rau has pointed out, unlike energy, which is widely available from the sun (we just need to implement appropriate technologies for harvesting it), access to materials is effectively limited by what is available on earth, and for some materials we have consumed most of the easily obtainable supply.

In a world faced with climate change, increased resource scarcity, and other environmental, social and economic challenges, access to new material resources and disposal of waste are becoming far more costly and constrained. Growing concerns about the loss of useful resources and physical limits of the earth's capacity to provide new resources and absorb the mountains of waste accumulating in landfills, as well as the increasing cost of disposal, are leading some to a rethink how we deal with resources.[6] The United Nations Environment Programme (UNEP) has noted that '*As global population continues to rise, and the demand for resources continues to grow, there is significant potential for conflicts over natural resources to intensify in the coming decades*'.[7]

The work of photographers such as Edward Burtynsky, Timo Lieber and Vik Muniz (Figure 1.2) brings to light the vastness of the process of dealing with materials throughout their linear life cycle and highlight some of the impacts this has on individuals, society and the natural world. As buildings gradually become less carbon intensive for operating energy use, the impact of extracting, processing and installing the materials used to create the built environment become increasingly important and the embodied energy and carbon that occurs from this becomes progressively more of a concern.

It is now commonly recognized that a linear economy, which focuses on maximizing 'throughput', is wasteful because it permanently disposes of valuable resources after their first use. There is an increasing awareness of the need to move towards a circular economy, based on cyclical systems as observed in nature, which aims to transform the value of existing resources that have come to the end of their usefulness in their current form. Many governments around the world are beginning to consider resource efficiency, resource productivity and waste reduction, in addition to climate change and other development issues in their policies. In 1999, John Prescott MP (then UK Deputy Prime Minister and Secretary of State for the

Figure 1.2 'Atlas (Carlão)' is one of several amazing portraits created by photographer Vik Muniz and the catadores – self-designated pickers of recyclable materials, using waste from Jardim Gramacho waste dump located on the outskirts of Rio de Janeiro.

Environment, Transport and the Regions) stated that '*In the past, focus has centred mainly on improving labour productivity. In the future, greater emphasis will be needed on resource efficiency. We need to break the link between continued economic growth and increasing use of resources and environmental impacts*'.[8] These factors will, in future, have significant repercussions for materials availability and, thus, architectural design and building construction. Supply of bulky, low value, construction materials may in future be far more dependent on local proximity and local availability. The need to design and build using local, readily available, renewable or reused resources, and to develop closed-loop systems for the life cycle of building materials are likely to become major drivers for the design of the future built environment. And this will create new design opportunities, but will also change the design and construction processes.

Some designers and building owners have begun to explore alternatives to the produce–use–dispose linear model of resource use in the built environment and to consider closed-loop approaches that aim to find use, value and inspiration in what was previously classified as waste (Figure 1.3). Materials destined for landfill can be put back to use, with positive effects on the economy, society and the environment. Such an approach has potential to alter the design and construction processes in ways that may lead to more place-based architectural solutions. It is also important to differentiate between reuse today, which has to deal with material that is already in use, and future reuse of materials that we can now ensure will be more readily reusable.

Although green building rating systems such as LEED and BREEAM encourage a move towards closed-loop systems through strategies such as choosing recycled materials and reused components, at present in the developed world the reused building material sector is fragmented. There is an absence of a clear system or infrastructure with recognized business models and processes aimed at reuse. There is a need to establish a supply chain and inform designers about the

Figure 1.3 The Mountain Equipment Coop explored the potential for material reuse in several of its stores such as this one in Winnipeg, Canada.

potential of such materials and components, and to create a demand that will encourage demolition contractors to deconstruct old buildings due to the value they can get from them. Inventories are needed of salvaged products to enable designers and their clients to have confidence in the availability of materials. And certification processes for materials are needed to facilitate their use without concern.

At present, such factors are preventing the construction industry in most countries from embracing a more long-term view of the value and potential of existing materials and components, and this is hindering the establishment of mechanisms for their widespread reuse. However, in future, when choosing materials, it will be necessary to consider the social, ecological, and technical relationships and the networks that materials are part of.[9] Identifying new business models that make such strategies profitable, and using appropriate design approaches that address consumer needs and create unique buildings, can overcome industry hesitance to embrace new material ecologies.

Successful case studies of reuse of components and materials in building projects discussed in this book are gradually becoming accepted in the mainstream. Although the designers featured are innovators and leaders in this field, they present a foretaste of a potential future that recognizes the value of existing resources, how they can be transformed and the resulting environment that can be created. They also offer some ideas about the infrastructure that will be necessary to establish reuse as a common feature of the built environment.

Box 1.2 Current Resource Use[10]

It is estimated that as much as 40% of the raw materials consumed in North America is for construction.

The European Union (EU) uses 8 566 million tonnes of material resources, of which 7 654 million tonnes (89%) are non-renewable.

From 1980 to 2010 worldwide metals and minerals use increased 66% from 19 bill tonnes to 31.5 billion tonnes (and is expected to grow to 53.7 billion tonnes by 2030).

Typically we still use materials on average only once.

People in rich countries consume up to 10 times more natural resources than those in the poorest countries. On average an inhabitant of North America consumes around 90 kilograms (kg) of resources each day. In Europe, consumption is around 45 kg per day, while in Africa people consume only around 10 kg per day.

Sixty percent of discarded materials is either put in a landfill or incinerated, while only 40% is recycled or reused, but usually for low value uses.

Ninety-five percent of the value of material and energy is typically lost at the end of the first use. Material recycling and waste-based energy recovery captures only 5% of the original raw material value.

1.2 SCARCITY OF RESOURCE

Scarcity appears to be a simple concept based on the notions of availability and shortage. However, it is a term that encompasses economic, political, social and ecological domains each with different associations to resource allocation and material use. Systems-theorists, such as Donella Meadows and others, suggest that scarcities occur when resource flows are in some way constrained or exhausted. Economic doctrine encourages us to dismiss such concerns, relying on the market to achieve optimal flows. In the 1970s, economist Georgescu-Roegen was the first to apply the thermodynamic law of entropy (which states that energy tends to be degraded to ever poorer qualities) to mineral resources, arguing that resources are irreversibly degraded and will eventually be exhausted when put to economic use.[11] His work inspired the field of ecological economics and the study of natural resource flows in economic modelling and analysis. He claimed that the economic process irreversibly transforms low entropy (valuable natural resources) into high entropy (valueless waste and pollution), thereby providing a flow of natural resources for people to live on but at the same time degrading the value of these resources.

Others argue that scarcity is a socially and economically constructed condition – there is enough food in the world, it is just in the wrong place. There is enough housing in the developed world, just in the wrong ownership. In the developed world of seeming abundance it is difficult to comprehend the relevance of the concept of resource scarcity. Thus, in reality, scarcity is extremely complex and mutable, and fundamental to the essential question of whether we can really have continual growth on a bounded and limited planet.

There is growing consensus that material availability in the future will be significantly constrained compared to the recent past. This may be due to physical exhaustion of supply of some materials (such as rare metals or platinum) but in many cases scarcity is linked to ease of availability, energy intensity of processing, cost of extraction and processing, and transport. There may be a lot of iron ore or aluminium ore in the earth but it may not be realistic to extract such large amounts of it in future. Conversely, as we have seen with the recent advent of fracking and tar sands oil extraction, sources become more or less economically and politically viable due to price changes for a particular resource and government policies and ideaologies.

Nevertheless, there is mounting evidence for all the major resources – energy, water, food and materials – that our existing global industrial models are leading to a series of persistent shortages and/or uncertainties. The Stockholm Resilience Centre has shown that using the concept of planetary boundaries, of the nine boundaries that the Centre has identified, by 2015 four have already been breached and several others are close to the

threshold.[12] In 2007 the New Scientist magazine looked at the availability of many key minerals and calculated how many years these minerals would last based on various use scenarios.[13] They speculated that material scarcity will call into doubt the aim that the planet might one day provide all its citizens with the sort of lifestyle now enjoyed in the west. Researchers at Yale University suggest that '*virgin stocks of several metals appear inadequate to sustain the modern "developed world" quality of life for all of Earth's people under contemporary technology*'.[14] The Worldwatch Institute has estimated that by the year 2030 the world will have run out of many raw building materials and we will be reliant on recycling and mining landfills.[15] Increasingly, questions are being asked about whether we have the resources to deliver?

Consequently, consideration of building materials scarcity goes beyond simple availability and cost, to include engagement in the whole supply process from extraction, through processing, delivery, technologies used, skills required, assembly on site, use, maintenance and end-of-life disposal methods. It requires consideration of all the tangled social, economic, environmental and technical networks that are necessary to make a resource useful, and their consequent impacts. As Till and Schneider[16] suggest, scarcity in an architectural context is much more than just an actual lack of material, space or energy. Rather, scarcity is revealed as socially, economically and politically constructed and requires a discussion of patterns of creation, consumption and behaviour. They also suggest that scarcity presents a radical challenge to the architectural community as the most appropriate solution to a spatial problem under conditions of scarcity may often be the avoidance of new building.

A changed approach to materials, or a '*new materialism*' based on ecological principles and recognizing limits, demands a rethinking of the nature of material processes in architecture, leading to a

Box 1.3 Resource Use In Construction

In England, the Construction Resources Roadmap states that around 380 million tonnes of resources are consumed by the construction industry each year. The table below provides estimates of global use of five principal construction materials.

Material	Global production (Mt/yr)	Use per person – based on world average (tonnes person/yr)	Carbon intensity (kgCO_2e/kg)	Approximate % used in building construction
Steel	1400	0.2	1.5	42
Cement	4000	0.57	0.7	75
Aluminium	70	0.01	9.2	24
Plastic	299	0.04	3.3	
Timber	534	0.075	0.31	40

Note – these data are a best estimate based on a variety of sources.

fundamental revision of both the way we create our built environment and what the urban environment will be like in the future. This may lead to new forms of architectural practice and new procurement processes, some of which are explored in this book.

1.3 WASTE AND OBSOLESCENCE

The way we see it, waste is what you call something when you have no idea what to do with it. The fact that waste exists anywhere is more a testament to our lack of imagination than it is to the inherent value of any material. If you have a purpose for it, it's no longer waste. (Omar Freilla[17])

The increase in waste generation is inextricably linked to urbanization and economic development. As countries urbanize and standards of living increase, consumption of goods and services increases, so waste generation typically increases. In recent years there have been increasing concerns about the vast garbage dumps that are necessary to service urban areas, and the huge amounts of waste (particularly plastics) that accumulate in the world's oceans, endangering humans and wildlife and taking hundreds of years to degrade.

Waste has become a significant concern, having major impacts on people's health, the environment and national economies. Waste disposal has significant costs to municipal governments, pollutes the local and global environment and contributes to climate change in the form of greenhouse gas emissions from transport and processing. Yet, much of this discarded material has significant potential value and usefulness. Discarding it is therefore negligent. In developed countries, construction and demolition waste typically contributes about 35–40% of the total waste stream. It is estimated that about 75% of this demolition waste (by weight) has residual value that can be utilized by reintroducing it into the urban fabric through reuse or recycling.

The problem of waste as a concept is reflected in the difficulty of defining waste and the assumption that it is a burden that requires discarding. Often definitions are not useful and reflect the current linear attitude to resource use. In many countries complex rules define different types of waste and how they can be treated, with legal implications. Sometimes these can prevent legitimate reuse of potentially useful materials. The UK government rules for defining waste state that '*A material is considered to be waste when the producer or holder discards it, intends to discard it, or is required to discard it*'.[18] This ignores any useful value the material may have. Zero Waste America defines waste as '*a resource that is*

not safely recycled back into the environment or the marketplace'.[19] A new and evolving ecology of material sees waste streams not as a burden but rather as a valuable resource. In the book *Wasting Away*, Kevin Lynch suggested that '*Architects must begin to think about holes in the ground and about flows of materials*'. A new type of infrastructure of valuing, recovering, sorting, processing, managing and using is beginning to evolve to exploit discarded materials. A new aspirational target of '*zero waste*' (along with zero energy and zero carbon) has been proposed for new and existing buildings and urban areas which will require the redesign of urban systems and material flows.[20] As with zero carbon buildings, a discussion is needed about the appropriate scale and strategy for achieving zero waste – should we address waste at the level of the component, building, district or city? Most likely all should be considered.

Although in recent years waste management and recycling schemes in some countries have reduced the volume of waste going to landfill, to achieve fundamental change in our approach to waste we need to rethink our approach to design, component life cycles and building life cycles. This requires reconsideration of the concepts of obsolescence and decay. Since the built environment uses a lot of materials and lasts a long time, there is a need to carefully reconsider how a material, component, or building decays and when it becomes obsolete. Extending the life of resources (not necessarily buildings) should be an essential aspect of design and management of the built environment.

Obsolescence is defined as when something becomes no longer useful, is outmoded, out of date, or falls into disuse. In construction, a component or building is regarded as obsolete at the point when it is discarded for whatever reason. Conversely, decay is the process of rotting or decomposition and is closely related to physical effects. It has been noted that obsolescence occurs for many reasons and is strongly connected with economic value, regulations and market forces, and less with physical decay; thus, architectural design has a limited impact on building obsolescence. A study by the Athena Institute into the reasons for the demolition of 227 buildings in Minnesota, USA, showed that only one-third of the buildings were demolished due to decay and, thus, their physical condition. The study highlighted urban issues and site planning as well as aspects of building construction and maintenance as ways to increase building longevity and avoid obsolescence. Various researchers have presented obsolescence as the divergence over time between declining performance and rising expectations. For building stocks, Thomsen and van der Flier have defined obsolescence as a process of declining performance resulting in the end of the service life. But the reasons for this can be many and are often not technical. They claim that '*obsolescence of building stocks is only partly a physical phenomenon. It is*

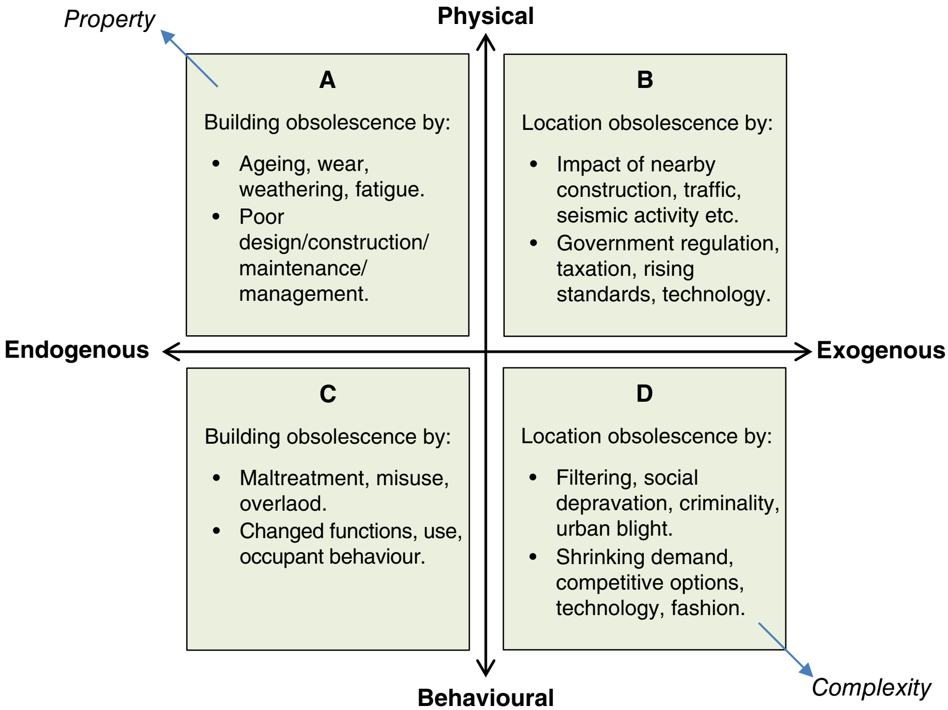


Figure 1.4 Conceptual model of obsolescence redrawn based on Thomsen and van der Flier.

essentially a function of human action or disregard. Therefore a distinction should be made between actual and potential performance'.[21] A variety of causes have been suggested for obsolete buildings, including: physical, economic, financial, functional, location, environmental, political, market and fashion. Figure 1.4 shows a conceptual model for building obsolescence as proposed by Thomsen and van der Flier.[21]

Abramson has explored architectural obsolescence and the idea that buildings and cities can suddenly lose their value and utility. He claims that our current concept of architectural obsolescence evolved out of early-twentieth-century US capitalist real estate development and spread globally in the mid-century urban and social realms before impacting architecture directly.[22] He states that '*a building's value was represented in time and money, inextricably declining and rending demolition inevitable*'. Abramson also identifies obsolescence related to urban renewal and the resulting removal of many technically usable buildings, and related to the corporate strategy of planned obsolescence and the general infusion of a culture of short term-ism. In this context, issues of physical or technical obsolescence become less important as financial concerns dominate.

Some designers have embraced obsolescence's liberating promise of expendability and short-life buildings. Others object

to its implications of transience and waste, and have sought to reverse obsolescence through tactics of preservation, postmodernism and ecological design. Abramson proposes obsolescence as the forerunner for today's dominant paradigm of sustainability as a way of comprehending and managing architectural change.

Box 1.4 Waste In Construction

The Wold Bank estimates that urban waste generation worldwide will increase from about 1.3 billion tonnes of solid waste per year in 2012 to 2.2 billion tonnes by 2025.

Construction and demolition waste typically constitutes about 25–30% of the total solid waste stream in developed countries.

Construction and demolition waste (CDW) consists of numerous materials, including concrete, bricks, gypsum, wood, gypsum drywall asphalt roofing glass, metals, plastic, cardboard solvents and excavated soil, many of which can be recycled or reused.

In the United States, annual construction and demolition (C&D) debris from buildings (not including roads and bridges) was estimated to be around 162 million tons in 2013 – or about 0.5 t/person/yr.

In the European Union, construction and demolition waste from buildings is estimated 180 million tonnes/yr or about 0.5 t/person/yr.

The Construction Resources and Waste Roadmap in the United Kingdom estimates that total construction and demolition waste in England, including road building, was at 120 million tonnes.

The US Green Building Council (USGBC) estimates that only about 10% of construction waste is diverted from landfills in North America. The European Union has a target of 70% diversion.

Researchers in the United States estimate that the 'typical' North American home generates about 1600 kg (3500 pounds) of wood waste during its construction.

Repair and remodelling tends to generate more waste than new construction because many repair and remodelling projects involve both demolition and construction activities, both of which generate waste.

Many countries have established recycling strategies that prevent much C&D waste going to landfill but much is downcycled as low grade road fill products.

Note – these data are a best estimate based on a variety of sources.

1.4 PERMANENCE AND REPAIR

Permanence is not a matter of the materials you use. Permanence is whether people love your building. (Shigeru Ban[23])

Western culture traditionally attaches long-term meaning to architecture. It is usually assumed that most buildings will last a long time (whatever that may be) and that this is best achieved with new materials. It is rare to think of buildings as being disposable. Yet cultural, technical and economic undercurrents lead to the fact that our buildings often become waste sooner

than expected. The concept of permanence in architecture is contrary to obsolescence and relates to attitudes about durability and maintenance –and also perception. Most architects hope that their creations will last and become permanent and unaltered. In traditional societies the large investment required to create a major building was justified by the conviction that important buildings should be permanent. But the concept of permanence can mean very different things. For example, in Europe permanence in architecture is traditionally equated with stability, mass and solidity. Stone monuments and their durability of construction are often used as examples of permanence. Yet as Ford has pointed out '*Much of Renaissance Venice is a 19th-century reconstruction; the Venice Campanile dates from 1910. The Vienna Opera and Milan's La Scala date from the late 1940s. All the members of the Eiffel Tower have been replaced at least once. The Lincoln Bedroom….. dates from the Truman administration*'.[24] So what about these buildings is permanent? Ford also argues that although the Parthenon still consists of its original stones (and indeed they are treated almost as religious relics), much of the original content of the architecture – the colour, detailing, context – no longer exists. So permanence of the physical matter has not conserved all the original content and ideas. An alternative view of permanence is represented by the Ise shrine in Japan, which, although originally constructed in the seventh century has been reconstructed in an elaborate ritual approximately every twenty years. So, is it 1300 years old or 20 years old? As Ford and others have pointed out, in Japanese culture, where architecture was typically created from timber and so easily destroyed by fire and other natural forces, value was embedded in the ideas and not the material reality.[24] In this case it is the style and ideas enshrined in the building that are preserved, although the physical matter is constantly renewed. Many vernacular buildings such as earth buildings have an extended life because of the willingness of the community to regularly spend time renewing and maintaining the buildings in order for them to endure in their original form. This highlights the link between permanence and maintenance – most buildings can last a long time with appropriate maintenance, and become obsolete for other reasons.

Since the industrial revolution architects have been more willing to reject the traditional view of permanence of buildings and recognize that the fast changing nature of modern life may require more transient built environments. Le Corbusier's call to treat a house as a machine suggested that both maintenance and durability for houses should be similar to the way machines are maintained. Machines are generally seen as more transient but at the same time require more maintenance. Furthermore, technical advances and the introduction of codes have changed expectations for building performance in a way that has undermined permanence in buildings, and questioned how we should treat even some historical buildings. For example discussions

about whether, and how, to improve the performance of historic parliament buildings in England and Canada highlight the friction between permanence, heritage value and thermal performance. Groak argues that it is meaningless to speak of building lifetimes, since different parts of the building have very different lifetimes. He asserts that '*buildings have to be understood in terms of several different time scales over which they change in terms of moving images and ideas in flux*'.[25] Nevertheless, most new buildings are designed with the often unrealistic assumption that they will not substantially change (typically for a 50–60 year life), so whether measured in money or carbon this can lead to considerable waste.

In the book *How Buildings Learn*, Stewart Brand discusses how buildings adapt to changing requirements over long periods. He challenges the proposition that architecture is permanent and that buildings cannot evolve, and proposes that buildings adapt best when constantly refined and reshaped by their occupants (Figure 1.5). This raises the question of the role of architects and Brand is in favour of an evolutionary approach where owners can change a building over time to meet their needs, and the architect's role is to facilitate this process. He proposes that rather than being artists of space architects need to becoming artists of

Figure 1.5 This Victorian industrial building in London has been regularly transformed to a new use throughout its life. It has been used for industrial, commercial, retail and catering uses in the last 40 years.

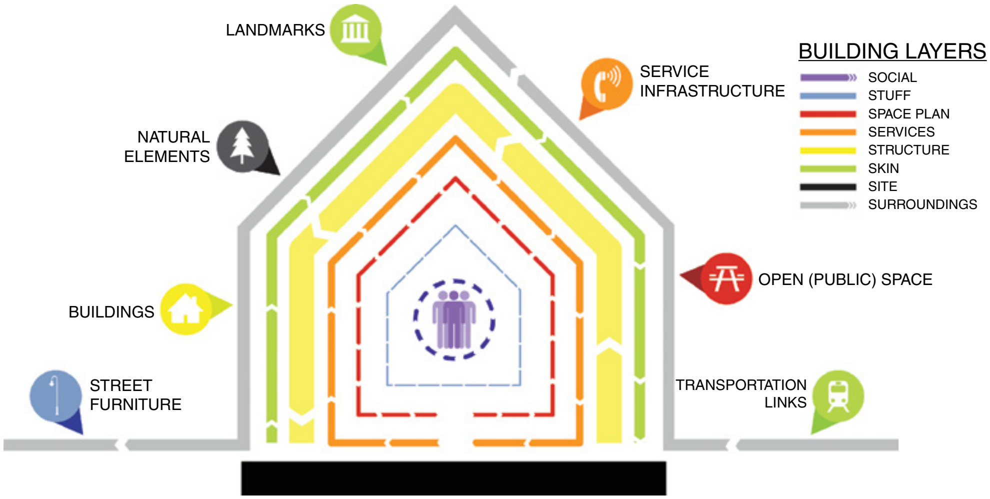


Figure 1.6 Building layers of change (from *Adaptable Futures* based on the work of Brand and Duffy).

time, using the conceptual model of layers of a building – site, structure, skin, services, space plan and stuff (Figure 1.6), each of which has a different timescale and can be maintained and replaced to suite its individual needs (see also Chapter 2.6).

Groak notes that buildings are only ever sustained as coherent artefacts by incessant microrenewals (small repair and improvements). Historian David Edgerton claims that '*although central to our relationship with things maintenance and repair are matters we would rather not think about*'.[26] Consumer culture has developed a prejudice against repair (as a sign of poverty) and permanence as a way of increasing economic activity. Edgerton states that until the mid-twentieth century more expensive and complex equipment was kept working by a constant interaction with repair regimes. Repair was the means by which they were kept functioning. Early automobiles, for instance, required constant attention to keep them running. Complex contemporary buildings have some similar characteristics, as without knowledgeable operators capable of appropriate control and repair they do not function optimally. Thus, Cairns and Jacobs conclude that durability is not an intrinsic attribute of architecture but rather a feature of how the world views architecture.[27]

But the idea of permanence can also be applied to materials and components, even when the building is no longer treated as permanent. Current consumer culture encourages a disposable approach to everything, and permanence expressed in the value of components and materials challenges this (Figure 1.7). Can we design ways of assembling buildings that creates permanence at a subbuilding level and avoid obsolescence for the components and

Figure 1.7 The Re:START temporary mall was created using shipping containers to breath new life to the devastated centre of Christchurch NZ, after the 2011 earthquake.

materials? And what type of infrastructure and industry would this require? Long-life construction materials, components and buildings require effective decision tools that can be applied at the critical early stages of design. The effects of longer product/ building life on life cycle costs, revenues and environmental impacts need to be better understood to inform design strategies.

1.5 MATERIAL EFFICIENCY

"Buckminster Fuller was keen to know how much a building weighed. A better question would now be, how much material resides in the building plus how much material was displaced and energy consumed in the making of the building." (John Fernandez.[28])

Energy efficiency entails providing energy services with less primary energy and has become accepted as a requirement for a sustainable future. In the same way the concept of *material efficiency* suggests providing material services to humanity while

reducing demand for primary materials (using less material, for longer, to achieve the same function), and is also seen as essential to a sustainable future that is compatible with ecological systems. The importance of this concept was highlighted by analysis at the University of Cambridge of the worldwide manufacturing sector that found it very unlikely that manufacturing could meet the 2050 IPCC greenhouse gas (ghg) reduction targets by a strategy of energy efficiency alone.[5] But combining energy efficiency with material efficiency has a reasonable chance of meeting ghg and energy reduction goals for the manufacturing sector.

Key elements of material efficiency are products with longer life cycles, finding ways to return products and materials into service after the end of their current or initial use (reuse, recycling) and designing components that use materials efficiently (reduce). In this way the same level of material services can be provided with reduced extraction of primary materials and less waste generated. Unfortunately, this is inconsistent with many current practices, as construction materials are often relatively cheap but labour is expensive. Thus, many of our buildings use materials such as concrete and timber wastefully, as a more resource efficient proposal requires more labour and design effort.

Some other industries are more advanced with the process of rethinking how products are put together to increase material efficiency. This is partly due to EU legislation that is increasingly putting the responsibility for disposal of products at the end of their useful life onto the producer. Features such as reversible joints, upgradeable components and materials that can be separated are now gradually being incorporated into new products and appliances. Car manufacturers increasingly consider the end-of-life disposal of their products, designing cars to enable recovery of components on '*unassembly lines*' and for easier replacement and reuse of worn parts. Simpler designs and assembly processed using less materials and components can lead to cost savings and are often more applicable for disassembly. Although the nature of construction and the timescales involved are very different to most other industries, there is a need to consider how to apply similar principles and approaches in the built environment. This may necessitate producers of goods taking them back at the end of their life for reuse, recycling or disposal. Ideas such as leasing materials and components are being explored, and '*materials passports*' (see Chapter 2.7) can provide information necessary to facilitate reuse. In the United Kingdom, the British Standards Institute has recently issued a new *British Standard, BS 8895: Designing for Material Efficiency in Building Projects*, which is intended to help design teams to consider the materials that they use, factoring in high recyclability, designing out waste and considering circular strategies before any work is undertaken.

Box 1.5 Energy Savings from Reuse and Recycling

The US EPA undertook a study to calculate the energy benefits of improved material management throughout a material's life cycle.[29] The study developed net energy factors for a selection of materials analysed for four waste management options: source reduction, recycling, combustion, and landfill. The study showed that recycling and reuse generates energy savings for all the materials studied but reuse can reduce greenhouse gas emissions over 60% compared to recycling for materials such as steel and glass. The savings vary depending on the material and are driven largely by the difference between manufacturing inputs.

1.6 EMBODIED ENERGY AND CARBON

Even before a building is occupied, between 30 and 70% of its lifetime carbon emissions have already been accounted for. (Guy Battle[30])

Our current age is defined by the imperative to address climate change, which requires reducing carbon emissions from human activity. As operational energy performance in buildings improves, with more demanding codes and standards pushing building performance towards net zero energy (and carbon), focus is gradually shifting towards energy and carbon emissions related to the processes of supplying and incorporating materials into buildings (embodied). The embodied energy and carbon of a typical new building represents a significant proportion of its impact, possibly as much as 30–70% of its lifetime carbon emissions.[31]

The embodied energy concept refers to all the energy resources spent in the extraction, manufacture, transportation and assembly of a material or component. It is directly related to the '*emergy*' concept as proposed by ecologist Howard Odum to account for the variations of energy quality. Emergy (sometimes referred to as energy memory) is a measure of energy used in the past life cycle of a material/product and represents an alternative measure of value based on natural systems. It provides an environmental accounting system that considers the historical energy needs from the life cycle of the material/product and of every system participating in its past: its energy memory. When used in the context of buildings, embodied energy and embodied carbon are usually calculated using life cycle analysis principles and practices as defined by ISO standards. Embodied energy/carbon is also related to the concept of *the 'ecological rucksack*', which comprises all resources necessary to produce and transport a product all the way to the consumer.

Further emphasizing the importance of embodied impacts is emerging literature suggesting the importance of the cumulative carbon affect.[32] The carbon cycle has reached saturation and excessive carbon emissions are not being recycled, so carbon is accumulating in the atmosphere.[31] Due to the long time frames involved, the date at which carbon is released into the atmosphere affects the climate change impact it will have during this century. For example, one tonne of carbon emitted today will have ten years more impact by the end of the century than one tonne emitted in ten years. This implies that a greater weight should be placed on reducing current emissions as opposed to future emissions as the impact will be immediate. Thus, a greater focus on embodied carbon emissions is implied, which mainly

occurs during the material manufacturing stage. Greater focus on embodied carbon is also likely to promote local sourcing, manufacturing innovation and job creation.

Reducing embodied carbon can complement initiatives already being taken to reduce operational carbon. Already today organizations, such as Skanska UK PLC and Sainsbury's, are actively measuring and reducing the embodied carbon of their construction projects and looking at whole life carbon impacts. Conceptually, for a building achieving net zero operating energy (or carbon), all emissions are due to construction or renovation. The Green Building Council Australia state that '*buildings need to have zero emissions in their construction, operation and embodied energy to be truly carbon neutral*'.[33] Research in the United States[34] suggests that embodied carbon emissions can be reduced by around 30% by selecting appropriate existing materials and technologies, by using lower-carbon materials and by employing

Box 1.6 Embodied Energy (and Carbon) of Materials

It has been estimated that embodied emissions (from the extraction, processing, manufacturing, transport of materials and construction of the built environment) amounts to 63 $MtCO_2e$ in 2007 or 9.5% of the United Kingdom's 2007 reported domestically produced emissions of 666.1 $MtCO_2e$ emissions.[35]

The production of five key materials: steel, cement, aluminium, plastics and paper, account for about 20% of world greenhouse gas (ghg) emissions.[36] *So even if some people feel that material stocks are not a concern, the production process for these and many other construction materials is a challenge at a time when climate change is seen as a age defining problem.*

By 2050 the total embodied carbon from building construction that will be emitted in the United Kingdom is estimated to be about 3100 $MtCO_2e$, equivalent to over 5.5 years of current annual UK total emissions.[31]

In the United States, the embodied emissions from the construction of 500 million m^2 (5.7 billion sq. ft.) of new buildings per year are estimated to be about 300 $MtCO_2e$ tons per year,[34] *and the embodied emissions from those new buildings are expected to outweigh the operating emissions from those buildings over the next 20 years.*

Contribution to UK CO_2 emissions made by the construction sector in 2008[37]

Subsector	CO_2 (Mt)	% of total	% of Construction
Construction			
• Design	1.3	0.2	0.4
• Manufacture	45.2	8.6	15.1
• Distribution	2.8	0.5	0.9
• Operations on-site	2.6	0.5	0.9
• In Use	246.4	46.9	82.6
Demolition	1.3	0.2	0.4
Total Construction	*298.4*	*56.8*	*100.0*
Other Sectors	226.6	43.2	
Total UK	*525*	*100.0*	

more efficient design and construction processes. But an even more effective way to reduce embodied carbon emissions is to reuse existing buildings, components and materials. Building renovation and component reuse usually generates significantly less emissions than new construction and creates an opportunity to reduce operating emissions from existing buildings.

In future, it is likely that whole life cycle carbon budgets for buildings will be assessed and regulated, and it may be necessary to evaluate the initial embodied carbon investment against the carbon savings generated in operation. For example, a UK Green Construction Board report on creating a more sustainable construction industry sets out a route map for a 21% reduction of embodied carbon by 2022 and a 39% reduction by 2050 (compared with a 2010 baseline).[38] The report suggests that all future projects will require analysis of how much carbon was invested and how long it will take the savings from increased efficiency to offset that investment. In such an analysis reused material choices can have a big impact, as studies indicate that impacts are significantly reduced when materials are reclaimed and reused (rather than recycled or discarded).

1.7 THE CIRCULAR ECONOMY

A circular economy… aims for the elimination of waste through the superior design of materials, products, systems and business models. (Ellen MacArthur Foundation[39])

The world's current economic model is largely based on linear '*take–make–dispose*' processes that rely on large quantities of cheap, easily accessible materials and energy, and create large volumes of waste. In the building industry this has taken the form of linear material flows: raw materials extraction, transport, materials processing, assembly, use, demolition and disposal. In recent years, the green building agenda has managed to increase recycling for some materials but the underlying processes are still largely linear. Gradually governments, policy makers, and some companies are realizing the physical limitations and consequences of this model, and the need for a circular economic system that operates within planetary boundaries.

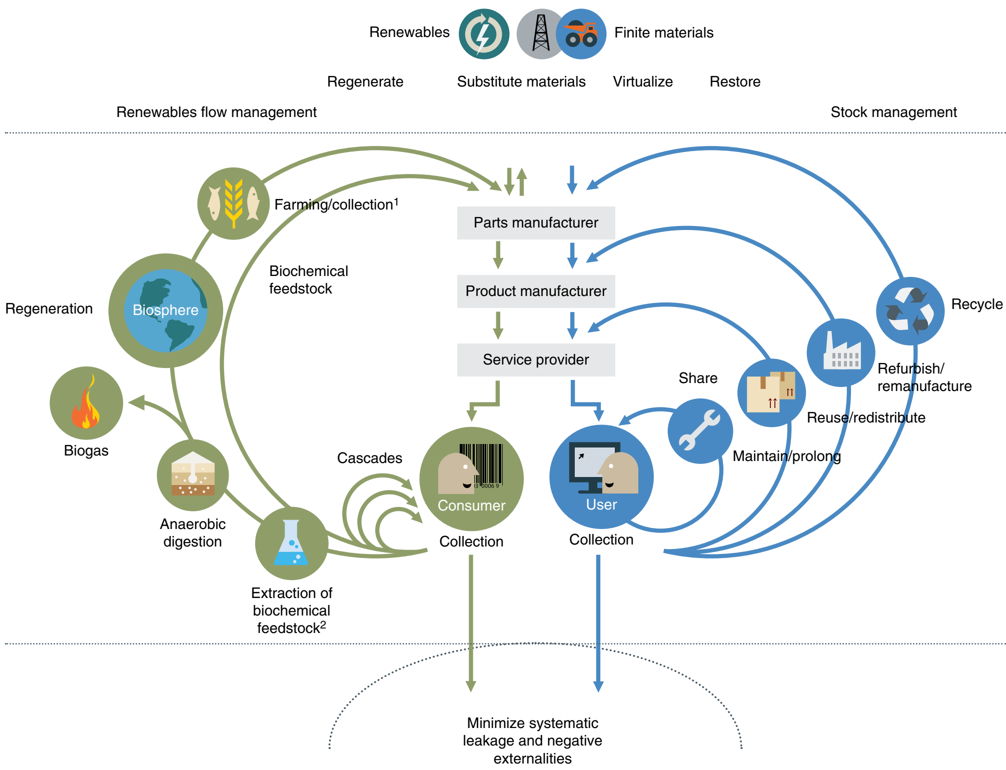
With global population continuing to grow and urbanize, and three billion new middle class consumers expected to enter the market by 2030, high material and component prices and volatility are predicted to be here to stay. Management consultant McKinsey & Company claims that rising commodity prices since 2000 have wiped out the decline in real prices that took

place over the whole twentieth century. At the same time, we are surrounded by a sea of discarded materials and McKinsey predicts that adopting circular economy principles could generate a net economic benefit of €1.8 trillion by 2030 in addition to environmental and social benefits.[40]

The circular economy is based on system thinking and was explored in the 1960s and 1970s in work such as EF Schumacher's pioneering[41] *Small is Beautiful* and the Club of Rome's *Limits to Growth* report.[42] Architect and industrial analyst Walter Stahel set out a vision of an economy in loops (or circular economy) and worked at developing a closed-loop approach to production processes.[43] In 1982 he created the *Product Life Institute* in Geneva that pursues four main goals: product-life extension, long-life goods, reconditioning activities and waste prevention. It also focuses on the importance of selling services rather than products, embodied in the notion of a '*performance economy*'. Stahel argued that smaller closed loops, such as reuse and renovation, are more beneficial than recycling as they require less input of new resources.

More recently, the Ellen McArthur Foundation has pioneered initiatives that explore the policy implications of a circular economy and has published a variety of documents exploring its principles and applications. A circular economy is centred on closed loops of material flows and on a financial system that maximizes the value of materials and products at every stage of their life cycle. It challenges the concept of waste and assumes that every material and product contains useful technical or biological nutrients that, with the proper infrastructure and incentives, can have value and feed into established or new processes.

'The circular economy is one that is restorative and regenerative by design and aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. This new economic model seeks to ultimately decouple global economic development from finite resource consumption. It enables key policy objectives such as generating economic growth, creating jobs, and reducing environmental impacts, including carbon emissions'.[44]



1. Hunting and fishing
2. Can take both post-harvest and post-consumer waste as an input

SOURCE: Ellen MacArthur Foundation, SUN, and McKinsey Center for Business and Environment; Drawing from Braungart & McDonough, Cradle to Cradle (C2C).

ELLEN MACARTHUR FOUNDATION

Figure 1.8 The circular economy.

The circular economy model for the built environment goes beyond individual strategies such as recycling, design for deconstruction, or extending building lives (Figure 1.8, Box 1.7). It implies full systemic change and requires innovations in technology, organization, finance methods and policies to create an integrated model that redefines concepts of value and ownership and connects the start and end of life, making recovery and repurposing the obvious financial choice. In a study for Denmark, the Ellen McArthur Foundation identified the built environment as one of the sectors with the highest potential for applying circular economy ideas, with several main opportunities:[44]

- Industrial production processes, modularization and 3D printing.

- Reuse and high quality recycling of building components and materials by applying design for deconstruction techniques, material passports and so on.
- Sharing, multipurposing and repurposing of buildings, peer-to-peer renting, better urban planning.
- Substituting complex mixed compounds of materials that are difficult to reuse or recycle.

Denmark and The Netherlands have been front-runners in exploring the implications of circular principles, recognizing that products/buildings in such a system can require less energy, produce fewer ghg emissions and reduce the demand for raw materials. Now, other countries are also responding; in 2016 the European Commission adopted a *Circular Economy Package*,[45] which includes revised legislative proposals on waste '*which will boost global competitiveness, foster sustainable economic growth and generate new jobs*'. In Canada, the *Ontario Strategy for a Waste Free Ontario: Building the Circular Economy* published in 2015 by the Ontario Provincial Government recognizes that '*circular economy drives innovation. A shift to a circular economy encourages businesses to design long lasting, reusable and easily recyclable products. The reuse of products adds significant value to the economy by creating or expanding the reuse and remanufacturing sectors*'. London's *Circular Economy Route Map* was published in 2017, with the built environment being highlighted as offering the greatest net benefit. Initially such strategies have been motivated by waste reduction and are merely a start towards a full circular system, but they indicate a growing awareness of the importance of moving towards a circular model.

Box 1.7 Principles of Circular Economy

The Ellen MacArthur Foundation proposed five principles on which to base a circular economy:[39]

1) **Design out waste**. *Waste does not exist when the biological and technical components (or 'materials') of a product are designed by intention to fit within a biological or technical materials cycle, designed for disassembly and repurposing.*
2) **Build resilience through diversity**. *Modularity, versatility and adaptivity are prized features need to be prioritized in an uncertain and fast-evolving world.*
3) **Work towards using energy from renewable sources**. *Any circular story should start by looking into the energy involved in the production process.*
4) **Think in 'systems'**. *The ability to understand how parts influence one another within a whole, and the relationship of the whole to the parts, is crucial.*
5) **Think in cascades**. *For biological materials, the essence of value creation lies in the opportunity to extract additional value from products and materials by cascading them through other applications. The complete biological entity should be considered.*

See https://www.ellenmacarthurfoundation.org

Box 1.8 Service Economy

In a service-based economy focus is on services provided and not ownership of products. Examples of a service-based economy include:

- *In the aerospace industry, Rolls-Royce has offered an engine and accessory replacement service on a fixed-cost per flying hour basis since 1962.*
- *Michelin has leased tyres on a per kilometre basis since the 1920s.*
- *With RAU Architects, Philips developed a 'pay per lux' model for its lighting products, where it offers a guaranteed light level rather than sell the light fitting and luminaire products.*

In the built environment, moving towards a circular economy suggests that processes are re-examined at the material, product, building and urban scale, focusing on long-term value rather than just first costs. It suggests a fundamental shift in how the built environment is designed, constructed, maintained, owned and deconstructed. A circular economy challenges the significance of ownership, with value arising from service, performance and transformation rather than from ownership of a physical object. Rather than selling products, manufacturers would become providers of a guaranteed level of service (Box 1.8). Buildings would become adaptable and durable and be disassembled into components that could be reused or recycled. Underlying financial investment and insurance models will need to change if components are to be leased rather than owned and if buildings are to embed flexibility and be allowed to evolve to comply with circular economy principles (see section 3.1.1 for an example).

Two different types of circular systems can be expected:

1) Closed cycles – where companies take back their product after its lifespan expires to process it and integrate it into their own production. Examples include take-back of plasterboard (drywall) to make new plaster products and rental contracts for materials or services such as heating and cooling equipment.
2) Open cycles – where exchange is possible across different production processes and knowledge is shared about the materials that are cycling around. Examples include use of waste clothing as an insulation material (see Chapter 3.4.4) or use of waste tyres as a building product (see Chapter 3.4.1).

1.8 REUSE v RECYCLING

In recent years, recycling initiatives have become commonplace and many government policies aim to address waste by increasing recycling rates. Some European countries, such as The Netherlands, Belgium and Denmark, already claim to recycle around 90% of their construction and demolition waste, although mainly this is downcycled as road base. Some construction material suppliers have focused on recycling partly driven by the growing sustainable building agenda, as represented by green rating programmes such as BREEAM and LEED, and also from an increased awareness of potential economic benefits. Demolition protocols propose carrying out a pre-demolition audit to identify materials that can be recycled, and often the first activity of a demolition contractor is to identify materials that may have value.

However, recent research indicates that recycling in itself is insufficient for solving resource problems, as it does not deliver

sufficient decoupling of economic development from the depletion of non-renewable raw materials. Grosse and others argue that '*depletion of the natural resource of raw material is inevitable when its global consumption by the economy grows by more than 1% per annum*'.[46] They claim that recycling can only delay the depletion of virgin raw materials for a few decades at best, since growth in consumption is greater than the recycling rate. Their research shows that only maintaining annual growth below 1% and recycling rates above 80% would allow a significant slowdown of the depletion of natural resources.

Thus, recycling is an important but not sufficient component of sustainability policies to address primary resource depletion and waste reduction. Recycling processes often still require significant amounts of energy and lead to emissions. For example, although it may be correct to claim that recycled aluminium has only 5% of the embodied energy of primary aluminium made from ore, Allwood and Cullen have noted that when considering a particular aluminium product like a drinks can, the difference is reduced and the recycled can requires about 25% of the energy to produce compared to a new can from primary material – still an improvement, but not as dramatic.[5] Reuse, however, usually has much less reprocessing, so the benefits can be considerably greater. For example, when a glass bottle is reused many times, each subsequent use involves only cleaning, refilling and transport. As long as these are reasonably local and carried out in an efficient manner, energy and materials can be saved (Figure 1.9).

A report from the Institute for Local Self Reliance (ILSR) in the USA profiled nine private and four government reuse operations from an economic point of view.[47] Based on these, ILSR estimates that on a per ton basis, reuse operations generate nine times more jobs than traditional recycling and thirty eight times more than land-filling and incineration. Another study concluded that seven jobs are created for every 1000 tonnes of waste diverted with an economic benefit four times greater than the net cost.[48]

Reuse embraces three levels of preparation for secondary use:[49, 50]

1) The first is direct reuse, where components are used as close as possible to their original state and for their original purpose, requiring almost no preparation.
2) The second is renewed reuse, where materials are slightly altered by cleaning, repairing, refurbishing, or mild remanufacturing to serve a new function.

Figure 1.9 The Bedzed project in south London featured reused steel components; BRE calculated that this had only 4% the environmental impact of new steel.

3) Finally, the third is rethought reuse, where reclaimed materials are fused with other materials to create a secondary product with a new function.

From an architectural design perspective, using recycled materials usually requires little change. Whether the steel, aluminium or glass comes from a recycled or primary source does not greatly impact the design process of a building. However, reusing components can have a much more significant impact on the design and procurement process. For reuse to be effective, specific data need to be available about the component, its technical characteristics, available amounts, sources and so on. Currently, the supply chain does not readily provide this data. Also, a suitable supply infrastructure has not yet been established in most developed countries to facilitate reuse. The design and construction process of many of the projects shown in this book have been significantly affected due to reuse of components. This can be seen as both an opportunity and limitation, as will be discussed later.

1.9 SUMMARY

As we move from the industrial age to the digital age does this provide an opportunity for a new way of thinking about materials. Products should not have a 'life' but should be part of an ongoing technical cycle. (Jeremy Till[51])

The motivations for reuse of building materials and components can be categorized as:

- Aesthetic/Design opportunities – What might a new materialism in architecture look like? How can limited availability of components be a source of inspiration for architects rather than a constraint?
- Environmental – Reducing climate change impacts and other emissions to air and water, and reducing waste disposal.
- Resource conservation – Reducing stress on the earth from extraction and creation of materials from primary resources.
- Economic – Local supply of resources leading to increased local employment and a strengthening of the local economy.
- Social – Development of skills within the community and a new approach of respect towards the built environment.

If we accept the premise that availability of materials is unlikely to continue as has been the case in recent years, and that environmental, economic and social pressures will constrain supply, architects will be forced to respond and develop alternative strategies. Future materials supply will likely focus on what is already in the system, and is currently in use but coming to the end of its useful life. As Till puts it '*a shift under conditions of scarcity from the production of more stuff to the realignment of stuff that it is already there*'.[52] In such a system buildings should be seen as transient borrowers of matter rather than final destinations, and construction should be intrinsically reversible. Some materials may be able to go back into natural systems and be decomposed, etc, but others will return to industrial systems. Such materials are used in one form in their present use but may be employed in a different way in a future use, and it is important that their usefulness and value is maintained and not destroyed by their use or extraction. Our cities, our buildings and our infrastructure then become a store and a mine for future uses.

The present inherent difficulties with the incorporation of reclaimed materials into new buildings can discourage clients

and designers from embracing reuse, unless it is for principled reasons. Although the cost of materials can be lower through reuse, these may be offset by higher labour costs and increased design fees resulting from more research required by the design team. There is also greater uncertainty over cost and schedule, as delays can occur if key components cannot be readily sourced or there are delays in the demolition process. A few architects have started to focus on the creative opportunities offered by reuse for new mainstream buildings and to develop a design language based on local waste streams and local renewable resources. As the exhibition *Matiere Grise*[53] hypothesized, a new outlook on materials generates a new approach to architecture – less form based and more concerned with matter and the opportunities it provides. A new building design and production process and new know-how grounded in a new material reality is evolving founded on ingenuity, collaboration and the opportunity of working with what is already there, and drawing on the skills and knowledge of those most familiar with the materials. This book explores what this architecture may look like.

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IMAGE CREDITS

Figure 1.1 (a & b) Courtesy of Brooks Freehill/Mike Moore and tres birds workshop; figure 1.2 Courtesy of © Vik Muniz / SODRAC, Montréal / VAGA, New-York (2017); figures 1.3, 1.5, 1.7 & 1.9 By Author; figure 1.4 Redrawn based on work of Thomsen and van der Flier; figure 1.6 Courtesy of Adaptable Futures, Loughborough University; figure 1.8 Courtesy of the Ellen MacArthur Foundation, www.ellenmacarthurfoundation.org; Box 1.1 Courtesy of Saman Deilamani

2 CONCEPTS SUPPORTING REUSE

God has lent us the Earth for our life: it is an entail. It belongs as much to those who come after us… as to us; and we have no right, by anything we do, or neglect, to involve them in unnecessary penalties, or deprive them of benefits which it was in our power to bequeath. (John Ruskin, 1849[1])

Today it is recognized that environmental concerns need to transform architectural strategies and designs. This requires new ways of thinking about materials based on local and natural systems, moving toward a cyclical use of the available materials, components, energy, spaces and places. The depletion of natural resources, increasing waste flows and increasing competition for energy and water have stimulated a number of legislative initiatives to support the development of circular approaches. Three trends have a particular impact in the design, construction and operation of the built environment. Firstly, the gradual introduction in many jurisdictions of carbon accounting (either carbon tax or cap and trade) is likely to impact building design and construction materials supply, particularly as the cement and steel industries are two of the largest industrial emitters of carbon. Secondly, extended product responsibility (EPR) is a strategy being embraced by governments to make manufacturers responsible for the entire life cycle of their product and, especially, for the take-back, recycling and final disposal. This is intended to encourage manufacturers to develop strategies to minimize materials entering the waste stream. Thirdly, resource shortages are leading to legislation to encourage industry to embrace circular economy principles. These are all likely to lead to a re-evaluation of material paths in the built environment.

At its most practical level, reuse is a waste management strategy that uses reclaimed materials or components in their original or close to original form for new uses. Thus, most of the initial resources that went into producing the material or component carry through to its subsequent lives, and economic value can be maintained. But more fundamentally reuse is a different attitude

Resource Salvation: The Architecture of Reuse, First Edition. Mark Gorgolewski.

to the natural world and the resources we take from it. It offers a way of thinking cyclically, taking something that already exists to a different stage of its life, an altered state of usefulness, but without major changes to its physical state. It allows designers to find new frameworks and connections for existing objects resulting in new useful states. A focus on reuse requires designers to think about all stages of a building's life, including the end of life, where deconstruction rather than demolition becomes a priority, thus saving value. Beyond the technical and process aspects, the reuse of building materials and components can be seen as a positive driver for architectural design and an opportunity for a changed way of thinking about architecture. A process (or means) oriented design (and construction) approach can challenge the predominant view of architectural design and provide opportunities for creating meaningful architecture for a low carbon society (Figure 2.1).

However, old habits, established processes, and current ideas that are well established in the industry create barriers to change and can hinder wider reuse of materials and components. This may be due to perceptions of convenience, availability, familiarity, risk,

Figure 2.1 Architect Juan Luis Martínez Nahuel reused laminated beams, steel components, glazed doors in the main façade and parquet flooring in the Recycled Materials Cottage in Pirihueico, Chile.

Box 2.1 The Delft Ladder

This waste management strategy was developed and adopted in The Netherlands and later elsewhere. It can be applied to the full life cycle of building design, construction and demolition as well as individual products and other industries:[2]

1) *Prevention – Future waste can be reduced at the design stage, by careful consideration of material and component choices.*
2) *Building reuse/renovation – The objective is to renovate and improve existing structures/buildings rather than demolishing them and taking the materials to landfill. This avoids creating new components for constructing new buildings.*
3) *Component reuse – Taking apart a building and reusing the individual component parts, rather than letting them go to waste avoids creating new components. Designing for deconstruction is part of this strategy.*
4) *Material reuse/recycling – Separating materials out of the waste stream, those materials that cannot be reused in their current form should be recycled.*
5) *Useful new application – This is often called downcycling, reusing the element or material for a new purpose, for example crushing concrete and reusing it as a road base.*
6) *Immobilization with useful application – Turning a potentially polluting or harmful material into a harmless new material, for example the use of blast furnace slag as a secondary cementitious material in concrete.*
7) *Immobilization – Rendering a potentially dangerous material harmless before sending it to landfill.*
8) *Incineration with energy recovery – Burning combustible waste materials and recovering the energy produced.*
9) *Incineration – Burning combustible waste materials.*
10) *Landfill – As a last resort disposing of waste materials in landfill.*

cost and quality. This section discusses some of the concepts and ideas that have been proposed that help facilitate building material and component reuse and that break down some of the barriers. Concepts such as salvageability, secondary use, material flow analysis and urban mining all help to establish a theoretical base for processes that enable buildings to be created using components and materials that have had a previous use.

2.1 HISTORY OF BUILDING COMPONENT REUSE

There is a strong tradition in art and architecture of exploring the aesthetics of old materials. Artist such as Jean Tinguely and Anthony Gormley have created works that challenge aesthetic acceptability using old materials. Reuse has been practiced in architecture to some degree throughout history and was the norm in many societies until recently. In some parts of the world it is still common today. Before the industrial era the use of new building materials from elsewhere was confined to the rich, and generally to high profile projects such as religious, ceremonial and government buildings and palaces. Most building materials were sourced from close to the site, using materials such as wood, rock and earth that were readily available, creating vernacular solutions based on the locality. In such societies reuse of building materials was the rule, as the investment into producing new materials required a significant effort, and thus

Figure 2.2 The great mosque in Cordoba, Spain, reuses stone columns from various older Mediterranean structures.

availability of new materials was often constrained. Reusing old materials was often easier and cheaper than sourcing new. For example, medieval buildings in Europe were often constructed from reused masonry taken from ruins of Roman buildings (Figure 2.2). In Canada, high quality timber from dismantled grain elevators has been reused in new buildings. Even Le Corbusier's La Chapelle Notre Dame Haute du Ronchamp in France built in 1950s includes masonry walls built from stones salvaged from a former chapel.

Past societies usually had an infrastructure for salvaging to facilitate reuse. An informal economy often grew up around scavenging, rag-and-bone merchants and junk collectors. The scavenging of used and waste materials and products was important to economic growth, as it provided much of the raw materials necessary for other industrial processes. Indeed even the US cement industry in the early twentieth century used mainly waste from the iron manufacturing industry as a raw material.[3]

Salvaging and recovery of materials and components has varied over time and place depending on the economy, technology advances, codes, fashions, trends towards convenience and

disposability of components. Even today in communities in which building materials are scarce, such as in informal settlements, slums, favelas and shanty towns in developing countries, millions of people construct their built environment with creativity and ingenuity using many previously used, leftover, scavenged materials. The stunning documentary *Wasteland* about the work of photographer Vik Muniz who documented the lives of scavengers working in the waste dumps of Rio de Janeiro highlights that, in some parts of the world, scavenging and reuse is still widespread and an essential part of the economy (see Figure 1.2 and www.wastelandmovie.com).

The need for a stewardship approach to materials was often part of local culture and sometimes the history of a material and its scars (or signs of previous history) were celebrated. For example, in Japanese culture the tradition of wabi-sabi highlights a world view that acknowledges transience, imperfection and repair, accepting whatever deficiencies exist in the material as its features. In India the term Jugaad Urbanism has been proposed for creative, out-of-the-box thinking leading to resourceful use of readily available salvaged materials, respect for improvisation and making new things with meagre resources.[4]

Throughout the twentieth century a small group of architects and researchers have explored the creative and technical aspects of reuse. For example, some of Bruce Goff's houses in the central United States were created from locally available and scavenged materials, and their design evolved from the possibilities inherent in these materials (Figure 2.5). Dutch Architect John Harbraken recognized that often component reuse is limited by the initial design of a product. He developed a design for a Heineken beer bottle, known as the WOBO bottle, that would facilitate a second life as a brick-like component intended for assembly to construct low cost houses (Figure 2.3). Unfortunately, only one house was built and the beer company was hesitant to adopt this new bottle shape. Michael Reynolds developed the concept of Earthship buildings using old car tires and drinks containers filled with compacted earth to construct the walls of buildings. These have been constructed in various locations around the world by enthusiasts with mixed results (Figure 2.4). More recently, a variety of small projects by groups of students participating in Auburn University's Rural Studio initiated by Sam Mokabee showed the potential of creative reuse of materials and components and cheap labour to meet community needs in Hale County in rural Alabama (www.ruralstudio.org). Nevertheless, these examples are often ad-hoc projects located where local building codes and other limitations such as climate are not restrictive.

In some locations, salvaged or surplus construction components are offered for sale by organizations such as Habitat for

(a)

(b)

Figure 2.3 The Heineken WOBO bottle designed by John Harbraken for a second use as a building component to make walls in developing communities.

Figure 2.4 The Orangeville Earthship in Ontario, Canada, was built using the system of waste tires developed by Michael Reynolds.

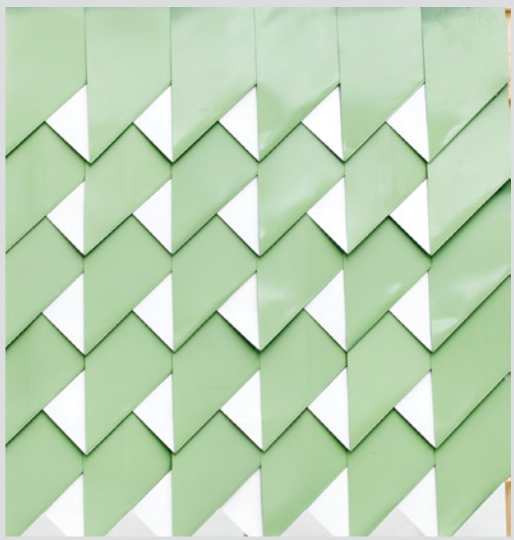
Figure 2.5 The Eugene and Nancy Bavinger Residence, Norman, OK, 1950. Architect Bruce Goff used found materials in the area to create some of his houses such as this one.

Humanity ReStores and other organisations that collect used or surplus materials and components. They deal mostly with interior components such as doors, bathroom fittings, hardwood floors and kitchens, as well as windows, and are often used in small remodelling projects. In some economically challenged areas more widespread reuse has occurred; where communities have limited economic power they may look to the materials available from old buildings as a source for new projects. For example, in cities in decline such as Detroit, USA abandoned buildings become a resource. Also, some of the post-earthquake reconstruction in Turkey in 1999 created locations where salvaged materials were collected and stored for reuse.

Box 2.2 Patterns – Quilting

Quilting is the age-old craft of creating new garments and other cloth items out of old scraps with a philosophy of repetitiveness and avoiding waste. This form of craft celebrates the differences in material and the connections. Japanese peasants and artisans create 'boro' garments, stitched together from scraps of cloth and the repairs become the object. Although a practical and often necessary use of small scraps of cloth, boro is also about an aesthetic idea and celebration of connections and the acceptance of imperfections.

Dan Phillips of Phoenix Commotion (www.phoenixcommotion.com) uses a form of quilting in his building projects. He accepts the damaged character of a material and develops an aesthetic approach that embraces repetitiveness and connections using patterns. Phillips takes the approach that rather than trying to return materials to their original pristine form he accepts the damaged/imprinted character of a salvaged material and develops an appropriate aesthetic that embraces this.



Examples of patterning and weaving from the NBCR (see Chapter 4).

2.2 BARRIERS TO REUSE

Much of the available literature on reuse and recycling includes a discussion about barriers to reuse. The following barriers have been commonly identified:[5]

- *Existing perception towards reused materials* – There is a general view in society that second-hand materials might be substandard and a higher risk. Concerns that reused material may not perform as planned are often exacerbated by prejudice and lack of clear information and guidance. In particular, there are concerns about reuse of structural materials; these may be legitimate in certain situations. This needs to be address by education, certification, and real world examples.
- *Economic considerations* – These are often vague and uncertain; it is assumed that designing for deconstruction or with salvaged materials or components will require additional design time and, therefore, cost. Costs are unpredictable when including dismantling, refurbishment, storage, transport and construction due to more intensive labour, and possible change orders caused by materials sometimes becoming available only during construction. In many cases clients find it hard to justify unpredictable initial costs, particularly if they cannot see how they will benefit. At the end of the building's life demolition is still perceived as the most cost-effective option, despite increasing landfill costs and evidence that savings can be achieved through deconstruction and sorting of materials. Increasing disposal costs are gradually changing this balance.
- *Time and scheduling* – Several aspects of time affect reuse: firstly, the long lives of buildings mean the buildings coming up for demolition may not be suited for component reuse; and, secondly, component reuse has been associated with increases in design time, procurement/sourcing of materials, dismantling and refurbishment of materials, additional training, as well as longer construction time due to customization of non-standard size materials.
- *Health and safety* – This is perceived to be more of an issue when trying to extract building components from an old building compared with simple demolition. This is countered by the increasing value of some materials and components in old buildings, and the increasing cost of disposal. Acceptable, safe methods for deconstruction need to be established.
- *Incentives to deconstruct and reuse* – In contrast to many sustainability objectives, the lack of legislative drivers and few government incentives to encourage deconstruction and reuse is one of the major barriers in most countries Although circular economy initiatives may soon begin to address this.

- *Certification of materials (particularly for structural reuse)* – This varies depending on material and location but often there is a bias against structural use of old materials. Even if there is a mechanism in place to regrade old material, some engineers are hesitant to take on the liability. It is not clear how CE (Conformité Européene) markings should be dealt with for reused components in Europe.
- *Insurance/liability constraints* – Liability related to design or construction decisions may be perceived as a problem. Educating insurance companies about the actual risks and the advantages of using reclaimed materials and components is needed to encourage them to reduce their premiums and thus help to promote reuse, rather than the opposite which may occur.
- *Code/specification issues* – Building codes in many countries do not properly address the reuse of building materials and components and limit their inclusion into new construction projects, unnecessarily favouring new options. Some reclaimed materials require a performance specification and, in some cases, alternative solution paths are necessary for building code approval, which requires additional work. A system of certifications, warranties or performance guarantees for reclaimed materials and components would help to reduce the risks.
- *Material availability* – Currently in most developed countries there is a lack of a supply chain for reclaimed materials and components, particularly for acquiring a uniform supply in large quantities suitable for larger projects.
- *Ownership* – Questions can arise about ownership of materials when a building is deconstructed. Who owns the materials on a deconstruction site – the original manufacturer, the building owner, or the deconstruction company? This needs to be clearly defined. Currently, recovered materials and components are often claimed by the contractor (selling these may well be included within the tender for the job). In future it may be that many components will go back to the company that made them (lease agreements). The gradual introduction of material passports and growth of the salvaged component market can start to address these issues.
- *The lack of technical and procedural knowledge and unknown risk factors* – There is a need to develop a strategic plan and work structure for reuse projects that addresses all relevant concerns specific to the reused material objectives for the project and distributed to all the team members.

The above issues create a fragmented value chain with confused incentives for the various parties that need to commit to the concept of reuse, leading to limited uptake. The various concepts and initiatives described below are aimed at addressing these barriers and providing a framework that will help make reuse more widely achievable.

2.3 URBAN METABOLISM AND RESOURCE FLOWS

Groak observed that creating contemporary urban environments and buildings depends on tapping into and benefiting from a complex web of flows for energy, water, air, materials, money, food and so on.[6] Jongert has categorized these flows as:[7]

- physical: tangible observable matter such as people, materials, water;
- energy: heat, light, sound;
- value: data, money, identify and culture.

Urban metabolism is the description and analysis of such flows, mapping their systems and providing a holistic model of the resource flows of a city. The concept is based on systems theory and thermodynamics. It is defined by Kennedy *et al*. as, '*the sum total of the technical and socioeconomical processes that occur in cities, resulting in growth, production of energy and elimination of waste*'.[8] Urban metabolism principles have been employed to analyse the interrelations between environmental, sociological and economic factors of cities to understand the flow of resources through a city, as well as the relationships between urban areas and their hinterlands. Such studies use material flow analysis (MFA), a method originating from industrial ecology that accounts for resource flows and stocks over time, where total resource input is equal to the sum of the total stock and output in a designated time (Figure 2.6). Such analysis

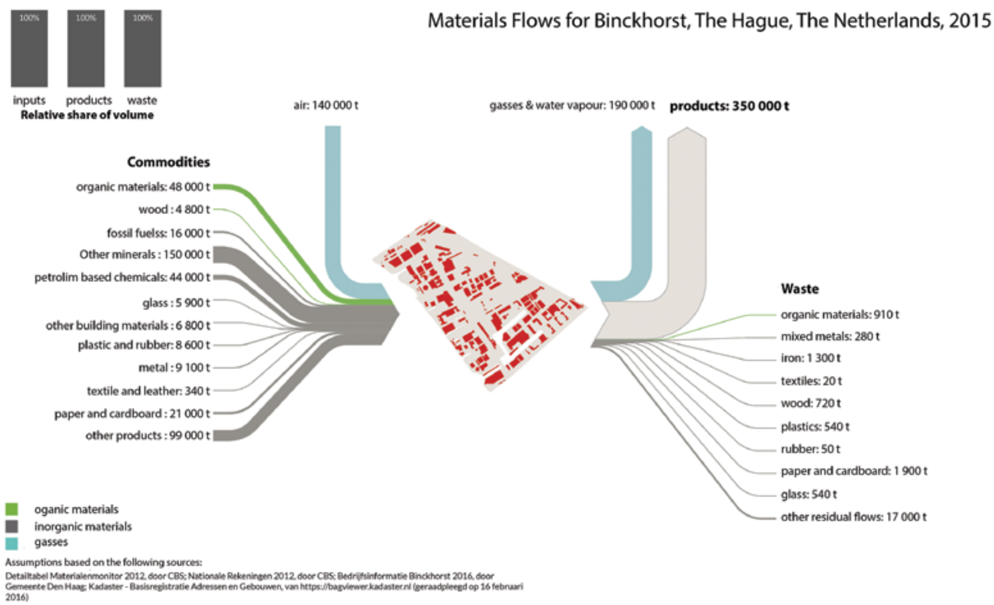


Figure 2.6 An example of a materials flow analysis chart created by Superuse Studios.

at the urban scale has tended to focus mostly on input and output flows and less so on internal resource stocks. However, understanding stocks within the system can be important when studying reuse opportunities, as well as the resilience of the city to shocks in available flows. A review by Kennedy *et al*. of 20 comprehensive urban metabolism studies indicated that contemporary cities have become increasingly material intensive in the past few decades.[8] They also suggest that alternative waste management practices, such as reuse and recycling, that focus on stocks already within the city promote cyclical material flows and, therefore, reduce incoming and outgoing flow intensities (and thus increase resource efficiency). Conversely, landfilling promotes linear metabolic flow and facilitates the necessity for greater raw resource inputs and creates greater waste outflows.

Construction materials are usually durable and long lasting, so accumulate in the urban fabric and their stocks grow slowly overtime. A significant quantity of the total extracted natural resource stock used for producing such materials resides as stock in the current urban fabric and forms a potential resource that can offset new materials coming into the system. There are many opportunities for these resources to be treated in a circular way in order not to burden the virgin (and non-renewable) resources.

So from a construction materials perspective, it is important to look at flows not only *through* the city but also *within* the city – circulating in loops – and at stocks available within the existing fabric. For example, Falk used lumber production together with housing construction and demolition data to estimate that 2.2 million m^3 of timber is available annually from house demolition in the United States.[9] Ergun carried out a study of the available bricks within Toronto that are stored in single family houses and could be made available for further use at the end of their current life, offsetting the use of new brick and reducing waste flows.[10] Such analysis can help understand the stocks of resources available in a city and can also help highlight opportunities for change.

However, the demand for increased flows of resources depends on the age and stage of a city's development. New and growing cities have large and expanding inflows of new construction materials to create the new buildings and infrastructure. Conversely, they have small stocks within the urban fabric and small outflows of construction materials, as there is little demolition. New cities also have growing energy needs with potential to integrate energy efficiency and renewable energy sources. For example, fast-growing Asian cities have an input–output ratio for solid materials greater than 10:1. For such cities, the potential for recovery of

materials from the urban stocks is low due to small stocks. Conversely, old established cities have less need for new materials to create new infrastructure, so they have reduced inflows. But they have large stocks within their fabric and greater outflow of demolition waste that offers potential for reuse. They may also need greater volumes of energy to satisfy population demand due to old infrastructure. Brunner suggests that for cities in a steady state, it is conceivable that 80% or more of primary resources could be substituted by secondary resources found within the city.[11]

The reuse strategies explored in this book provide a mechanism for shifting away from existing patterns of materials use, reducing in- and outflows from a city and focusing on existing stock. They also conceive the urban processes as integrating, open and dynamic metabolisms closer to natural system flows.

2.4 URBAN MINING

Today's stock of materials within the built infrastructure of a city will become tomorrow's waste and could serve as a future resource. Urban mining recognizes the embodied value of this stock and proposes the systematic reuse of these anthropogenic materials, which are already present and underused within urban environments. This was normal practice prior to the industrial era and is still common in some parts of the developing world. Urban mining comprises actions and technologies designed to recover materials, food, water and energy that are currently wasted or stand unused in cities. It represents a way to tap into and exploit the large stocks of resources incorporated into cities, in particular in buildings and infrastructure, as well as in landfills that previously had little value. This approach postulates that cities can produce sufficient amounts of secondary resources for large-scale production of raw materials through the use of inherent materials stocks.

Urban mining activities range from: mining metal from obsolete urban reservoirs, sorting through household waste streams to extract materials that can be recycled, to dumpster diving for food and other valuable resources. It has associations with questionable legality, disadvantaged people finding uses for discarded materials and the concept of '*gleaning*' – collecting spare resources (traditionally applied to collecting leftover crops from farmers' fields). But urban mining activities can provide a methodical approach to tapping into anthropogenic stocks and waste flows, aiming at long-term environmental protection, resource conservation and economic benefits. Brunner notes that to effectively design the infrastructure to facilitate wide-scale urban mining and establish it as a practical tool for increasing urban resource efficiency, research is needed to quantify material stocks and flows.[11] Hence, data about stocks

and flows generated through urban metabolism studies are useful to facilitating urban mining.

From a construction materials perspective, ageing, abandoned and obsolete buildings are a stock of potentially valuable materials within the city. Practices such as historic component salvage, the use of spare or excess material from construction sites and recovery of used bricks, and local material exchange websites, are current examples of urban mining.

Superuse Studios uses the concept of a '*Harvest Map*' to facilitate urban mining (see Chapter 5.4).[12] This is a way of mapping the available supply of useful waste, surplus and other unused materials in the vicinity of a building project. For an architect, rather than using manufacturer's catalogues to choose components the harvest map functions as a regional material catalogue that is used to choose materials.

2.5 UPCYCLING – CRADLE TO CRADLE

McDonough and Braungart's *Cradle to Cradle* concept is based on the critique that most current eco-efficiency initiatives are being merely about being '*less bad*' – most products are not designed to become lasting parts of a manufacturing cycle and, therefore, contaminate the environment through pollution and disposal.[13] Their alternative is about becoming '*more good*', based on the philosophy that '*waste equals food*', so nutrient management rather than waste management should be the focus. By this they mean that all materials have an ongoing value, even at the end of their current life, and require intelligent management to bring them back to usefulness.

They differentiate between materials that are based on technical nutrients, which need closed-loop systems in which high-tech synthetic and mineral resources circulate in an endless cycle of production within industrial cycles featuring recovery and reuse, and materials based on biological metabolisms that naturally grow and then biodegrade in a benign and continuous way. An example of a technical nutrient would be nylon fibres in a carpet that is leased to a customer and later returned to the manufacturer for refurbishment or recycled again and again for the same end use (not downcycled). A biological nutrient could be wool or cotton fibre returned to the soil as mulch at the end of its life for biological decomposition.

In 2005 McDonough and Braungart Design Chemistry (MBDC) launched Cradle to Cradle (C2C), a conceptual framework for assessing and certifying the impact of products, including building components. In principle, any C2C certified construction product must comply with some level of material reuse criteria and should have the capacity to be either returned to a technical/industrial process or biodegrade naturally. The

certification considers the levels of material/product recovery as well as use of component materials that are from recycled or rapidly renewable sources, and whether they are recyclable or compostable at the end of their useful life. The C2C process as applied by MBDC focuses on products but the concept can be considered for entire buildings (Box 2.3). In that case, any materials used in the building should be removable at end of life and either recycled, reused or returned to nature and biodegraded. Reuse would form part of such a strategy.

McDonough and Braungart also popularized the term '*upcycle*' to describe the process of turning something old, used, or discarded into a something new and useful.[14] To implement upcycling requires sharing information on technical nutrients and a thorough understanding of material and energy flows, so that this knowledge can be incorporated into practical everyday design. They proposed Intelligent Material Pooling (IMP), which

Box 2.3 Park 20/20

The Park 20/20 (www.park2020.com) is an urban development located at Haarlemmermeer, The Netherlands, designed by William McDonough and Partners for Delta Developments. It applies cradle to cradle principles in its architectural design. The park comprises six buildings including a hotel tower, offices tower, athletic facilities and retail space, in addition to green zones, public gardens, urban plazas, canal boardwalks and public open spaces on approximately 114 000 m^2 (1 226 000 sq. ft.) of land. The development process used innovative, inclusive methods to capture the ingenuity of the contractor and suppliers and a transparent accounting system that allows suppliers to innovate with confidence. The buildings incorporate design for deconstruction principles allowing sorting into constituent technical and biological nutrients, asset tracking for future reuse and products that meet cradle to cradle objectives. For example glass, steel and aluminium are technical nutrients used in the construction of FIFPro office building (see image), which can be disassembled so the components can be reused/recycled. The skeletal frame of the Biological Nutrient Pavilion building is manufactured from certified FSC (Forest Stewardship Council) wood and the façade is constructed from cradle to cradle gold certified acetylated wood. Also, some of the interior component such as lighting and furniture is provided by a service contract.

(a)

(b)

a) FIFPro offices at Park 20/20.
b) Bosch Siemens at Park 20/20.

is a type of materials bank, as a mechanism for companies to agree to share access to a common supply of a particular material, pooling information and purchasing power to generate a healthy system of closed-loop material flows.

Organizations such as the Lendager Group and Superuse Studios are exploring how to implement this concept at the scale of a component or building. Jongert *et al*. propose a superuse design strategy that focuses predominantly on upcycling local materials considered as waste or as being of no value to give them a new function in their architectural designs. The strategy involves using as little energy as possible for transport and transformation into the new design (see Chapter 5.4).
In Denmark, the Lendager Group in collaboration with Genbyg (a used building materials handler) has developed an upcycled wood wall panels using exclusively recycled wood from discarded windows, old doors, floor boards and scaffolding wood (see Chapter 5.3).[15]

2.6 SALVAGEABILITY AND DESIGN FOR DECONSTRUCTION (DfD)

DfD aims at the design of transformable building structures made of components assembled in a systematic order suitable for maintenance and reconfiguration of their variable parts. Every scenario for transformable building results in a different technical composition and different hierarchy of parts. The DfD concept therefore affects the design of all material levels that are accounted for by the technical composition of buildings. (Elma Durmisevic and Ken Yeang[16])

It is commonly recognized that in the future reuse of components and materials could be more common if (when) components and buildings are designed to make the process of deconstructing them easier. Recognizing the unpredictability of building lifespans, researchers and designers have been considering how to design future buildings to ensure that, although the buildings as a whole may become obsolete, the stock of materials and components contained within them do not. The value of these materials and components will change depending on demand for the various items in the stock, their current price on the market and also, fundamentally, on the ease of extracting them from the stockholding (building). Thomas Rau points out that considering materials in this way

leads to a different balance sheet, which supports new insights and facilitates actions that preclude writing-off the materials.[17] Norby *et al*. have investigated the concept of '*salvageability*', which they see as the design strategies that facilitate salvaging of building components. They have investigated the opportunities this provides not only to address environmental concerns but also architectural tectonic explorations.[18] They shift the focus from perceiving salvageability as a restriction upon architecture to highlighting it as a positive driver for creating meaningful architecture, and the potential it offers for creative design solutions for a low carbon society.

Estimates by various researchers suggest that deconstruction is about 17–25% more expensive than demolition and can take 2–10 times longer to complete.[19] However, this is because in the past most buildings were designed in a way that makes them unsuited to deconstruction. Various commentators have proposed guidelines about design for deconstruction (DfD) or disassembly (generally used interchangeably) as an effective strategy to increase the future supply chain of reused building materials.[20]

Fundamentally, deconstruction can be thought of as the reverse of the construction process and so DfD involves planning for the end of life of a building at the design stage. Recent examples of buildings that have focused on deconstruction include the Brummen Town Hall (Box 2.4), the 3XN Architects offices in Copenhagen (Figures 2.7 and 2.8), Vulcan House in the United Kingdom, Chartwell School in California (which developed some useful guidelines for DfD[21]) and some of the facilities for the London 2012 Olympics.

The Canadian CSA Standard Z782-06 suggested that design for deconstruction guidance may be grouped under the following headings:[20, 22]

- Systems level – Adaptable, long life, durable, flexible structures that can adapt to suit changing requirements. Design of such buildings may require some overspecification of structure to allow for future change.
- Element (or Product) level – The focus here is on the major parts of the building, roof, foundations, wall, floor system including modular and panelised elements, designed to allow upgrading, repair, reuse and replacement.
- Component or assembly level – This level considers groupings of subcomponents that are non-structural. To achieve this it helps for buildings to be constructed in layers, so that the most replaced components form the most accessible layers. Examples may be a window, or a cladding system. These need to be assembled in such a way that they can be extracted without damage.

Box 2.4 Brummen Town Hall

The request for proposals for a new town hall in Brummen, The Netherlands, in 2011 asked for a building that would last only 20 years due to expected changes to municipal boarders. The successful proposal was by architecture firm RAU working with Turntoo, a resource consulting firm, and construction firm BAM. The design is based on the assembly of largely prefabricated timber components from high-quality, reusable and renewable materials which are leased. They can be dismantled and returned to their manufacturers at the end of the building's 20-year life and reused in other projects. In effect, the building was designed with the intent that it would be a 'raw materials storage facility'.

The project shows what design for deconstruction can look like in practice. The design team considered the costs of dismantling, process logistics, storage of components and who will take care of the future tasks. Without this, costs and practical issues could prevent future reuse. Also, the condition of the components after 20 years was considered to maintain their value. This required that durable products were used. Also, the size of some components are not optimal for their present use so that future use can be safeguarded. Standard sized timber beams were used that were not necessarily the most efficient choice for the current building, but are expected to provide greater flexibility for the material to be reused in the future.

The designers created a system where the building elements, including overall shell, cladding, internal partitions and some HVAC components, could be in effect owned by their manufacturers and provided to the building owner under a 20-year service contract.

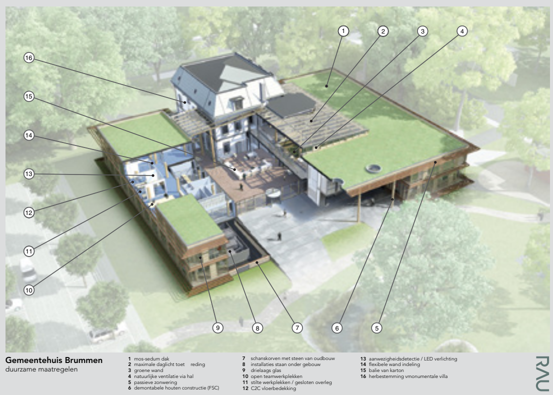


Figure 2.7 The offices of 3XN Architects in Copenhagen were designed to be easily dismantled with mechanical connections.

Figure 2.8 Detail of 3XN Offices' in Copenhagen showing bolted connections.

- Subcomponent level – This breaks down into smaller pieces, bits of ductwork, glass in a window system and so on, which can be reused or recycled.
- Material level – When a component has been stripped back to its constituent materials, these can undergo recycling, such as with rebar. For this to occur the design of components needs to facilitate easy separation of the constituent materials, so that economic recycling can occur, and that processes such as bonding and finishing do not make recycling difficult.

Durmisevic and Yeang argue that to create an industry that embraces deconstruction requires a fundamental change in architects' perception of buildings; waste should be seen as designer error and buildings conceived as dynamic and open structures that can easily adapt to changing requirements.[21] To achieve this, buildings need to have the capacity to transform/adapt, building materials should be treated as long-term valuable assets through their life cycle and systems should be reconfigurable. Furthermore, this requires that the construction industry is involved in the whole life cycle of buildings and building systems and not just at the initial stage of creation.

Norby *et al.* reviewed many sources and have distilled the following general principles to facilitate design for deconstruction and salvageability:

- *Limited material selection* – Use of a small number of materials, components and connectors, facilitates deconstruction and sorting. Composite and laminate materials create end of life problems, thus mono-material components (homogenous material used throughout) are preferable. Toxic and hazardous materials and finishes that contaminate a material should be avoided, as they reduce the likelihood of reuse.
- *Durable design* – To be reused components need to be able to stand up to repeated use and the process of removal and reinstallation. This requires attention to both the material characteristics and to the jointing/connection mechanisms. Durable design as applied at a building scale is about flexibility of layout.
- *High generality* - This is proposed as being the opposite of specialization. It means that both the building and components can change functionality. Thus, simple and standardized construction methods, standard dimensions and grids, and small to moderately sized components provide more opportunity for use in different architectural contexts.
- *Flexible and reversible connections* - Are seen as a prerequisite for dismantling. Thus, mechanical fastenings are preferable to chemical bonding. Connections can

be exposed, which makes dismantling easier and can be directly linked to tectonics and expression of joints – weaving, stacking, patterns and so on.

- *Suitable layering* – Highlights the need for careful thought about how a building's components are layered to ensure accessibility for removal at the end of life of a component (see Figure 1.6). Recognizing that contemporary construction methods often feature layering to achieve various technical requirements, these layers should be arranged to reflect their functional and technical life cycles. Layers should be independent and arranged base on expected component lifetimes and to enable exchange of each component based on its needs and functional lifetime.
- *Accessible information* – Highlights the importance for information to be available in the future about the building and its components to facilitate possible future uses. In this context as-built drawings, materials logs, connection details, structural design, deconstruction plans and materials passports all become important.

Norby *et al.* argue that these strategies imply more restricted and localized materials selection and a need for careful investigation of each building material. This can lead to a localized material culture and aesthetic, and offers the possibility of a rich architectural language based on these characteristics. But emphasis on the deconstruction of buildings needs to focus not only on the type of materials but also on interfaces, arrangements of materials and the process of installation.

2.7 INFORMATION – MATERIALS PASSPORTS

Waste is sometimes described as material without information. The importance of tagging or attaching information about a product is recognized in industrial design; by providing adequate information about a product or material it may be possible to pass this to future generations. Technical specifications can be encoded in what are sometimes referred to as '*materials passports*' (or resource passports). These can provide details of all a product's qualities, nutrients and properties as well as production information such as location, date and name of manufacturer. This enables future reuse or recycling to occur when a product reaches the end of its initial life. For some components it can also aid in maintenance throughout its lifetime.

Marking materials with their characteristics is not new. The Romans had a tradition of stamping their bricks indicating production site or brick maker. More recently, imprints into a material, bar codes, QR codes and electronic chips have been used. With current technologies this can be done in a variety of

ways, including molecular markers or infrared signatures. Addis and others have pointed out that any method depends on the existence of appropriate technology and equipment for future reading or decoding, and electronic technology is changing so quickly that some current systems may not be decodable in the typical lifespan of a building.[23, 24] Therefore, direct physical tagging or marking may be a more robust measure.

In the shipping industry, Maersk has introduced product passports for its container ships. These are live documents that are updated throughout the life of a ship and are effectively a database that documents approximately 95% (by weight) of the materials used to build a ship. It should enable better recovery of components and materials used in the making and maintenance of the vessels. In buildings, as-built drawings are intended to afford some of this information but seldom provide the necessary detail and are often incomplete. A further step rarely undertaken is to provide full materials logs for a building and guidance for deconstruction. In addition, as Nordby *et al*. have pointed out, there is potential for aesthetic expression of some types of markers such as stamps on bricks and timber.[18] Components may be designed so that surfaces containing information give added texture/relief that may contribute to distinctive architectural expression.

The adoption in Europe of compulsory CE certification for construction products may be useful in this regard. CE marking demonstrates that the product complies with the appropriate harmonized European Standard. The CE mark and basic material properties could be placed on the product as this would make it easier to identify. Others have suggested that building information modelling (BIM) is a suitable method of storing design information, drawings and deconstruction plans for future access. If there is clear information about the properties of a component then it should be much easier to recertify and reuse it. In Denmark, architects 3XN and contractor MT Hojgaard are experimenting with BIM and virtual design and construction to better understand the potential for building deconstruction.[25] They have identified the following principles to consider in a materials passport:

- documentation that includes all relevant information from the material level to the entire building;
- physical identification on the construction components;
- guidance for the physical maintenance of individual materials and components;
- information on safety for handling of materials and components in all lifetime phases;
- information on transition phases such as handling, transport and storage requirements.

Box 2.5 Circular Building

Engineering consultants Arup, together with partners Frener & Reifer, BAM and the Built Environment Trust, designed and constructed a circular demonstration building for the London Design Festival, in September 2016. The project investigated how the circular economy can benefit the industry and the built environment, reflecting on the commercial, social and environmental opportunities of employing circular principles.

The Circular Building is a prototype that tests the maturity of circular economy thinking in the supply chain and examines what it means for building design. It was found that supplier engagement is critical, with both designers and suppliers challenged to think differently about materials and construction processes. The multidisciplinary team learnt that there needs to be a significant change in the design process with a focus on connections, modularity and materials.

A materials database was created using a cloud-based platform from which data have been fed to both the Circular Building website and the BIM model. Each material that was used comes with its own QR code containing the information required to facilitate future reuse (effectively a materials passport – see Section 2.7). This required input from manufacturers as well as Arup's designers and material experts.

For details see: http://circularbuilding.arup.com

2.8 COMPONENT REDESIGN – DESIGN FOR REASSEMBLY AND SECONDARY USE

In 1975, architectural critic Martin Pawley was interested in using garbage to address housing shortages and proposed low cost housing based on products designed with a secondary use.[24] Pawley claimed that '*while waste remains valueless it will be wasted*'. He reasoned that this was the result of the tunnel vision of the west and the academic non-credibility of using garbage for building, and he advocated the need to learn from other cultures where resources are scarce.

Pawley claimed that '*the theoretical argument for secondary use is unanswerable*' based on the enormous social, economic and

resource benefit that would result. His greatest concern was with acceptability to occupants and society in general. He suggested that secondary use was more likely to succeed than some other strategies to reduce waste because it would not require abandonment of typical patterns of consumption in developed countries. Rather it linked the mass consumption of everyday products with provision of housing and merely required the redesign of some everyday products.

His visionary, if idealistic, proposals were based on the WOBO beer bottle prototype developed by John Harbraken for Heineken (Figure 2.3). Pawley proposed the development of other similar products with a secondary use in the built environment after their original use was complete. This transformational system requires creative design effort to establish an acceptable image for such buildings. Also necessary are technical developments to demonstrate acceptable performance and a reorganization of commodity retrieval to facilitate recovery of second use products after their first use is complete.

Others have proposed design for reassembly and design for reuse that feature strategies to ensure that components are strong enough to withstand repeated and appropriate collection, handling, cleaning, reprocessing and refurbishment of damaged components.

Pawley's ideas for secondary use products from other sectors to be used in buildings have had little impact on the building industry, but the concept continues to provide inspiration for extending the useful life of nutrients. However, secondary use of some construction components, such as bricks, steel

Box 2.6 RE-Fab House Project[26]

The RE-Fab House Project in the United Kingdom explores and demonstrates new forms of construction to transform resource efficiency. The aim is to create a framework for Flexible Life Buildings (FLBs) underpinned by a series of principles for design, construction and operation that facilitate building design for deconstruction and reuse. These principles are supported by a series of protocols, products, design proposals and data emanating from research and demonstration projects to develop a supply chain capable of delivering this type of construction. The project is also measuring the social, environmental and sustainability benefits, and aims to:

- *capture the existing benefits of offsite construction with lower whole life cost of buildings and components;*
- *extend building lifetimes through adaptation in use;*
- *deliver a range of new (reusable) products for adaptable building;*
- *deliver new models of supply and finance, including leasing partial ownership and service;*
- *improve the resource efficiency of UK construction and massively reduce waste;*
- *reduce the balance sheet pressure on public infrastructure;*
- *create new opportunities for product manufacturers and exporters;*
- *deliver usable BIM data and assurance for RE-Fab compatible products and systems.*

components, some heritage components and so on, does occur. These components are not specifically designed with secondary use in mind but their natural characteristics sometimes make them suitable for secondary use. New assembly and jointing techniques can increase the likelihood of secondary use.

2.9 TYPOLOGIES OF MATERIAL REUSE

In the book *Superuse*, Van Hinte *et al*. categorize two different approaches to design:[12]

1) *Means oriented design* – The design evolves from the means available, which include the materials. This involves more complexity, flexibility, experimentation and adjustment during process.
2) *Goal oriented design* – A goal is defined and all decisions are aimed at that goal.

To some degree, most building design shows aspects of both, as all projects have some goals and are constrained by means. But most current design strategies are more goal oriented with the main constraints being financial, programme and site related. Local material is not usually seen as a constraint. It is rare for a project to start with a comprehensive review of locally available means and adjust its goals based on the materials available from near the site and the resources provided by the climate. A greater focus on reuse requires starting with an inventory of the means (materials and components) locally available for realizing the project. When looking at what society discards, questions like '*Can this be used?*' and '*How can this be used in a building?*' lead to a very different process of design.

There are four typologies of reusing previously used materials or components in the built environment:

1) *Reuse an existing structure on the site and possibly add to it or extend it* – This approach, often called '*adaptive reuse*' is now relatively common with heritage structures, as they are seen to have cultural value. It is also possible for many existing buildings, where it may be appropriate to strip the building down to its bare structure to improve thermal performance. Financial savings are also possible. Adaptive reuse often implies a change of function resulting from building obsolescence.
2) *Relocate most or all of an existing building to a new location* – Relocation sometimes occurs for pre-engineered buildings, such as industrial buildings and warehouses, and occasionally for other building types. Temporary buildings offer lessons about how to design to allow for future relocation.

3) *Reuse individual components extracted from the demolition of one project in a new building* – This form of reuse is sometimes called '*component reuse*'. Structural components, such as beams and columns, or non-structural components, such as cladding panels, bricks or staircases, are taken from one project and used in another (see Sections 3.2 and 3.3). This is not yet common other than for heritage components. It helps to consider, at the design stage, how a building will be deconstructed to make it more feasible that components are reused.
4) *Use materials and components that were previously used for a different purpose* – These may be items that have a designed-in secondary use (although these are currently rare) or items that were previously not intended for buildings but through the creative design process are found to be suitable for secondary use in a building (see Section 3.4).

Another way to categorize reuse is to look at elements of a building and consider the potential for salvaged components to be used to create them. These can be broken down into:

- *Primary structure* – Materials such as steel and heavy timber offer the opportunity for deconstruction and reuse; *in situ* concrete can be more challenging to reuse, unless the entire structure is reused in its current location.
- *Building envelope* – Recent improvements in thermal performance standards mean that many envelope components need thermal upgrade before they can be reused. Layering of many modern building envelopes can assist in reusing some of the layers. Windows need careful consideration but old windows can be used in less thermally critical locations.
- *Services* – Although mechanical equipment is often replaced with newer more efficient models and so reuse is limited, much of the infrastructure such as ducts, conduits and connectors can often be reused. But additional care is required in its extraction from its first use.
- *Interior finishes* – These offer many opportunities for reuse. Interiors are replaced often in a building's life, and the nature of their performance means that reused materials and components can often be suitable.
- *Feature components* – Architectural salvage of heritage components is an established business in many locations and much reuse of such items already occurs. This can be extended if the acceptability by society to a wider range of character items were to increase.
- *Landscaping* – The performance requirements of landscape mean that there are many opportunities for reuse of older items to create landscapes of instant character.

Box 2.7 SELF-BUILD

Much urban development today in massively expanding cities in the developing world is created through unauthorized, informal dwellings in urban waste spaces, usually built by the occupants without engaging an architect, or contractor, and using free or cheap and discarded local material or components and using very little off-the-shelf or new building materials. This world of self-build is an interesting source for creative ideas of reuse.

Architect Santiago Cirugeda of Recetas Urbanas (Urban Prescriptions) architectural studio in Spain uses tactics borrowed from informal housing in developing countries to challenge concepts of municipal control of urban design, acceptable design, ownership, use of public space and the social role of design. Cirugeda describes his practice as 'an urban and social renovation' *and a form of civil disobedience. Its subversive projects include systematic occupations of public spaces and empty lots, construction of prosthetic facades and roof structures, and backyard buildings, often using local, readily available, pre-used materials. These projects address the complex social reality of urban life and challenge local laws and norms of both the use of space and materials. Their work aims to empower citizens to act in their own locality by showing how it is possible to overcome limitations and get access to readily available materials. The projects capture the ingenuity of the self-builder and appropriate technology, offering lessons about the potentials for architects to create change. The images here show the Aula Abierta a 2012 project that responds to the need of a community space for physical activity and mental reflection in Seville. It was created from dismantling an earlier Recetas Urbanas project in Granada, which was due to be demolished, and creating the new building in Seville with community builders, using the same materials.*

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IMAGE CREDITS

Figure 2.1 Courtesy of Juan Luis Martínez Nahuel; figures 2.2 & 2.4 By Author; figure 2.3 Courtesy of Heineken Collection Foundation; figure 2.5 From the Bruce A. Goff Archive, Ryerson and Burnham Archives, The Art Institute of Chicago. 199001. Bavinger_ext_color2.; figure 2.6 Courtesy of Supersue Studios; figures 2.7 & 2.8 By Adam Mørk, courtesy of 3XN; Box 2.2 By Kristine Autzen, courtesy of Vandkunsten; Box 2.3 By of Sander van der Torren; Box 2.4 By P Appelhof, courtesy of RAU; Box 2.5 Courtesy of Arup; Box 2.7 Courtesy of Recetas Urbanas

3 CASE STUDIES

This chapter describes a series of projects that all use previously used materials in some way and provides useful lessons for how the industry needs to respond in addressing circular issues. The projects are divided into four categories:

1) Projects that reuse what is available at the site – the architectural response is based on what is readily available at the site.
2) Projects that reuse construction materials from elsewhere – where reclaimed construction materials from elsewhere are used.
3) Projects that find second uses for non-construction materials – creative use of materials that have been discarded by other supply chains.
4) Projects that include adaptive reuse of whole buildings along with component reuse – where parts or all of an old building are reused and supplemented by other reclaimed components.

Resource Salvation: The Architecture of Reuse, First Edition. Mark Gorgolewski.

3.1 ADAPTIVE REUSE WITH COMPONENT REUSE

3.1.1 Alliander – Nothing is New

Architect:	Rau Architects
Construction:	2015
Location:	Duiven, The Netherlands
Floor area:	Total 25 709 m^2 (276 600 sq. ft.), reused buildings16 009 m^2 (172 200 sq. ft.)
Use:	Offices, workshops, laboratories, meeting spaces
Owner:	Alliander
Construction cost:	€26 million for building and €10 million for fit-out (€1400/m^2)
Certification:	BREEAM-NL Outstanding
Reused material:	Existing buildings, waste timber, suspended ceiling, sanitary appliances, steel, blockwork, doors, asphalt roofing, clothing as insulation.

Alliander is the worlds' first building organised as a resources depository. For 80% of the resources we know their origin and how they are used in the building. The building is built for disassembly and uses resources passports so a future purchaser knows the exact amount of the different resources in the building. This secures usability of the resources: in this way they stay resources instead of turning into waste. (Thomas Rau[1])

This project is an experiment by Dutch energy grid company Alliander with its team of experts to explore a new way of meeting its needs based on circular principles. Its innovative approach is largely due to the client challenging the construction industry to think creatively about how circular approaches can change the way we create and operate large, multipurpose, commercial facilities (Figure 3.1).

The starting point was that Alliander wanted to consolidate its activities in the eastern part of The Netherlands into one location in Duiven, where they had property consisting of a group of offices and workshops built in the 1980s (Figure 3.2). It did not want a traditional project; rather it established a series of challenging goals, including optimum use of existing buildings, energy positive, connectedness and identity.

Figure 3.1 Alliander offices in Duiven.

Figure 3.2 The old buildings prior to reconstruction.

Recognizing that it did not know how to achieve their goals, Alliander invited the industry to collectively propose solutions. It was clear that such a large project focusing on circular principles would need a creative procurement process based on collaboration and trust, requiring an interdisciplinary approach involving a diverse range of expertise (design, construction, installation, maintenance and interior design). Alliander consulted with potential industry partners, and consortia were invited to submit proposals based on a design, build, maintain and operate contract (for a period of 15 years). The consortium of VolkerWessels Vastgoed/RAU won the tender with its strong commitment to the notion that everything is temporary and cyclical, thus treating the existing complex as a materials bank and proposing an overarching roof linking the existing buildings.

The architectural concept developed by Rau Architects focused on maximum retention of the existing buildings and components, while at the same time creating a unified, high quality complex to house offices, laboratories, workshops and a training centre (Figure 3.3). This increased the capacity of the location from 600 to 1550 employees. A large undulating roof unites the various existing buildings and creates a large atrium space (Figure 3.4), which is principally a circulation and meeting space but includes informal flexible workplaces. The various existing buildings have been converted into a variety of different types of work space to accommodate flexible working patterns – there are no personal work places but rather spaces are arranged according to activity – the workshop for collaboration, the library for concentrated working and the traditional office space.

Design strategies aimed to get most value (aesthetic, ecological and financial) from the existing resources based on an assessment of material inputs, financial capital, technology, knowledge/history and labour. Where appropriate, the existing materials and components were kept in place, but in other cases they were removed, cleaned, reprocessed and reused in the building. Creative approaches led to partnering with unusual organizations, such as a roller coaster company to minimize the need for metal in the undulating roof structure and ensure it was easily demountable. The project also benefited from an engaged and creative approach by the contractors and subtrades.

In total, about 90% of the existing buildings were preserved. The buildings comprising steel and concrete structures with brick facades were completely remodelled. The deconstruction contractor recorded everything that was removed and this

Figure 3.3 The new Alliander offices were based on how to get most value out of the existing buildings.

Figure 3.4 The new atrium clad with reused timber.

Figure 3.5 Deconstructed materials were recorded and stored for reuse.

became the materials bank for the new building (Figure 3.5). The deconstruction was more expensive than a traditional demolition but material costs for the rebuild were reduced. Any removed materials and components were first considered for other uses on site wherever possible, but if not needed they were send for reuse or recycling off-site. For example, the ceiling tiles were removed cleaned, repainted and reused in the building, which was a similar cost to using new tiles. Steel from the selective deconstruction was used for the new structures, while demolished concrete was crushed and used as aggregate. Doors could not be reused but were converted into new cabinets and seats. Even sanitary fixtures, such as wash basins and toilet bowls, were cleaned and reinstalled with new taps. This required some flexibility from the design team to adjust its proposals as the materials became available. Materials that could not directly be reused in the new building were sorted into thirteen separate waste streams and returned to industry. Only a small amount (maybe 5%) of materials was not used somewhere.

The floor area was increased by adding extra floors to some of the existing buildings (Figure 3.6). To deal with the additional weight on the structure, some of the heavy non-load-bearing brick walls were removed, replacing them with lighter windows to improve natural lighting. Most of the existing facades were left in place but clad with a new prefabricated skin consisting of panels with integral windows, insulation and a new exterior timber cladding (Figure 3.7). It was intended to clad them in waste timber from electrical cable reels used by Alliander in its network installations but this was not possible

Figure 3.6 Additional floors were added to some blocks.

due to limited availability, so a heat treated timber cladding was finally used.

A neighbouring incinerator was found to have a large supply of scrap wood from pallets and other waste timber (Figure 3.8) that was suitable for use as an interior cladding material in the atrium. A group of local workers on a training programme dismantled the pallets and selected better quality pieces, which were cleaned, planed, sawn to size, sorted by colour and made into modular prefabricated panels for use inside the building. Similarly, waste timber was used for some ceilings.

Some reuse required reprocessing off-site, such as old Alliander employee uniforms, which were sent away to a company that turned them into an insulation material that was used in the building. Similarly, the bituminous roofing was removed and returned to industry for processing into a new roof covering. About 80% of all the material inputs for the project are either reused directly on site or reused from elsewhere.

Future use of components at the end of their first life is a critical element in a circular economy. This building is seen as a temporary resources depot that can be largely demounted at the end of its life. Thus, a material (or resource) passport was created that provides information about all the materials used within the building, including their lifespan and potential opportunities for reuse. This is intended to provide the owner with knowledge of all materials and quantities that are

Figure 3.7 Prefabricated overcladding was installed.

Figure 3.8 Waste wood from nearby was used for internal cladding.

temporarily in its care, and ensures that in future when deconstructed the components of the building are likely to have further value. For this project the material passport took the form of a spreadsheet, but Rau Architects is now developing a database approach, creating BIM models of existing buildings and using this as a starting point for the components that are available.

In addition to the material reuse, this building has many interesting features that make it energy and water efficient, and create high quality work spaces (Figure 3.9). Energy production on the roof of the adjacent warehouse and car park means that it achieves energy neutral performance, which was required in the contract. It is the first renovation project in The Netherlands to obtain the BREEAM-NL outstanding sustainability certificate.

An important aspect of the project is the use of a design, build, maintain and operate contract that places the long term success of the building on the consortium and means that it has an incentive for the building to operate efficiently. Also, Alliander was willing to work in an experimental way and was interested in innovation, and for this trust, openness and clearly organized communication structures were essential.

Figure 3.9 High quality interior spaces lined with reused timber cladding.

Element	Source	Processing	Comments
Existing buildings	On site	Stripped down and refurbished	
Waste timber for internal wall surfaces	Nearby incinerator	Pallets were dismantled, and timber sorted and made into panels	Local under-employed workers were used
Suspended ceiling panels	On site	Removed, cleaned, repainted and reinstalled	Cost neutral
Sanitary fittings such as toilets, wash basins	On site	Removed, cleaned, new taps added and reinstalled	
Steel structural components	Removed during selective demolition on site	Used in new structures	
Doors	On site	Removed and used to create new furnishings	Creative uses by interior designer
Blockwork	Removed during selective demolition on site	Used in floor of parking area	
Clothing	Alliander employee uniforms	Shredded and made into an insulation product	Product available commercially
Asphalt roofing	On site	Removed, shredded and reprocessed into new roofing products	Product available commercially

3.1.2 Posner Center for International Development – the Horsebarn

Architect:	tres birds workshop
Construction:	2013
Location:	Denver, CO, USA
Floor area:	2 800 m^2 (30 000 sq. ft.)
Use:	Non-profit offices and community resource
Owner:	Denver Housing Authority
Construction cost:	$2.2 million (approx. $790/$m^2$ or $75/sq. ft.)
Reused material:	Old horse barn building, boxcar timber, carpet tiles, plumbing fixtures, door hardware, kitchen appliances, taps

This building, originally from the 1800s, was constructed as a horse barn and had been used as a warehouse (without heating, cooling or lighting) since the 1920s. By the time tres birds workshop took on the project, the space had been abandoned for 16 years. The building was literally falling down because it was not draining properly (Figure 3.11). The masonry walls were degraded, some wood was rotten and the pigeons had moved in. Most people probably would have knocked it down. But tres birds workshop transformed the building into a place of beauty and purpose with many historical details kept intact using mainly reclaimed components. It has become the Posner Center for International Development and a local neighbourhood hub (Figure 3.10).

Figure 3.10 The reconstructed Posner Centre.

Figure 3.11 The building was in a very poor state of repair.

Many parts of the original structure were recycled and used for structural improvements. Instead of replacing the inner skeleton with new materials, careful architectural surgery reinforced the original structure, revealing beautiful wood beams behind that give the space its primary shape and character (Figure 3.12). As principal architect Michael Moore put it, '*nothing is straight, level, plumbed, or regular. You can't make any assumptions and must play to accommodate this fact'*. The original grid of support posts averaged nine feet on centre and sometimes was as little as five feet apart. The best location for the open, multifunction space that could be used for lectures was also the zone with a dense layout of posts, so the team decided to restructure this one area to create larger, open spans and a central atrium to bring natural light into the space (Figure 3.13). A rather complex set of shoring and rigging had to be installed in order to allow for the large footings to be cast and steel work to be installed. To the surprise of the design team, the soil bearing capacity beneath the building was extremely low. In the end the area had to be excavated and compacted fill was added. If this condition had been known at the start then the building may have been torn down.

The structural materials that were removed were used throughout the building to replace other columns and to make headers

Figure 3.12 The interior was transformed using mainly reclaimed materials.

for new doorways. Star-shaped exterior washers used to hold interior walls in place via tension were improved and increased. Where necessary, bricks were replaced with reclaimed bricks. New holes were carved out of the building to create windows and the bricks from these new openings were used to replace interior bricks that were damaged. Energy efficiency was addressed by adding insulation to the building's skin and using energy efficient windows. The dense and irregular posts made it difficult to efficiently use any sort of systems furniture for the office workstations. For this reason, all of the workstations were built into and around columns and walls using second use timber.

Almost all of the finishing materials in the building are reclaimed. All work surfaces and conference room tables, doors and stair treads were made from maple boxcar flooring from retired coal rail cars that were built prior to 1940 (Figures 3.14 and 3.15). Because the wood and steel become fatigued over time, the cars have to be retired after 70 years of heavy use. Typically, the retired cars are scrapped (mostly for the metal, as it is easily and widely recycled). A total of 10 tons of this wood were used. However, it was found that boxcar maple is difficult to work with because it is impregnated with chips of steel and coal, and has been around so long and used so much that the material is very hard. It has to be planed and was quickly eating through planer

Figure 3.13 The new atrium space required some restructuring.

blades. The planer's blade system had to be completely replaced with thin, disposable blades that could easily be changed each day.

Since tres birds workshop has a design and construction capability, it is also able to deconstruct buildings to secure many useful components this way. It became aware that the 93 000 m^2 (1 000 000 sq. ft.) Hewlett Packard Technology Center in Colorado Springs was being demolished due to expansive soils that could not support the building's foundation. From this building carpet tiles, plumbing fixtures (toilets, sinks, water fountains), bathroom fixtures, door hardware, AV equipment, projection screens, kitchen appliances, sinks, taps and

Figure 3.14 Maple from rail boxcars was used for many interior elements, including built in desks.

mailboxes were saved. These were brought straight to the horsebarn project site and were used there (Figure 3.16). From experience 30% excess was gathered, as some of the used items are inevitably not in perfect working order. Some carpet tiles were damaged or dirty and, occasionally, the insides of taps and fixtures needed reworking. The serendipitous arrangement with the Hewlett Packard Technology Center would have been difficult to pull off with a typical client–designer dynamic. Because tres birds workshop is a design–build firm, it was able to be responsive and make a quick decision when the opportunity for materials arose. Within two weeks, it surveyed the demolition site, obtained client approval for the used materials and extracted all of the material.

Experience in this and other projects has taught tres birds workshop that there are often timing and financial challenges with using reclaimed materials, and the design of something that uses reclaimed materials is almost certainly very different to the design of that same element if it were using new materials. The time between design and construction means that to plan for the use of a specific available reclaimed material is to take a significant risk if the materials are not procured or reserved during the design process. It is rare for any bank financing to be in place during the design process, which means that an owner

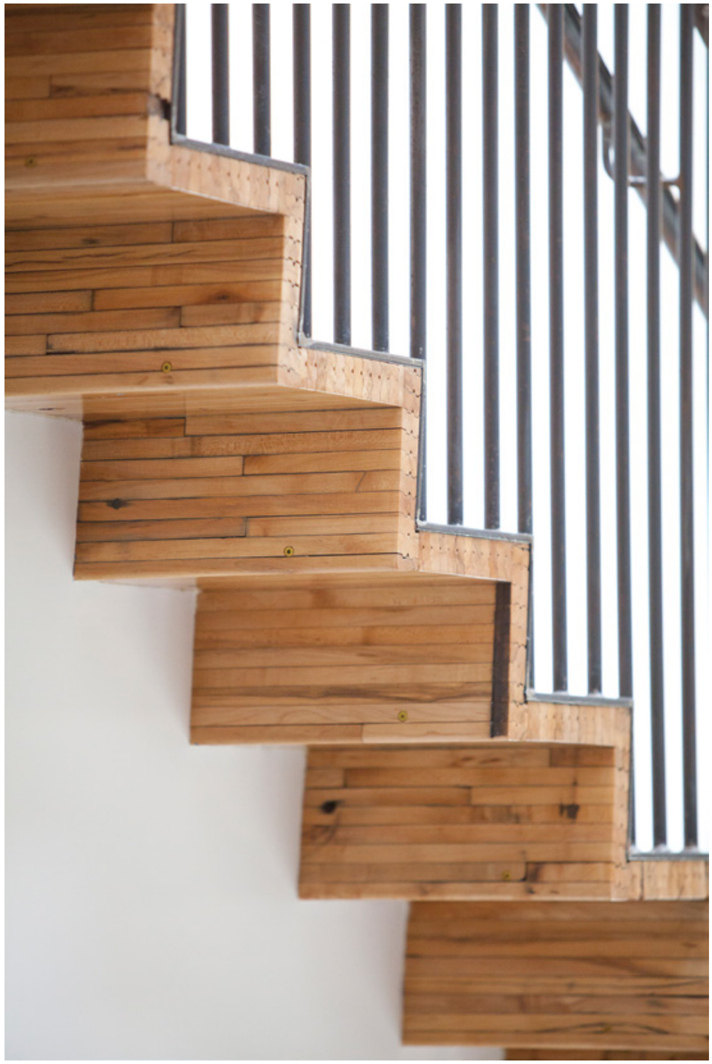

Figure 3.15 Maple from rail boxcars used for new stairs.

may have to pay out of pocket to procure the reclaimed materials. This often proves to be difficult for various reasons, from complex ownership structures, to bank lending and lien waiver requirements, to an owner simply not wanting to front the cost of materials. Sometimes tres birds workshop deals with this problem by directly purchasing items that it may use on a future project. If the team waited for the right project to come along before purchasing, then many reclaimed items would no longer be available. This exposes it to some financial risk, as it is effectively stockpiling materials without having a client for them. In the case of the Posner Center, the owner had to write multiple checks to secure the wood and work closely with the lender to

Figure 3.16 Washroom fittings came from the dismantled Hewlett Packard office building.

address reimbursement and insurance requirements while the materials were off-site. But this led to significant cost savings – tres birds workshop estimates that using reclaimed materials saved about $400 000 or nearly 20% of the construction cost. Although environmental benefits were not quantified, the majority of materials for the project were reclaimed and replaced things that would have been new products.

Element	Source	Processing	Comments
Structure	Existing structure, reconfigured in some locations		Unexpected problems with soil bearing capacity caused extra work
Stairs Doors Tables	Boxcar maple flooring from retired coal rail cars	Difficulties with processing and planning the timber due to hardness and presence of coal and steel chippings	
Furnishings Plumbing fixtures Door hardware Various internal fittings Electrical fittings Carpet tiles	Deconstruction of the Hewlett Packard Technology Center in Colorado Springs	tres birds workshop undertook the removal of useful items from the building before deconstruction	Some tiles were damaged, so 30% extra was required.

3.1.3 Energy Resource Center (ERC)[a] – A Learning Hub

Architects:	WLC Architects (Wolff/Lang/Christopher Architects)
Construction:	1995–1998
Location:	Downey, CA, United States
Floor Area:	4 140 m^2 (44 500 sq. ft.)
Use:	Office, exhibition space and information centre
Owner:	Southern California Gas Company
Reused materials:	Materials from demolition including: roofing materials, metal, ceiling tiles, wood flooring, electrical equipment and mechanical systems. Also reprocessed wood, steel stairway

The upgrade to the Energy Resource Center for the Southern California Gas Company by WLC Architects (Figure 3.17) was a project that capitalized on the collaboration between team members to embrace reused materials in the design, accepting the uncertainty of material availability as an integrated part of the process.

Figure 3.17 The refurbished Energy Resource Center.

[a] Prepared with assistance from Sandra Wojtecki and Larry Wolff.

The Energy Resource Center is an exhibition centre and resource hub for the Southern California Gas Company. The original building was constructed in 1957 and was set for demolition to be redesigned elsewhere. The client wanted the new building to incorporate leading edge green design features and strategies. Larry Wolf of WLC Architects and his team decided to take another look at the existing building and assess it for any fatal flaws, such as structural integrity, inability to comply with current codes, enclosure status, presence of toxic materials, site constraints and flexibility to accommodate new uses, that might eliminate the possibility of reusing it in part or whole. They discovered that the building had $4 million of embodied value, which meant the original budget of $3.1 million could become an equivalent value of over $7 million. An additional benefit was the 4–6 month time saving by reusing much of the existing building. With the enormous cost benefits available from upgrading the existing structure, the project budget could be dedicated to a building that embraced the idea of minimizing embodied energy and maximizing value.

Designed through a process Wolff coins '*open heart surgery*', the existing building needed to accommodate an additional 1 100 m^2 (12 000 sq. ft.) of space for an exhibition hall as well as a 700 seat auditorium. This was done by demolishing the middle third of the existing building and creating a new double-height space using a large curved roof atrium (Figure 3.18). By keeping

Figure 3.18 The middle section of the Energy Resource Center in the process of being rebuilt.

the building occupied during construction even more money was saved, and could be allocated to the project.

The idea of incorporating reused materials merged with the idea of retrofitting the existing building and became part of the manifesto that guided the process. The Energy Resource Center provides energy-efficient solutions for businesses and wanted to be perceived as an organization that embodies sustainable principles in its own facility. Due to the unpredictability of reused material availability, it became evident that to truly embed this concept into the process, every stakeholder, including owner, design team, contractor and tradespersons, had to be actively involved and that opportunities could emerge from various participants. Thus, the team actively encouraged various trades people and construction team members to seek out opportunities as they presented themselves. This mutual accountability became a key part of the project's success.

Since everybody subscribed to a common goal, opportunities for recycling emerged in ways that a design team alone could not anticipate; but it required some flexibility and willingness to make alterations as opportunities arose. The starting point was to see what types of materials would be available to salvage from the existing portion of the building that was to be demolished. Brick was dismantled from the existing structure and was stored for later use (Figure 3.19). Similarly, about 1 800 m^2 (20 000 sq. ft.) of acoustic tiles were salvaged from open office areas and wood wall panelling was collected from the former auditorium. Where the materials would end up relied on an assessment of their condition, the quantity that was salvaged and how much refinishing was needed for an effective reuse. The brick became crushed aggregate, the acoustic tiles had to be trimmed and were re-installed into the new seminar rooms, and the wood panelling was refinished and used for flooring in the daylight room. Allowing for an assessment of material condition to determine future outcomes also drove the work of the electrical and mechanical trades. One ton of electrical conduit and fittings were salvaged from the demolished portion and reused into the new facility, as well as an existing electrical system and ductwork. All of these decisions relied on trusting the tradesperson's knowledge and allowing them to improvise as best as they saw fit. Reuse of components that are already on site can lead to considerable cost benefit, as transport and handling costs are reduced, and often these components require little reprocessing.

In addition to permitting a degree of unpredictability about material quality, there was also tolerance for the irregularity of material availability. As the construction progressed, various

Figure 3.19 Recycled brick stockpile; the original building is in the background.

salvaged materials were discovered that could be incorporated into the project. One of the more notable features of the new facility is a steel stairway from an old Warner-Brother's film set that was saved from going to landfill and incorporated well into the construction (Figure 3.20). This required minor modification to satisfy the relevant building codes. As other materials were discovered a playfulness about where the materials could be incorporated and how they would be revealed became a feature. Old aircraft aluminium became the decorative wall covering of the lobby wall (Figure 3.21), yellow plastic piping was broken up and used to accent the concrete mixture that formed the entrance paving and the lobby floor came from reprocessed wood from an old Banana Republic warehouse in San Francisco (Figure 3.20). This creativity extended towards the components that were built off-site. For example, steel rebars made from confiscated guns and knives from the police department were chosen for concrete reinforcement, and even the lobby countertop was chosen because it was made of broken glass.

What appears as a haphazard approach that could hinder time and cost predictions in a construction schedule was, in fact, calculated to integrate a value added method into the process. This included the source reduction approach – avoiding the need to use unnecessary and harmful materials. To

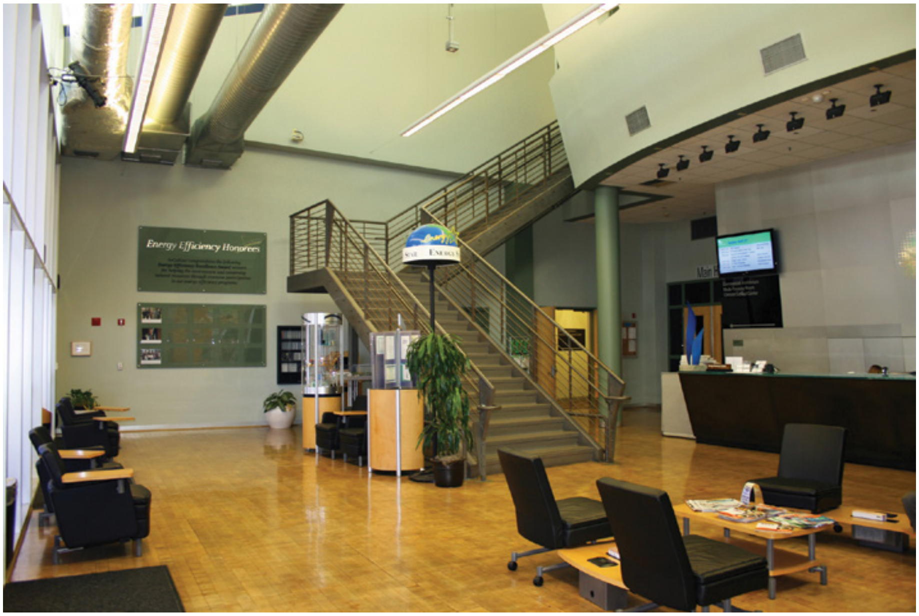

Figure 3.20 Interior lobby with a staircase reused from a movie set, and floor reused from a warehouse.

accommodate flexibility, the project employed a '*Work Breakdown Structure*', which is a deliverable-oriented analysis of a project divided into smaller components that organizes the team's work into manageable sections. This ensured that all work stages were accounted for in terms of size, duration and responsibility, and each package of work was competitively bid. Anytime an unpredictable circumstance arose with regard to material availability and discovery, added value or additional time and processing was assessed and embedded into the Work Breakdown Structure. In most circumstances, this resulted in both cost and time savings, although in others the demonstrated benefits of the ideas were valued as enough to outweigh additional resources. This flexible approach was relevant to both the design stage and construction stage, including added time needed for the design team to rework the drawings. As opportunities emerged and were accommodated, the drawings were adapted to suite, and thus were not complete until late into the construction. In this way, the overall scope and design intent was defined from the start, yet there was sufficient flexibility for the details to be worked out at a later time as materials became available. It is estimated that 80% of all the construction materials used in the final building were reclaimed, contained recycled content or were from renewable resources.

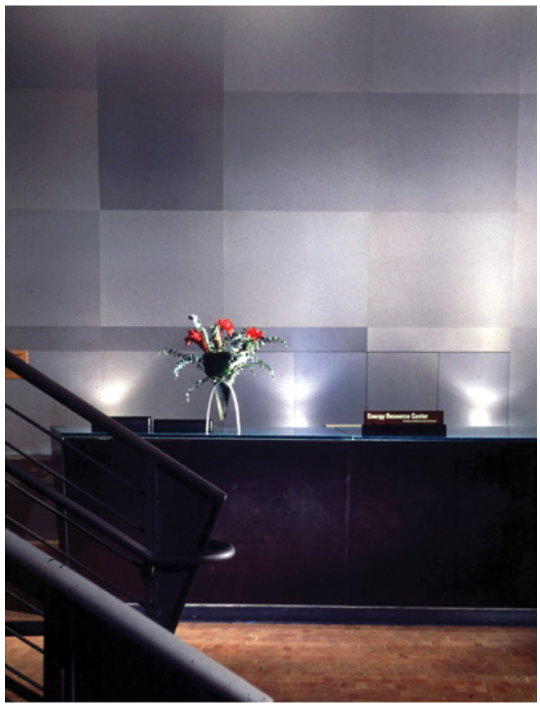

Figure 3.21 Aluminium from aircraft was used as decorative wall covering.

This method of working did, however, require alternative solution submissions for several aspects of building code compliance. In such cases the applicant (or usually their design team) is required to demonstrate that the proposed approach provides an equal or better level of performance to the prescribed provisions in the Building Code. Such applications can be tiresome and time consuming and rely on a process of negotiation with the Building Department.

Incorporating reused materials into the Energy Resource Center did not follow the typical top-down process of the designer making all of the decisions and the construction team then following through. It relied on effective collaboration between all those involved and finding a sympathetic management contractor at an early stage of the design process. Unpredictable timelines, quality of materials and professional judgement made by trades on site could only happen through an emerging process. Bringing all of the team members together at the beginning of the project was a crucial step to ensuring that seeking out salvaging materials was recognized as part of the planned construction development.

Element	Source	Processing	Comments
Structure	Confiscated guns and knives from the police department	Melted down into steel reinforcement for concrete	
	Structural roofing components from the old building		
HVAC	One ton of electrical conduit and ductwork from the old building	Also the existing electrical system could be used	This was on the initiative of the electrical subcontractor
Interior finishes	Approximately 1 800 m^2 (19 400 sq. ft.) of acoustic tiles were saved from the old building	These needed to be trimmed down to a smaller size due to damage and cleaned	Only a small portion could be reused in the project. More ambitious reuse of acoustic tiles was not possible
	Old aircraft aluminium became the decorative wall covering of the lobby		
	Yellow plastic piping from site	Broken up and used to accent the concrete mixture that formed the entrance paving	
	Timber floor from a Banana Republic warehouse in San Francisco	Reprocessed and used in the lobby floor	
	About 83 m^2 (900 sq. ft.) of wood wall panelling was saved from the former auditorium in the building	The panelling was refinished and used for flooring in the daylight room	
Stairs	From a Warner-Brother's film set	Required minor modification to satisfy the relevant codes	

3.1.4 Hughes Warehouse – Building Community

Architect:	Overland Partners
Construction:	2012
Location:	San Antonio, TX, USA
Floor area:	2530 m^2 (27 262 sq. ft.)
Use:	Leasable offices
Owner:	AREA Real Estate
Construction cost:	$1.8 million ($710/m^2)
Reused material:	Existing building, concrete flooring as paving, various finishes

This project along the banks of the San Antonio River in Texas also became a catalyst for the transformation of the River North district of downtown San Antonio, affecting not only the building but the culture of the neighbourhood. The renovation and transformation of this early twentieth-century warehouse into an innovative but functional studio space combines adaptive reuse of most of an old industrial warehouse building with reuse of individual components, which came either from demolition of part of the building or from other sources (Figure 3.22). Overland Partners, which was both the architects for the project and also now occupies most of the space (1 450 m^2 [15 595 sq. ft.]) approached the design by looking at the potential of the old building – how to reuse what was there either for its current function or in another location and use. It treated the building as a finite set of resources it could use and tried to minimize what

Figure 3.22 The Hughes warehouse transformed into an office building.

was added. If any components were to be removed, a secondary use was sought on site, and if this was not appropriate it attempted to find an alternative use elsewhere that maintained its value. Next, Overland Partners considered how to use the interior furnishings from its existing office for the new building. Thus, any materials and components that were available were treated as having value that should be realized wherever possible.

The project began by respecting and preserving the quality and industrial character of the existing longleaf pine and brick structure, which provided 18-ft-tall open spaces and a clear structural grid. Because these are leasable spaces, long-term flexibility was a critical driver for the project. The design team focused on preserving the open plan space and minimizing interventions to reduce resource use and maximize flexibility of the space (Figure 3.23). An important design strategy was to keep the new interventions separate from the old building enclosure to prevent awkward connections between old and new. Internal partitions were kept to a minimum with no private offices. Meeting spaces were provided in three freestanding conference pods inserted within the grid but separated from the enclosure. These were treated as new elements sitting within the space in contrast to the old fabric

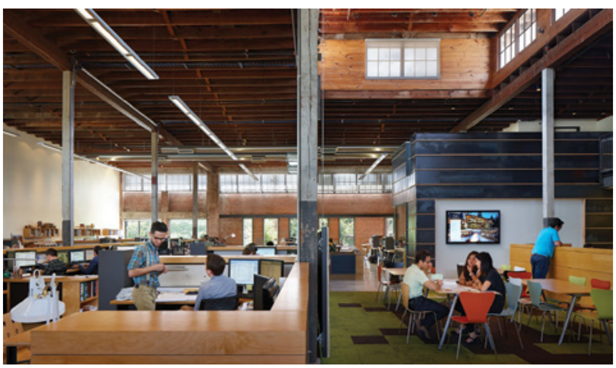

Figure 3.23 The new interior preserves much of the original character.

Figure 3.24 A new courtyard was created by careful demolition.

and are intended to be easily removable if necessary. They also help to organize the office space and create collaborative zones.

Careful demolition of part of the building resulted in a new 140 m^2 (1 500 sq. ft.) courtyard carved from the mass of building that allowed light into the interior through a new glass and steel wall facing the courtyard (Figure 3.24). This also gave access to tenant spaces and created a public meeting space. Some of the materials, such as joists and decking from the removed section, were reused in the building as features and some were sold. Further materials came as a result of an unfortunate storm during construction which caused part of the roof to cave in – this material was also reused where possible. During deconstruction care was taken to maintain the value of items – for example, rather than smashing the floor slabs they were carefully cut into regular sizes portions that could be reused as paving.

Existing elements, such as the solid brick external walls and the timber structure, were cleaned, restored and upgraded where necessary but remain largely intact to minimize material use (Figure 3.25). The old materials were left in their raw state as far as possible – old markings remain to show the history of the material. This provides a uniqueness and quirky charm to the space. In some cases, old materials were refinished, such as the concrete floor, which was polished to provide an amber sheen by highlighting the original aggregate in the concrete. This also created an interesting contrast between a slick floor surface

Figure 3.25 Old elements such as the brick façade were upgraded whenever possible.

and other old components. Prior to construction some concerns were expressed about potential acoustics issues due to the open spaces with predominantly hard surfaces. The architects considered using rugs for acoustic absorption but decided to try out the space and see how it performs. After occupying the building it was found that the acoustical qualities are quite successful, as confirmed through an occupancy survey.

Opportunities were sought to make use of available materials. So doors to the meeting rooms use reclaimed teak flooring. Furniture from the previous office was remilled and reassembled to create workstations. Stair treads were made from salvaged

and repurposed timber roof joists. Sections of carefully removed concrete floor became concrete pavers in a xeriscaped garden in the alley. An interesting tactic employed by the architects was to work closely with preferred suppliers who helped to identify leftover products that they had available from other projects, or end-of-line items and off-cuts. In this way, the project benefited from available material that would most likely have ended up as waste. For example, small areas of timber flooring were sourced in this way.

The project had a non-typical cost breakdown. The architects estimate that there were additional costs from careful deconstruction and reclaiming and remanufacturing processes but this was mostly balanced by reduced material purchase costs. So overall they estimate that there was little cost impact either way. It was a benefit to involve the contractor organization at an early stage in the design process, so it became part of the team, involved in feasibility assessments of what could be reused. Cooperation of the contractor in the salvage process and in creatively thinking about materials was important to the success of the project.

This is one of few projects for which a life cycle analysis (LCA) was carried out to compare design options for materials choices and analyse the embodied energy and the carbon footprint impact of the material conservation strategy. The analysis considered the impact of material manufacturing, maintenance and replacement, and end of life (disposal, incineration and/or recycling) across all life cycle stages. The study compared the impact of materials that were used in the retrofit with the same building using new materials. This approach was used as benchmark data for such LCA comparisons are limited. Building information modelling was used to calculate material volumes and an LCA database was used to convert this into their environmental impact. The analysis, shown in Figure 3.26, suggests that the materials strategies used resulted in a 48% reduction in embodied energy and a 75% reduction in carbon footprint.

Element	Source	Processing	Comments
Structure	Reuse of most of the existing building, in place	Some upgrade required	
Flooring	Waste and spare stock from manufacturers		Architects worked closely with preferred suppliers
Doors	Waste teak flooring	Made to suite	
Internal furnishings	Old office furniture	Remilling and refinishing	
Paving	Concrete floor cut from existing building	Careful process required by contractor	
Stairs	Repurposed timber joists	Remanufactured	

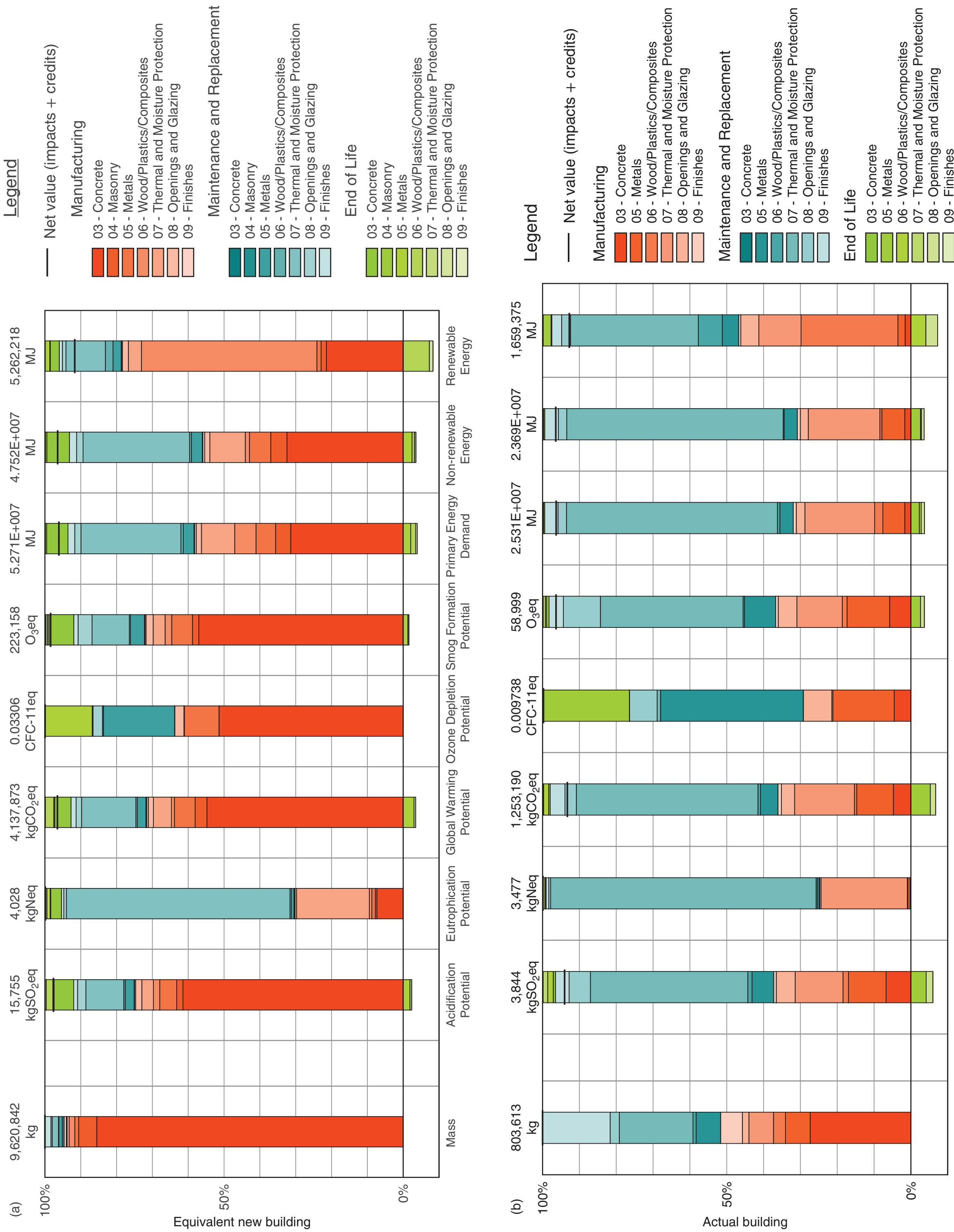

Figure 3.26 A life cycle assessment suggests significant reductions in carbon footprint for the renovation compared to using new materials.

3.1.5 Roy Stibbs Elementary School – A Building as a Material Bank[b]

Architect:	Killick, Metz, Brown, Rose Architects
Construction:	1994
Location:	Coquitlam, BC, Canada
Floor area:	3 450 m^2 (37 100 sq. ft.)
Use:	Elementary school
Owner:	School District 43, Coquitlam, BC
Construction cost	CAN $3.8 million ($1 100/m^2)
Reuse material:	270 tonnes of concrete and steel components from dismantled school

Relocating the structures of light industrial units, particularly for use as agricultural storage buildings, is not unusual but the Roy Stibbs School near Vancouver, BC, Canada, is an example of this strategy applied to a permanent school building (Figure 3.27). Many schools use temporary classrooms to provide additional space when permanent buildings are insufficient, but in this case the steel structure from a dismantled school from northern British

Figure 3.27 The relocated Roy Stibbs School building.

[b] Based on data collected by Vera Straka and Jordan Edmonds for www.reuse-steel.org.

Columbia was transferred to create a new building in Coquitlam in the suburbs of Vancouver. The project benefited from a particular set of circumstances, which enabled the reuse of most of the structure, but it demonstrates that if information about the materials used is available, and connections are appropriate, significant steel reuse is possible.

In 1991, the British Columbia provincial government financed and built a secondary school (William Storie High School) in Cassiar, a mining town just south of the Yukon border in northern British Columbia. Soon after, the mine was closed due to financial difficulties related to changing mining methods. Residents left the area in search of jobs, the town emptied and the school was shut down. Not wanting to waste a new building, the provincial government hired Norson Construction to deconstruct the building. The entire school was taken apart for potential reuse of the components. Efforts were made to salvage as much as possible: open web steel joists, steel studs, t-bars, ceiling lights, doors, hardware, fixtures, windows, exterior cladding and all mechanical systems (Figure 3.28). The open web steel joists were torched off the supporting beams (they had been welded to the beams) and the remainder of the structure was unbolted and transported to Fort St. John for storage. Some of the steel and other components were used in the construction of Robert Ogilvie Elementary School in Fort St. John. Other non-structural components were incorporated into the construction of a new school in Hudson Hope. But the rest went to rebuilding the Roy Stibbs elementary school in Coquitlam.

In 1993 a new building was urgently required at the Roy Stibbs School due to a fire that meant children were forced to commute outside their community. Killick, Metz, Bowen, Rose Architects

Figure 3.28 The steel frame being deconstructed.

which was appointed to design the new building had also been the architects of the Cassiar Secondary School and was aware that the material from that school had been dismantled and was in storage. When it was apparent that the Roy Stibbs School reconstruction required a tight schedule, the architects, in discussion with the construction manager, suggested the reuse of steel from the Cassiar School. Once this suggestion was made, the new school building was designed to maximize reuse of available components.

The Cassiar School had a central two-storey section, with single-storey elements on either side housing the gymnasium and shop. The new building needed to reuse only the two-storey, steel braced central frame with composite floors as used in the old school with an amended interior layout to suit the elementary school's functional requirements and smaller side wings (Figure 3.29). Due to changes in layout, some alterations had to occur to the structure. Also, due to its location in Burnaby, the new school was required to withstand approximately double the seismic loads, but less than half the snow loads compared to Cassiar. Reuse of the components was maximized, although there were some components that had to be redesigned to meet the new seismic loading requirements. The structural characteristics of the steel were determined from the original construction documents and shop drawings and were easily revised where

Figure 3.29 The layout for the new school was changed.

necessary. Bracing had to be redesigned, old interior bracing was replaced with fewer new interior braced bays and additional external braced bays. This impacted the diaphragm design and connections between slab and beams. A new foundation was designed to provide resistance to overturning and the structural steel was modified to accommodate changes in load paths. Dormers in the original Roy Stibbs School that were not damaged by the fire were reworked into the new building. In the end, it is estimated that over 75% of steel for the Roy Stibbs School came from Cassiar.

The steel was inspected and damage from deconstruction and transport was identified by an independent materials testing consultant. A total of 466 open web steel joists were reused, most in the condition in which they arrived, needing only to be cleaned and touched up with primer. Others were later modified on site to work with the new structure. Some of the open web steel joists had damaged chords and joist seats that required grinding where the flange was cut or gouged. The flanges of beams that supported the joists required filing and grinding at joist seat locations. Fire proofing was mostly removed and the primer paint was generally in good condition.

One of the major challenges with reusing the structure at the new site was scheduling. With a short project timeline, organizing the transport, redesign, reworking and assembly of the components created scheduling difficulties. From an efficiency perspective, the contractor noted that the multiple handling necessary due to the deconstruction, transport, storage, further transport and then reconstruction raised the cost so that it was comparable to the cost of a new structure. However, it is often difficult to coordinate deconstruction and timely delivery to a new construction site, and the stockpile of steel ready for reuse was an important factor in the success of this project. The relatively easy alteration of the steel structure from one seismic zone to another demonstrates what can be achieved with an appropriate mindset and design team. This project showed the value of a ready stockpile of materials and information about its characteristics, which facilitated easy adaptation for the new use. Particularly for building types such as schools that have similar spaces and design objectives, reuse of components or whole buildings can become realistic.

Element	Source	Processing	Comments
Structure	Steel components from dismantled school	Deconstruction, and some remedial work Upgrade of seismic performance Some missing components needed to be replaced	Some joints needed torching to deconstruct Steel structure allowed a revised school layout Avoid multiple handling Avoid priming if steel is not to be exposed?

3.1.6 Hindmarsh Shire Council Corporate Offices – Old Anchors New

Architect:	k20 Architecture
Construction:	2014
Location:	Nhill, Vic., Australia
Floor area:	1 295 m^2 (14 000 sq. ft.)
Use:	Civic offices
Owner:	Hindmarsh Shire Council
Construction cost	AUS $4.5 million ($3 400/m^2)
Reuse material:	Existing building

Many existing office buildings from the mid-twentieth century are seen as dated, poor performing, unfashionable and, therefore, unwanted. Such buildings are often seen as a poor asset and are frequently demolished and replaced with little consideration for their potential or the value of the materials and components within them. Completed in 2014, the Hindmarsh Council's new office in Nhill, Vic., Australia (Figure 3.30) demonstrates the potential for reuse of an unloved 1960s building integrating it within a contemporary built form.

The remote rural setting (a 5-hour drive to the nearest major city) and harsh, desert like, climatic conditions were the starting point for a project, which focused on local resources as well as sustainable solutions. The starting point of the design was to

Figure 3.30 Hindmarsh Shire Council's new offices.

assess the quality and potential of the existing buildings on the site. These consisted of several buildings, including portable buildings and the council meeting room, in poor condition and not suitable for reuse. However, one component, a single-storey structure with concrete footings, concrete slab, a clear-span steel portal frame roof and brick walls, had potential to be reused (Figure 3.31). A survey indicated that the building was technically suitable for reuse and the architects assessed that its form could accommodate the office programme.

Although reuse was not a priority for the client, it recognized the potential benefits, which included possible phasing of the construction and cost savings, which meant that resources could be assigned to other sustainability features. Thus, k20 Architecture began to develop a strategy based around reusing the building and integrating the old and new into a unified whole. The existing block was seen as an anchor or the heart of the new design, and it became one of three components arranged around a unifying street or spine. This strategy allowed phasing of the project and meant that the new components could be kept largely separate from the old, so as not to increase difficulties of integration, undermine the existing foundations or place

Figure 3.31 The old office entrance.

additional structural loads on the old structure. In total, about 40% of the new building is formed by reusing the old building while the parts that were demolished were 80% recycled.

The new building comprises offices to accommodate 70 staff with expansion up to 100, and associated facilities such as community use spaces, multifunctional rooms, council chambers, offices for local services and meeting rooms. The building was also inspired by the town's importance as a hub of wheat production. Thus, the design of the new complex refers to the folded metal aesthetic of steel storage silos and agricultural sheds in the surrounding landscape. It uses a material palette of timber, steel and glass, which comes from the local agricultural context, and uses the craftsmanship of locally sourced steel and zinc finishes along the building's exterior.

The architectural strategy of maintaining a separation between old and new elements simplified the construction, as little structural alteration was required in the existing building. Nevertheless, the building needed other improvements to meet current codes and expectations. Energy modelling was used to assess what thermal characteristics the new envelope would require and the building was stripped back to its structure and reskinned, fitted with new insulation and glazing. Internally it was refurnished and new services were installed (Figure 3.32). A pragmatic approach was taken of keeping what worked well but replacing those elements that clearly were no longer suitable (Figure 3.34). In addition, the design team tried to create flexible spaces adaptable to future growth and changing needs of the client to extend the useful life of the building.

Aesthetically the old components were not lost in the new building and are clearly identified, but the entirety is unified by the spine that connects them and provides circulation space, and by a timber screen that connects the elevations aesthetically (Figure 3.33). The new parts of the building use a glulam timber primary structure to minimize the use of steel; local resources were used wherever possible to avoid bringing in materials from afar and to minimize embodied energy. A variety of other environmental features were included, such as earth tubes and underfloor ventilation plenums, thermal stacks, green walls, natural ventilation, passive solar design, low VOC materials and durable finishes for lower maintenance and longevity.

The project illustrates how a decision to retain parts of an old building can inspire a unique design solution and also open up opportunities for additional features to be included that would not be affordable otherwise. The architect recognized that clients can often have concerns about using old buildings – these can

Figure 3.32 The remodelled interior.

Figure 3.33 Exterior unifying timber screen.

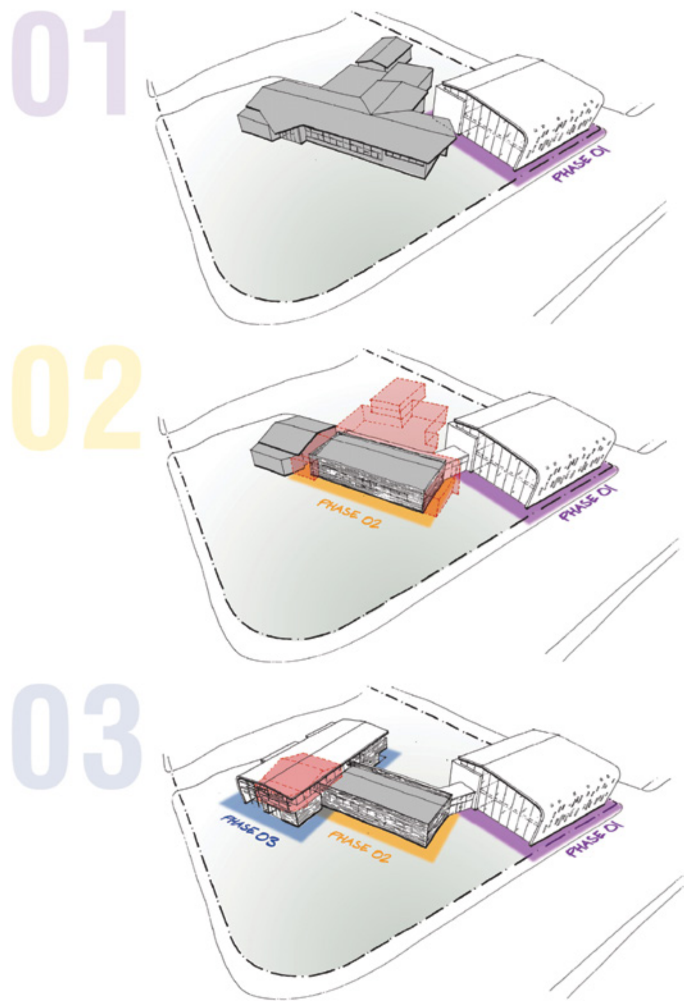

Figure 3.34 Axonometric of stages of renovation.

be for both practical and aesthetic reasons. If reuse requires significant compromise it is unlikely to happen, so a pragmatic approach is necessary. In this case some elements that were not well suited to the new building were recycled. The challenge is to consider how much to reuse – what is suitable for reuse? Clients need to have confidence in the outcome; reuse is often seen as second best and a compromise, but this does not have to be the case. Also, the aesthetics of many 1960 buildings are not attractive to clients today; the buildings often look tired, worn out and old fashioned. Architects need to highlight the potential of existing buildings to create solutions that have the quality and character that will satisfy their clients (Figure 3.35).

Figure 3.35 The new entrance area.

In heritage buildings this is understood but often the potential of more recent buildings is not appreciated and the value placed on them is often low. This project raises awareness of the need to consider the value of existing structures and provides an example of what can be achieved. At the same time it highlights the need to carefully align the reuse strategy with the client's needs and consider what makes sense and provides value to the client.

Element	Source	Processing	Comments
Structure	Portal frame structure of existing building	Re-cladding and new insulation was necessary to meet current codes	
	Existing foundations and floor slab		Avoided putting new structure close to the old to eliminate need for remedial work

3.2 REUSING WHAT IS AVAILABLE AT THE SITE

3.2.1 Ford Calumet Environmental Center – 'Form Follows Availability'

Architect:	Studio Gang
Construction:	Unbuilt, designed 2011
Location:	Hegewisch Marsh, Chicago, IL, USA
Floor area:	2 600 m^2 (28 000 sq. ft.)
Use:	Education and research facility
Owner:	City of Chicago Department of Environment and Public Building Commission
Certification:	Targeting LEED Platinum
Reused material:	Steel from the area, slag, glass bottles, bar stock and rebar.

What does a circular architecture look like in a post-industrial landscape with a rich manufacturing history and an abundance of available discarded materials? The currently unrealized project for the Ford Calumet Environmental Center (Figure 3.36) in Chicago by Studio Gang explores how the whole process of conception, realization and the final outcome of an architectural project changes when working with old materials. The proposal shows how a new type of architecture can emerge when embracing circular approaches and respecting ecological systems.

The building is intended to function as an education and visitors centre, allowing people to discover the industrial history and recent ecological revival of the Calumet region and also to facilitate research about the region's natural and industrial relevance. Its proposed location in Hegewisch Marsh is in a

Figure 3.36 Rendering of the south side of the Ford Calumet Environmental Center.

historic industrial region near Chicago, which was once the largest steel-producing region in the United States. The site is surrounded by a patchwork of industrial and natural habitats that demonstrate the importance and coexistence of industry and ecology in the area. Now the area has become an important resting stop for migratory birds and it is essential that the design protects the birds, which cannot see transparent materials like glass and are often hurt or killed following interactions with architecture that is not safe for birds.

The two contrasting aspects of the site – its industrial past and ecological revival – were the starting point for the project. The concept of a '*nest*', a home that is composed from abundant discarded materials gathered from nearby, was adopted as an inspiration for the project and as a way to integrate these ideas. A nest suggests a design embedded in its context, which simultaneously connects with its past and embodies the site's current and future role as a wildlife habitat. The building itself thus becomes both an exhibit of the complex and intertwined history of industry, environment and community and a learning tool as spaces are defined by an archive of locally salvaged components linking the design to this history. By starting with materials that are not off-the-shelf but locally salvaged and employed in creative new ways, the proposal introduces a fundamentally different paradigm for the project delivery process which profoundly alters the way a building is both conceived and made: '*form follows availability*'.[2] Thus, Studio Gang began by surveying the available discarded local materials, such as abandoned industrial structures, steel industry by-products (slag), waste rebar and steel components, offered on material exchange websites. These became the materials and inspiration to work with (Figure 3.37). Studio Gang liken this to the process of '*prospecting*' or searching for material deposits.[2] Next it researched and experimented with the available materials to shape the building.

From this process evolved a proposal with a structure of salvaged steel sections gathered from nearby yards and through local exchange websites. Since the size and specification of available salvaged steel is unpredictable, proposed elements can be seen as flexible '*placeholder*' elements that can be revised depending on material availability. Instead of a regular grid of identically sized columns, several steel pieces come together to form column bundles (Figure 3.38), which are designed to allow some variety of steel sizes depending on what is available at the time of construction. This allows for flexibility in the size and type of components used in each bundle, using diverse sizes of tube, wide-flange and pipe. The weld marks and fabricator's name on the old steel will reveal the wide diversity of the material as well as its origin. The columns are supported by piles at inclined angles.

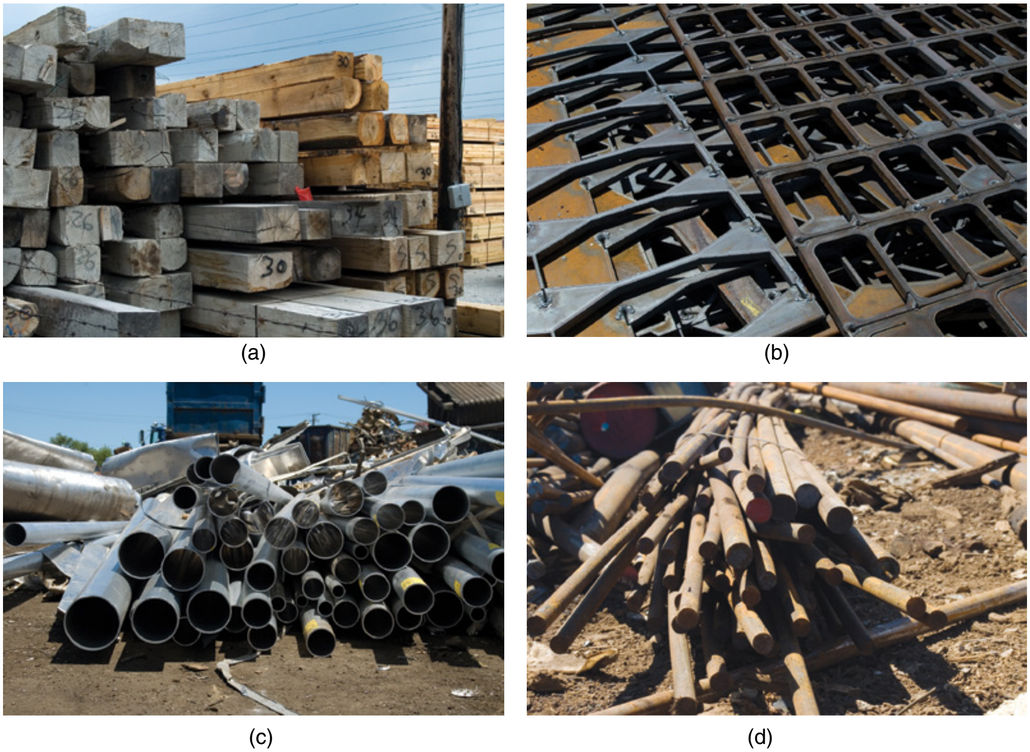

Figure 3.37 An inventory of salvaged material: (a) timber, (b) steel, (c) aluminium tube, and (d) steel reinforcement.

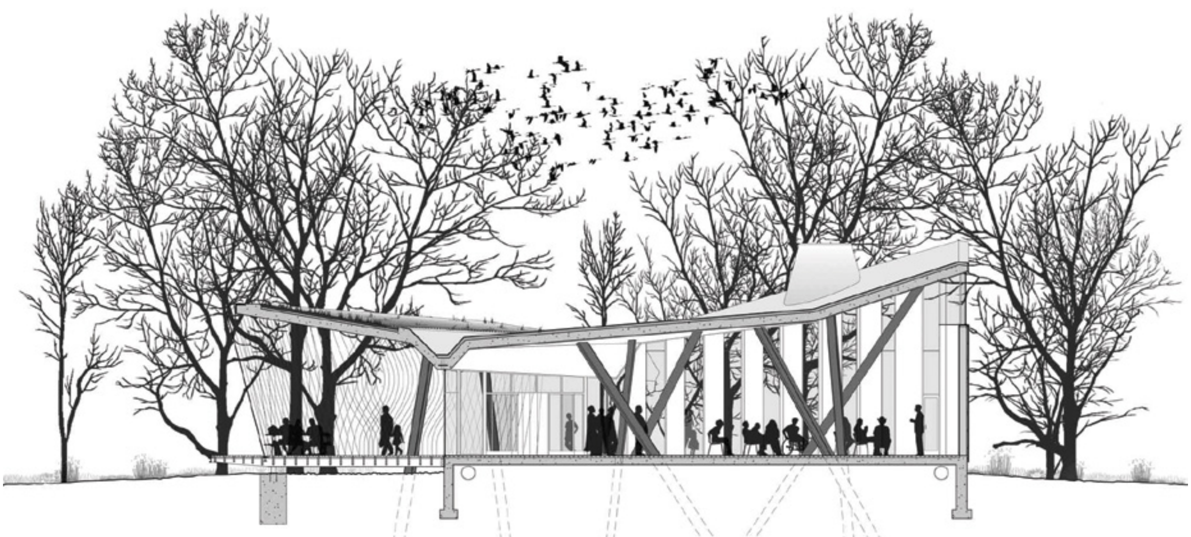

Figure 3.38 The building section.

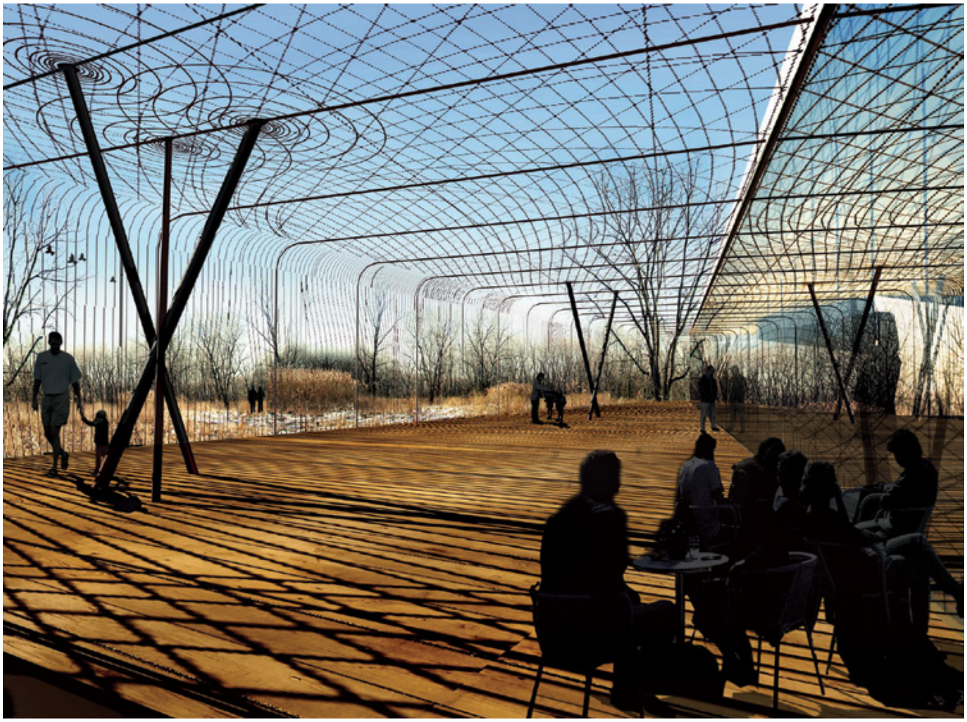

Figure 3.39 South porch with a steel mesh protecting the birds.

The south façade (Figure 3.39) was conceived as a lattice with a finer grain of smaller steel sizes to create a basket-like mesh wrapping the building's expansive exterior porch. Designed to use locally recovered rebar and bar stock, this mesh is intended to protect birds from collisions with glass they cannot see in this critical nesting spot and habitat. At the same time it will form an outdoor viewing area or bird-blind for visitors. The mesh will allow the building to function as a transparent pavilion in the industrial-natural landscape without killing the birds that people are coming to see. The use of local slag and broken bottles as aggregate in the terrazzo floors was investigated and local terrazzo suppliers helped to create test samples (Figure 3.40). The design team also wanted to use cottonwood trees removed from the site and, while it found that cottonwood has limited use as a building material, it was able to include the trees in the interior of the building as painted millwork. Working with wood reclamation companies, it identified wood staves from wine barrels as a potential cladding material and leftover punched metal scrap for site fencing and landscaping.

Ecological and circular approaches also guide other aspects of the proposal. The intended location of the building close to the existing road reduces site disturbance and minimizes the need for infrastructure access. Passive solar design measures will use solar energy and geothermal sources will minimize energy use. In addition, local timber scraps from nearby roads and a local sawmill will feed a biomass boiler, providing additional top-up heat in extreme winters. Rainwater will be collected for reuse in flushing toilets and all wastewater from the building will be cleaned on site using a living plant system. Ventilation will be aided by a high roof plane with work areas, exhibition space and an auditorium all connected through the tall space. A series of lower programme pods will enclose classrooms and service functions.

Figure 3.40 Test samples of terrazzo.

Although the building currently remains unbuilt, considerable thought has gone into the construction process, identifying potential material sources, anticipating procurement and material storage issues, and testing samples to ensure that the materials could be used as intended. The City of Chicago planning and building departments were consulted to smooth the process and anticipate any issues. The project hints at what it means to make architecture that embraces circular and ecological processes. It also highlights the experimental nature of working with used materials, anticipating what materials may be available, exploring their unique physical characteristics and inventing new ways of integrating them into buildings. Studio Gang does not see used materials as a straight replacement for new, but rather the materials' particular features offer unique solutions to be explored. It has likened this process to a cook who innovates with local produce at hand – the end product becomes unique and exciting, embedded in its place and history. However, the process departs significantly from traditional architectural practice and requires architects to work closely with other partners in an experimental way and become '*organizers of a set of chance circumstances, remaining flexible and open to an array of possibilities that only achieved their distinctive flavour when the building was finalized.*'[2]

Element	Source	Processing	Comments
Structure	Steel structural sections found nearby through local suppliers and web-based exchange sites		Designed in clusters to accommodate various profiles; weld marks are left to show the history of the material
South elevation screen	Waste rebar from the surrounding area	Tack welded together to create a lattice	
Terrazzo floor	Slag and broken bottles	Experiment with the material to develop test samples	Used as aggregate
Cladding	Redwood timber from wine barrels		Working with reclaimed timber industry

3.2.2 Hill End Eco-House

Architect:	Riddel Architecture (project architects Emma Scragg and David Gole)
Construction:	2008–2010
Location:	Brisbane, Australia
Floor area:	261 m^2 (2 800 sq. ft.)
Use:	Single family house
Reused material:	Timber framing, tongue and groove boarding, hoop pine flooring, hardwood weatherboard cladding, structural steel

Hill End Eco-house (Figure 3.41) in Brisbane, Australia, is a high-end private residence on a river front site that is constructed using many salvaged materials and components, including much of the house it replaced.[c] The new house was commissioned by a client who wanted a sustainable building that responded to the climate, employed passive design principles, maximized natural light, had appropriate landscaping and used resources readily available on the site. The existing 1930s timber-and-tin worker's cottage became the starting point for materials for the new project. As a heritage conservation based practice, Riddel Architecture would typically have attempted to conserve the existing house and add to it. This would exploit the embodied energy and carbon contained within the old house. Another alternative was to transport the whole existing house to another more suitable site, as is sometimes done in Queensland. In this case, however, the building was badly deteriorated and its layout neither used the potential of the site nor optimized passive heating and cooling. Thus, the house was dismantled, although at some cost penalty in additional handling and preparation, and its materials were largely reused in the construction of the new house that had a larger footprint. Architect Robert Riddel explained that '*the idea of deconstructing a previous property to create something new was really exciting to us. We are pleased with how the house manages to fuse beauty with eco-facilities*'. The challenge was to achieve all these aims for the same cost per m^2 as a mainstream high-end house.

The process started with meticulous deconstruction of the existing house; this resulted in about 95% of the house being recovered, approximately 80% of which was reused in the new building. The hardwood timber framing of the old house was de-nailed, neatly stockpiled and stored for protection from termites, rain and high tides in a shack constructed of salvaged, metal roofing and timber. The concrete foundations,

Figure 3.41 Hill End Eco-house.

brick infill walls and concrete slabs were sent away for crushing for reuse as gravel or as aggregate in new concrete. Hardwood and softwood flooring and timber tongue and groove wall finishes were salvaged for use as linings, cabinetry and flooring in the new building. The construction team had the creative idea of cutting the original bathroom floor into manageable sizes to incorporate into the new landscaping to fit between larger pavers. Some of the unwanted components were left at the kerbside and found new lives elsewhere in the local community. Recyclable elements from demolition that were not needed in the new house were collected and sent off-site. Windows and doors were carefully removed and sent to a recycling yard, with some of the doors retained for possible reuse in the new house. One trailer load of non-reusable metal was taken to a recycler. Only two 6 m^3 (210 cu. ft.) skips filled with non-recyclable/non-reusable materials were taken to landfill.

[c] see http://hillendeco.blogspot.co.uk

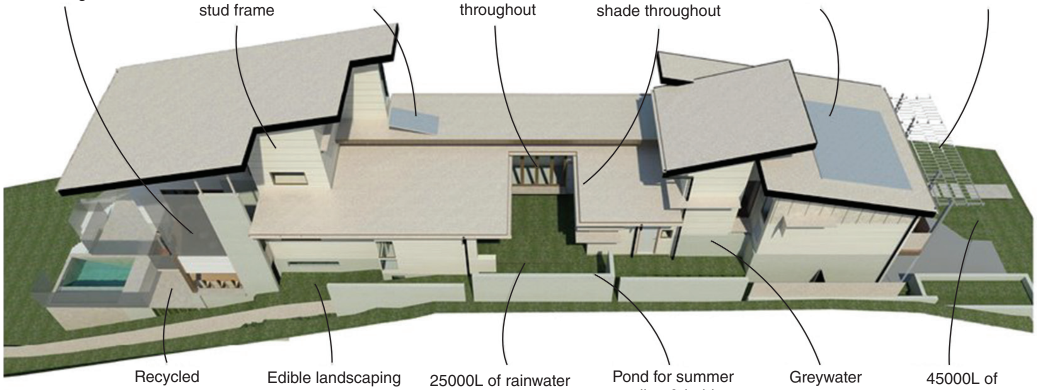

Figure 3.42 Schematic of the Hill End Eco-house.

Figure 3.43 Reused framing.

The team faced some challenging decisions about how best to dispose of some items – short, damaged lengths of timber of various sizes are difficult to reuse as a building material. The lead paint on them may be a hazard for other disposal methods, such as when used as a fuel source or in landfill. In the end they were left on the street frontage with a 'take me' sign for creative folk to build small things.

The new house (Figure 3.42) was designed to maximize reuse of the stockpiled materials and, in addition, reused materials from elsewhere were added wherever possible. The structure, including wall, floor and roof framing, was created from 100% reused timber (Figure 3.43), either hardwood framing from the old house or sourced locally by the contractor Rob Peagram, who was an enthusiastic supporter of maximizing reuse in the project. Using hardwood meant considerably more work to drill and assemble the framing but provided more protection from termites. The roof was designed to use laminated hardwood beams that were originally used for the weightlifting floor of the 1982 Brisbane Commonwealth games. After the games a lot of leftover building materials were put into storage. Eventually they were disposed of and Peagram bought a container load, using them over the years whenever appropriate, as in this project (Figure 3.44). The building department was happy to accept use of the salvaged materials as long as the project engineer approved the material. The cladding was

Figure 3.44 Laminated beams came from the Commonwealth games.

created from a mixture of recycled hardwood weatherboard sourced by the contractor and low-maintenance fibre cement sheet.

Design features throughout the new house were carefully created using a pallet of available salvaged materials. For example, a rafter from the original house was transformed into a handrail and a carefully composed screen of reclaimed pine rafters forms a balustrade (Figure 3.45). Interior wall and

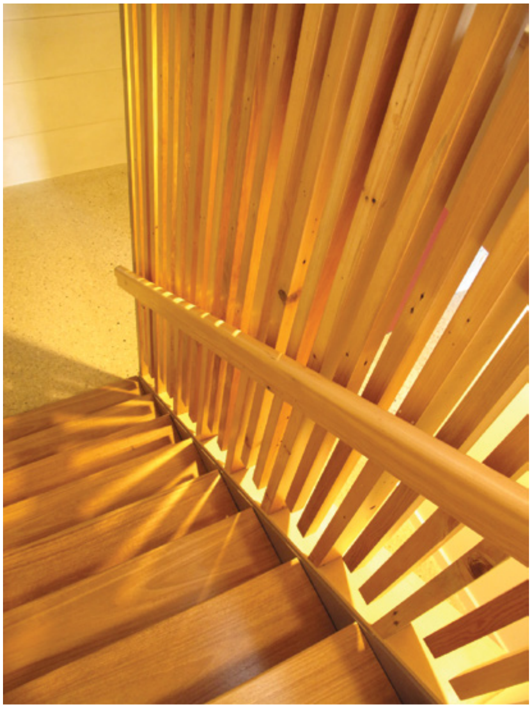

Figure 3.45 Hoop pine was used for the stair balustrade.

ceiling linings are a mixture of 95% recycled content plasterboard and the salvaged tongue-and-groove pine boarding (Figure 3.46). This pine was also used for shelves and cabinetry. Flooring is polished concrete with fly ash and reactive magnesium (which absorbs CO_2 rather than releasing it during curing), and FSC certified eucalyptus. Where appropriate, salvaged materials from the old house were used for landscaping, including palings to garden fences which use the decking, framing and chamferboard cladding, and paving that used salvaged concrete and tiles.

Additional materials, fixtures and finishes were locally sourced and went through a rigorous assessment of their sustainability credentials (Figure 3.47). This was based on recycled content, low toxicity, locally made (where possible) and low embodied energy. Examples include recycled polyester bulk insulation (min 80% recycled) and floor tiles with 70% post-industrial waste. Appliances were sourced to support local industry and reduce energy-miles. Also, future deconstruction was considered by avoiding adhesives, such as not gluing flooring as is typically done.

The construction process was longer than usual due to the careful deconstruction, and the architects estimate that there were significant additional costs due to the reuse strategy. But, conversely, the outcome is a house of unique character with significant environmental benefits. In total the new house has an estimated reused and recycled content of about 80%. But this has not hampered its performance, which achieved six-star energy rating in the Australian Nationwide House Energy Rating Scheme (NatHERS). It provides its own energy and water needs through solar hot water and PV panels and rainwater collection and storage. The project demonstrates that careful thought, design and construction using salvaged materials and components can create high performance buildings of character that are aesthetically appealing to the mainstream, and are able to achieve demanding sustainability targets.

Figure 3.46 Interior linings were salvaged tongue-and-groove boarding.

Figure 3.47 Interiors feature many reused components and recycled content concrete floors.

Element	Source	Processing	Comments
Structural frame	Timber from old deconstructed house on the site	Careful deconstruction, de-nailing and storage was required	Careful storage is required
	Timber from other local sites	Requires knowledge of local opportunities for picking up materials	Painted timber can be a problem if old lead paint is used
	Laminated beams originally used for the Brisbane Commonwealth games		This materials had been in storage for many years.
Internal finish	Salvaged tongue-and-groove pine boarding	Timber flooring from old house on the site was refabricated as wall lining and furnishings	Design features in the new house were created from salvaged materials
Paving	Waste concrete and tiles from old house	Careful deconstruction to minimize damage to tiles	Design team looked for creative opportunities to find uses for these materials
Fencing	Decking, framing and chamferboard cladding from the original house		Interesting designs were created using available materials

3.2.3 Tysons Living Learning Centre[d]

Architect:	Hellmuth + Bicknese Architects
Construction:	2009
Location:	Eureka, MO, USA
Floor area:	275 m² (2 968 sq. ft.)
Use:	Education and research centre
Owner:	Tyson Research Center, Washington University in St Louis
Construction cost:	$1 597 000 ($5 800/m²; $538/sq. ft.)
Reused material:	Various timber species harvested at the site for siding, flooring, interior trim: sanitary appliances, rigid board insulation, light fixtures, doors.
Certification:	Living Building Challenge
Key lessons:	A more flexible design–bid–build process may be more suited to circular projects.

Figure 3.48 Tyson Living Learning Centre is located in a forested setting.

[d] Prepared with assistance from Sandra Wojtecki.

The work of Hellmuth + Bicknese Architects, which designed the Tyson Living Learning Centre in Eureka, MO (Figure 3.48), is guided by an ecological interpretation of the modernist principle of form follows function. For them, biological processes are the ultimate functional paradigm, as the cyclical patterns of growth, decay and death tie us back to the nascent pattern of renewal that exists in nature. As architects, they see themselves as systems-makers who facilitate this process, which can lead to a new vernacular that is a true tie back to the local environment and ecosystem. In this project, they adopted a very hands-on approach using the availability of salvaged timber from the surrounding forest as inspiration for the building and to satisfy the requirements of the Living Building Challenge (LBC), which includes a very demanding set of environmental performance requirements[e].

The project started when Washington University's Tyson Research Center, located 30 km (20 miles) from St Louis, identified the need for an environmental field centre building that could also function as an educational facility. Early in the process a charrette was conducted with the design team, client and the biological field station staff who would be the future occupants. From this emerged the idea that the building itself should become integrated with the ecological research functions that would be housed within. Using the requirements of the LBC became a useful tool to help ensure that demanding goals would be achieved and recognized. The 'living' aspect of the challenge was a key tie to the idea of using biological processes and materials to guide design decisions.

The overall strategy for materials selection was to minimize ecological impact; this suggested looking close to home for possible resources, as this was sympathetic with the centre's broader research and teaching mission of ecosystem sustainability. Opportunities for material reuse are very place sensitive and rural locations provide very different prospects to urban locations. In particular, waste materials that occur in rural areas are more likely to be related to the local agricultural and land use industries. The process started with exploring the timber found within the biological field station's 2000 acre forest. The architects recognized that to achieve the project's goals would require them to have more hands-on involvement in selection of materials and components. They had to allow time to search out materials and components, and decide on processes in a way that is not typical for architects. They worked closely with Tysons' director Kevin Smith and his staff, forester Travis Mohrman and woodworker Scott Wunder to search the nearly forest for suitable wood that could be salvaged into the building's cladding and interior finishes. One of Tyson's research projects is restoration

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[e] LBC is a demanding set of requirements, including net zero energy and water use, a healthy indoor and local environment and careful sourcing and selection of materials to reduce toxicity as well as decrease waste generated through transport and construction. See http://living-future.org/lbc.

ecology and, in this case, eastern red cedar and hard maple trees were slated to be removed for experimental restoration of an Ozark Glade complex on the southwest part of the property. Appropriate trees to remove were carefully chosen with minimal impact to the surrounding forest, preferably close to roads. In addition, during the design phase, a particularly heavy rainstorm passed through the area, making available another layer of storm-downed trees, including oak, walnut and ash. Instead of cutting down healthy trees, the architects synchronized their material opportunities with what the forest had already rejected.

Wunder was hired (during the design phase) to fell the trees, skid the logs out of the woods, rough saw and then shape and kiln dry the lumber (Figures 3.49, 3.50 and 3.51). He also installed and finished the floor and built the casework (Figure 3.52). After assessing available quantities and wood characteristics, eastern red cedar was chosen for the exterior siding and trim with hard maple soffits, hard maple for flooring and casework, walnut for countertop and floor accents, white ash, red oak and hickory for both additional flooring as well as window trim and baseboards, and white oak for exterior decking.

Looking beyond the site to apply circular principles the architects pursued their ties to Washington University to obtain other components, including sinks and bathroom accessories that had been removed and stored from previous university washroom renovations. Also, working with Planet Reuse, a local business specializing in reclaimed building materials, the team was able to source salvaged rigid board insulation and a fire extinguisher cabinet from a nearby construction project. They even used Craigslist to find a collector of salvaged materials who provided them with some old schoolhouse light fixtures (Figure 3.53). A local sculptor and artist, Bob Cassilly, supplied interior wood doors.

To explore the economic implication of using salvaged materials, the team considered the cost ramifications of the different materials it proposed. Overall it found little financial impact, but costs were apportioned in a different way to a traditional project. Although the wood salvaged from the forest was free, by the time the team accounted for all of the labour from required removal, processing and milling, a similar cost per board-foot was achieved compared with FSC material. Similarly, many of the salvaged building components provided an initial cost savings but required some custom work to fit them into the desired locations. Conversely, sourcing the rigid board insulation from a nearby construction site allowed it to be shipped within three days, avoiding significant construction delays had it needed to be ordered from the manufacturers.

However, construction cost is only one measure of performance and does not begin to account for the many tangible benefits

Figure 3.49 The timber was locally harvested.

Figure 3.50 Processing of timber occurred nearby by local tradespersons.

Figure 3.51 The cedar was used for cladding for the building.

Figure 3.52 The flooring was from maple and walnut trees harvested nearby.

Figure 3.53 The interior included many reused items.

that the building creates and the higher levels of performance that it achieves. Beyond circular materials selection, other additional operational aspects of the building play into the same idea of circular biological processes. Composting toilets are used instead of traditional ones, supplying waste back into the composition of the soil. A rainwater harvesting system provides the potable water on site without the use of chemicals, and greywater from the building is stored and then treated in an infiltration garden. A subsequent analysis of the building showed that integrating these types of living systems into the project effectively eliminated waste leaving the site. In addition, the energy needed for the building is collected through passive solar design strategies (Figure 3.54) and electrical energy from photovoltaic panels on the roof. All of these systems effectively salvage resources on a continuous basis. Local benefit also comes from the use of local skills and craftsmen stimulating the local economy. Lastly, there is a significant educational component, both for the researchers, students and the visitors that come to learn and experience the building's sustainable features.

Complying with the material category of the LBC was very challenging, particularly as it was one of the first projects certified. Finding compliant materials placed considerable additional workload on the architects and required close supervision of the contractor. Although the materials section of the LBC was used as

Figure 3.54 The building features passive solar design strategies to minimize energy use.

a guide and baseline, this project goes well beyond the reuse requirements of the LBC, and the team engaged with the LBC representatives about the opportunities it found, negotiating how these could fit into the standardized set of prerequisites. Salvaged products can help with this process but require some flexibility on the part of the owner, contractor and design team. On completing the project the team suggested that a more flexible design–bid–build process may be more suited to such projects; maximum flexibility is needed, both during design to source available materials as well as during construction, when opportunities may occur for substituting materials. This makes accommodating the stringent performance requirements of the LBC more achievable.

Element	Source	Processing	Comments
External timber cladding	Invasive eastern red cedar + hard maple from TRC forest	Felled and processed by local craftsmen	
Internal timber floor finishes and casework	Invasive hard maple and storm-downed white ash, hickory and red oak from TRC forest	Felled, processed and installed by local craftsmen	
Countertop	Storm-downed walnut from TRC forest	Sawn, processed and installed by local craftsmen	
Window trim and baseboards	Invasive eastern red cedar and storm-downed red oak from TRC forest	Felled, processed and installed by local craftsmen	
Exterior decking	Storm-downed white oak from TRC forest	Sawn and processed by local craftsmen	

3.2.4 Parkwood Residences – Reuse of an Old Steel Frame[f]

Architect:	Core Architects Incorporated
Construction:	2006
Location:	Oshawa, ON, Canada
Floor area:	8 900 m^2 (96 000 sq. ft.)
Use:	Residential – 120 apartment units with associated car parking
Owner:	Atria Developments Incorporated
Construction cost:	CAN $1 300/$m^2$ ($120/sq. ft.) including demolition
Reused material:	In situ steel frame of an office building.

Reuse of parts of a building on the same site can take many forms. Adaptive reuse of a whole building is often preferred when a building can largely fulfil its new functions and limited changes are required. In other cases buildings are deconstructed and the components can be used for a new building on the same site. In the case of Parkwood Residences in an old urban neighbourhood in Oshawa, ON, something in between these two occurred. The entire steel frames of a pair of existing office buildings were used in situ for a new purpose. Deconstruction occurred down to the steel frame (Figure 3.55), and even some parts of this were removed, while in other areas the structure was extended with additional framing (Figure 3.56). This is an interesting example where the design team initially considered a full demolition but on close inspection was able to create new buildings without compromising spatial quality using the existing structural framing and floor slabs while removing most of the rest of the old building.

Figure 3.55 The existing building was stripped back to the steel frame.

[f] Based on research carried out by Carmela Sergio for www.reuse-steel.org.

Figure 3.56 Additional steel framing was added.

The site consisted of two government-owned office buildings constructed in 1970 that had been abandoned for the previous ten years and were suffering from neglect. The municipal authorities were keen to rejuvenate the area and Atria Developments Inc, a development company experienced in converting urban industrial buildings into residential lofts, identified the potential of these buildings. Working with Core Architects, which had familiarity in adaptive reuse projects, it developed a proposal for conversion of the buildings to residential use.

Due to the limited space in this tight urban site, demolition of the existing buildings would have been awkward and expensive. Thus, several other possibilities for redevelopment were considered. Initially, the design team inspected the old drawings from the time the building was constructed. However, these proved inaccurate and inconsistent with the existing building, leading to concerns about their usefulness. Also, original drawings were available only for one of the buildings. A new survey was required to ensure that accurate data were available. This showed that the structure had the flexibility to

provide adequate framing for residential units with high quality spaces. The 3.6 m (12 ft.) floor-to-floor heights permitted generous room heights and allowed for a variety of residential configurations. After the interior and exterior finishes were stripped back from the structure, including removal of structural fire proofing, the existing steel structure was inspected by the engineer and declared to be in good condition and suitable for reuse. All of the steel beams and composite steel floor decks could be kept.

It was found that one of the old buildings was too wide to be suitable for a double-loaded corridor arrangement and still provide sufficient daylight for the residential spaces. Two structural bays were removed, one from each side, to make the building more suitable for a residential layout and to accommodate terraces and balconies. However, owing to the lower floor loadings in residential buildings, the existing frame of this building could accommodate additional loads. Thus, two additional floors were added (making it six storeys). The two new levels consist of a steel structure replicating the bay sizes of the structure below (Figure 3.57). Since the old roof became a

Figure 3.57 Two floors were added to part of the building.

residential floor, the old slab was removed, including the metal deck and open web joists, and a stronger composite floor slab was added, which can accommodate the higher loads of a floor. Parking was relocated to the ground and second floors. This required an additional 150 mm of in situ reinforced concrete to strengthen the floor for the additional parking loads. The structural bay width of approximately 8.5 × 8.0 m allowed for three parking spaces within each bay and accommodated an appropriate layout for the car parking area with generous aisle space. Due to the additional floors that were added, the foundations of eight columns were strengthened to deal with the extra loads (Figure 3.58). This required excavation around the column pad footing and the addition of a wider concrete pad. Such work needs to be carefully planned, as access for machinery in an existing building is limited and smaller equipment may have to be used.

The second building, originally a 10-storey office tower, required only minor changes to the structure to convert it entirely into residential accommodation with basement storage.

Since these buildings were originally designed for office floor loadings, which are higher than residential floor loadings in building codes, reinforcing the floors was not generally necessary (except in the parking areas). However, to satisfy new requirements for progressive collapse and seismic resistance, the original structure had to undergo some minor alterations. These included stiffening the column to beam junctions to become moment connections, stiffening of some members by welding

Figure 3.58 Foundations of some columns were strengthened.

additional steel plate stiffeners in appropriate locations and the addition of stiffening across the bottom cord of the open web steel joists (Figure 3.59). This was all carried out on site with little difficulty. Since the fireproofing for the steel had to be removed, new fireproofing encased in drywall was installed.

The structure was encased with a new wall façade and the generous floor-to-ceiling height provided space for services. The existing vertical circulation could be reused, although one existing elevator shaft was no longer required and was removed.

The following key issues that affect structural frame reuse were identified from this project:

- In tight urban sites, avoiding demolition offers a variety of benefits that can be readily realized in many existing buildings.
- Reuse rather than new build does not necessarily require compromise on the number of residential units provided on the site.
- Flexible design approaches help to maximize the benefits of existing structures. It is important for the design team to remain open to changes during construction and to accept that decisions and details may need to be reviewed as issues arise on site to a greater extent than with new build.
- Good quality data on the existing structure are important. Old drawings need to be checked for accuracy. An understanding of the construction practices of the time of the original construction is also helpful.
- Structural steel frames can be readily strengthened and adapted at low cost.

Figure 3.59 Minor steelwork was necessary to upgrade the seismic performance.

The cost of the completed project (Figure 3.60) compares favourably with a new build. It has been estimated that this project generated a saving of about 10–15% from reusing the structural frame and elevators, including remedial measures necessary to ensure the suitability of the frame for its new use. This suggests that the approach taken is an appropriate model for other neglected steel-frame buildings no longer suited for their intended use.

Element	Source	Processing	Comments
Structure	Steel frame on the site	Some strengthening to meet new seismic codes was required; new fire proofing	
	Composite floors on the site		
Elevator	Existing elevator on the site	Some minor modifications were required	

Figure 3.60 The completed part of the building.

3.3 REUSING CONSTRUCTION MATERIALS FROM ELSEWHERE

3.3.1 Headquarters of the European Council and Council of the European Union[9]

Designers:	Philippe Samyn and Partners architects & engineers (lead design partner), Studio Valle Progettazioni architects, Buro Happold Ltd engineers
Construction:	2008–2015
Location:	Brussels, Belgium
Floor Area:	53 815 m^2 (579 000 sq. ft.)
Use:	Offices
Owner:	European Council
Reuse material:	Approximately 3 000 recycled oak window frames with single glazing panels form the outer layer of the double skin façade.

The expected efficiency and performance of building assemblies and systems are continually increasing, a necessary evolution to keep up with today's imperative of reducing energy. As a result of this, the components that make up the assemblies and systems that no longer perform up to par, either through deterioration or simply by their outdated technologies, are often discarded. When upgrading is not an option, landfills are typically the final destination. The design for the Headquarters of the European Union (EU) challenged this conventional practice, anticipating the upgrade of window systems across Europe and incorporating the old windows into the design of its new façade.

This project (Figure 3.61) arose due to the need to expand the facilities of the Headquarters of the European Union, previously operating out of the Justus Lipsius building in downtown Brussels. In addition, a site was needed to host future summits that could accommodate meetings between the 28 countries of the European Union. The Belgian state offered a portion of the site of the historic Residence Palace, where the development could benefit from the existing building. This original structure of luxury flats built in the 1920s had already been adapted and expanded several times during the second part of the twentieth century into government offices. The proposal was to develop these further to include the necessary functions for the European Union, including conference rooms, press rooms, ceremonial rooms, offices and parking.

[9] Prepared with assistance from Sandra Wojtecki and with information supplied by Philippe Samyn & Partners.

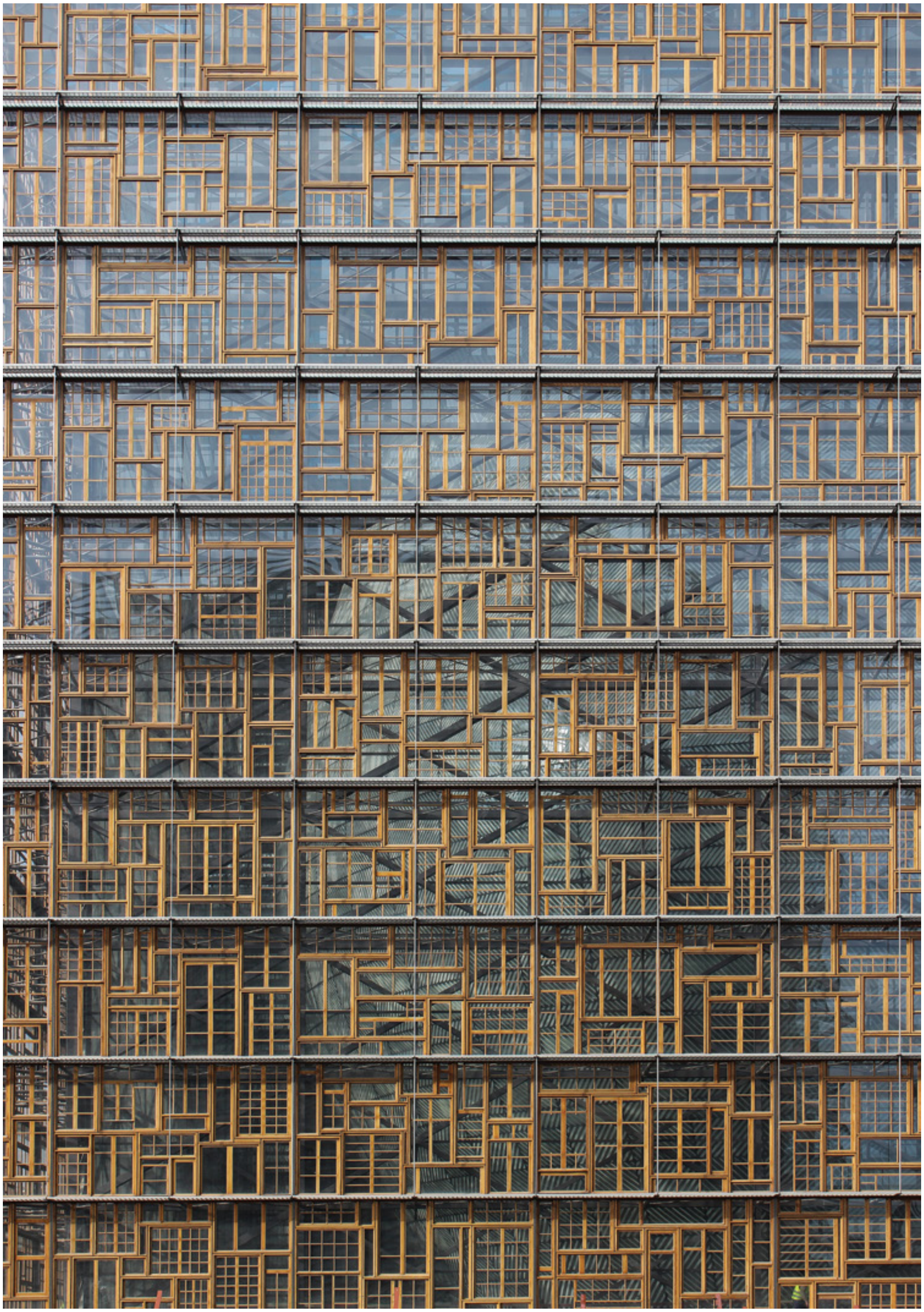


Figure 3.61 The façade of the headquarters of the European Council and Council of the European Union.

As a result of a design competition, in 2005 Philippe Samyn and Partners architects & engineers (lead design partner), Studio Valle Progettazioni architects and Buro Happold Limited engineers were awarded the project. Their proposal was to extend the building on the north-east side with two new transparent facades to transform its current L-shape into a cube. This created an atrium that forms the principal entrance and provides a dramatic space to suspend meeting pods. The transparent rectilinear structure embraced the competitions objectives to create an iconic representation of the political and symbolic values of the European Union's organization. One of the key messages the European Union wanted to embrace in the building was the organization's dedication to sustainable development. This applies both to the organization itself and also to the wider concept of a sustainable society which it serves.

The new double-skin façade with an outer skin composed of a patchwork of reused oak windows was a feature of the team's original proposal, demonstrating in a literal and very visual manner that sustainable practices could be an integral part of the EU's agenda. Oak window frame assemblies often with single glazing had been used in the past in various European countries and they were often being upgraded to higher efficiency windows. Instead of serving as the primary façade, which such windows were no longer suited for, in this building they became the outer layer of the building's double skin façade, serving as the first thermal and acoustic barrier before the higher efficiency glazing behind, and as the highly visible, external elevation.

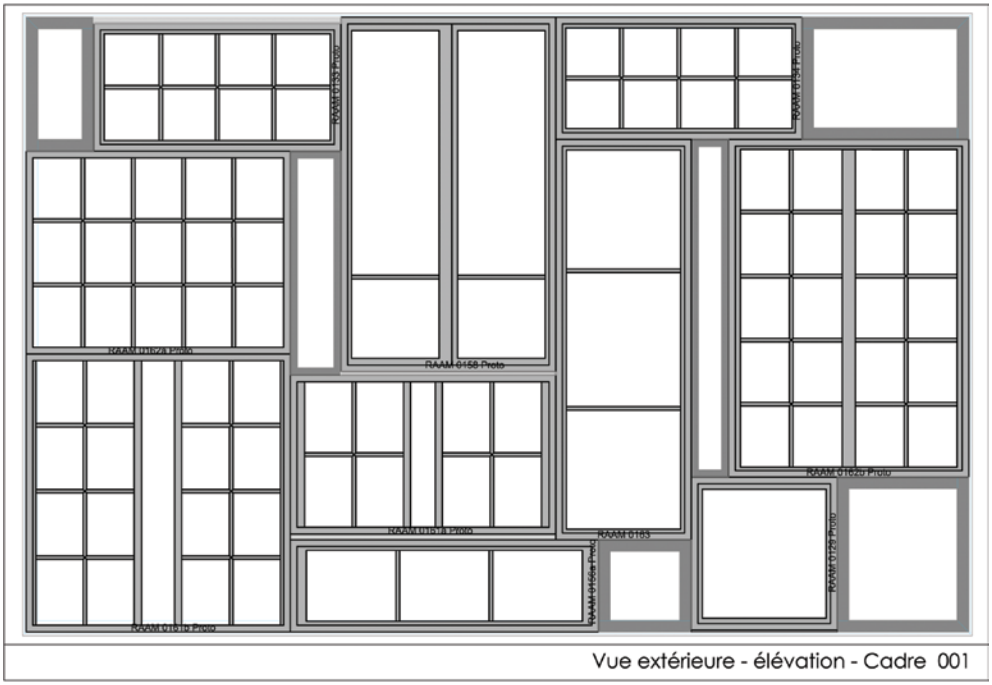
Having explored this idea in a former project, Philippe Samyn and Partners knew that there was a large supply available of recycled window frames. Because of this its initial competition proposal was a fairly accurate depiction of the final design. Collection of the windows was done by Antiekbouw, a company in Belgium that specializes in recovering and collecting historic materials. They already had a large collection in stock and were able to source further windows, primarily from Belgium and nearby countries such as France, Germany, The Netherlands, Italy and Spain. Although it is not known how long ago many of the windows were taken out of their original structures, all materials were checked for quality and durability.

One of the main design challenges was to stitch the various window dimensions into a coherent patchwork, maximizing a configuration efficiency that would also be visually appealing. The first task was to determine a module dimension for the

structural framework that could hold the various window frames together. A steel-framed module was used to enclose a patchwork of windows and serve as the connection element to the other units. In addition, these modules could help with prefabrication off-site, enabling a more efficient construction process (Figure 3.63). One module was determined to be 5.4 m (17′ 8″) wide by 3.54 m (11′ 7″) high, based on the floor-to-floor height dimension of the original Residence Palace building. This created a perceptible harmony when looking at the relationship of the addition to the original structure.

In order to efficiently fit the various window sizes into the module, a mathematical formula was created that would ensure visual coherence. The formula divides the 5.4 m (17′ 8″) width of the module into 2, 3, 5, 7 and 11 equal parts. The formula is also used for horizontal lines, creating 2, 3, 5, and 7 equal parts. The result is a grid into which the windows can be fitted, which is also multiplied by a tolerance factor of 1.02 and 0.98, based upon a theory by H. van der Laan that 2% variances are imperceptible to the eye. These parameters serve as the organizing framework, with enough rigidity to visually unite the design, yet enough flexibility to accommodate most window sizes (Figure 3.62). This coherence is also helped by the fact that the window frames often share many standardized dimensions. Once the windows were collected and measured, the layout was finalized within the framework as efficiently as possible, and gaps were filled with small wood panels.

Several durability and aesthetic issues also had to be addressed. Each window frame was cleaned, sanded and given a finish coating to unite their tones visually as well as serve as a protective barrier against moisture. At each module height, a horizontal overhang extending 60 mm (2.4″) was designed as a drip edge to protect rainwater from running along the surfaces below (Figure 3.64). In addition, each window frame was fitted in with new glass panels, as the old glass was no longer suitable, and, in some cases, additional mechanical fixing devices were added onto panels that were larger than 1 m^2 (11 sq. ft.) to comply with local codes. For future upkeep, the façade is also placed 2.7m (9 ft.) away from the inner layer to allow access for maintenance personnel. Altogether, there are 187 full steel framed modules on the façade, and 31 half modules at the corners and ends. Within the modules, the patchworks comprises roughly three thousand recycled window frames, with a surface area of 3 928 m^2 (42 250 sq. ft.).



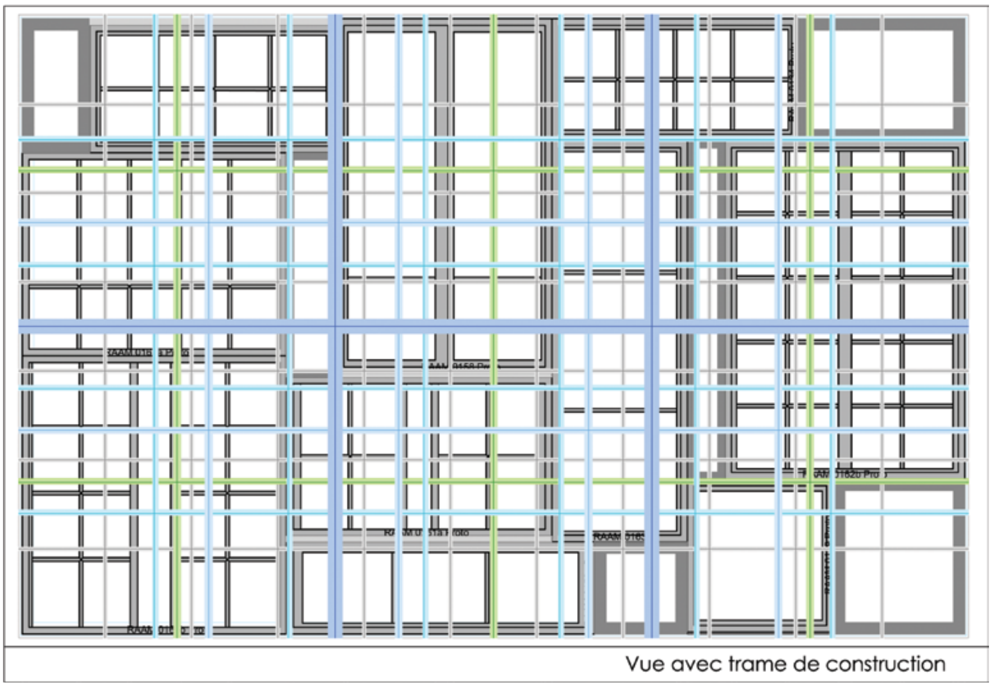


Figure 3.62 The geometry of the façade was carefully worked out.

Figure 3.63 Installation of the window panels.

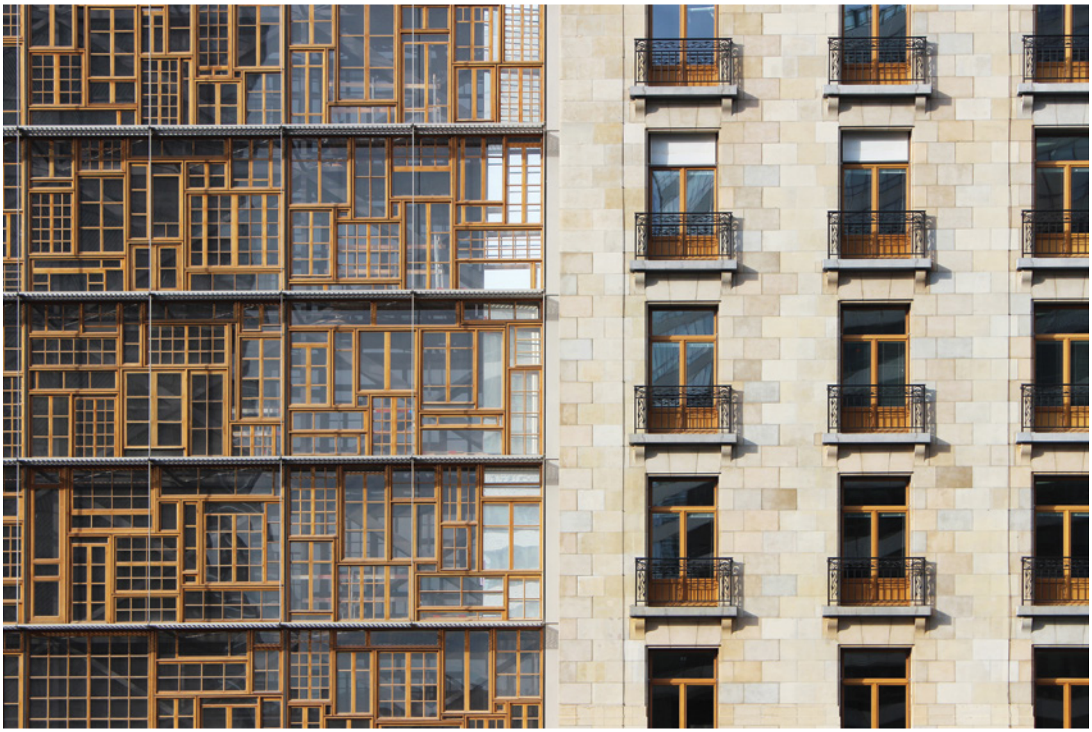


Figure 3.64 The new façade against the old.

The project is intended to be a declaration of the European Union's intent to be a leader in sustainable design, but at the same time to conserve resources and recognize the value of its past both from a cultural and material perspective (Figure 3.65).

Figure 3.65 The completed Headquarters of the European Council and Council of the European Union building.

It explores the idea of future change in building performance and what can be done with products that no longer perform to current industry standards. Old windows are often seen as unsuitable for reuse due to improved performance of modern glazing. But oak is a very durable material and oak window frames can last many years. Their use in a double-skin façade, where their low thermal performance can be compensated for by the second glass layer, is a creative use of this valuable resource that can be repeated elsewhere.

Element	Source	Processing	Comments
Facade	Timber windows from various locations across EU	Each window frame was cleaned, sanded and given a finish coating to unite their tones visually and provide protection against moisture	The designers had to stitch the various window dimensions into a coherent and visually appealing patchwork

3.3.2 La Cuisine, Winnipeg Folk Festival

Architect:	Monteyne Architecture Works
Project manager:	Gerry Humphreys
Construction:	2011
Location:	Birds Hill Park, MB, Canada
Floor area:	650 m^2 (7 000 sq. ft.)
Use:	Reception, kitchen and storage
Owner:	Winnipeg Folk Festival
Construction cost:	CAN $420 000 ($650/m^2)
Reused material:	Structural steel, steel cladding, timber framing, cedar hydro poles, flooring.

The environmental policy developed by organizers of the Winnipeg Folk Festival identifies minimizing waste and promoting environmentally responsible construction among its goals. This is particularly relevant as the festival is located in a provincial park outside of Winnipeg, MB, for only for five days every July. Their aim was to create facilities that would have the minimum possible ecological footprint and that could be disassembled and removed if required. They encouraged the designers working for them to look at alternative ways of creating buildings and to explore the use of reclaimed and salvaged materials, while maintaining high design standards. As a result, they embarked on a construction programme of several interesting buildings where the final form, structure and detail of the building was inspired or at least influenced by the available salvaged and locally available materials.

Completed in 2011, La Cuisine (Figure 3.66) is perhaps the most interesting of these buildings. The design team seized the opportunity for material reuse throughout. Designed by Monteyne Architecture Works, it is a 650 m^2 (7 000 sq. ft.) building used for the preparation and serving of 10 000 meals/day to performers and volunteers during the festival. During the remainder of the year, the building is used as a secure, weather-protected storage and drying facility for the festival's massive tents, requiring a 7.5m (25 ft.) high space. The budget was a low $650/m^2 ($60/sq. ft.) maximum.

The building does not need to achieve the thermal performance standards of most buildings due to its pattern of use, but it needs to be flexible. Thus, no insulation or mechanical HVAC system is installed. However, during the brief but intensive use as a kitchen throughout the festival the building needs passive ventilation, which is achieved by the canted and tall open space. It also needs to be open and easily accessed by many users, serving as a greeting space for arriving visitors and performers and as a general backstage hangout space. It also includes a

Figure 3.66 La Cuisine building at the Winnipeg Folk Festival.

public veranda that functions as a bus and transport drop-off area. For the remainder of the year sliding walls shut down the sides for weather protection and security.

A key part of the success of the project was involvement of Gerry Humphreys, a project manager with experience of reusing materials, working closely with the design team (see section 5.2). The process began with the architects developing some initial ideas on form and shape. At the same time, the project manager began to search for appropriate materials and came across a group of old, pre-engineered, steel-framed industrial buildings due to be demolished in Winnipeg (Figure 3.67). These were inspected prior to demolition and found to contain appropriate steel components that could be used for the structural frames and wall and roof supports, as well as providing miscellaneous materials for the new building. The steel was purchased for less than 10% of the equivalent new cost and the project manager organized its dismantling and transport directly to the site of the new building (saving on storage and double handling costs). The space to stockpile materials and refabricate them on site was a significant benefit.

With the structural material identified, the design team considered alternative options for the form and structure to

Figure 3.67 Deconstruction of a steel-framed building nearby provided structural material for the new building.

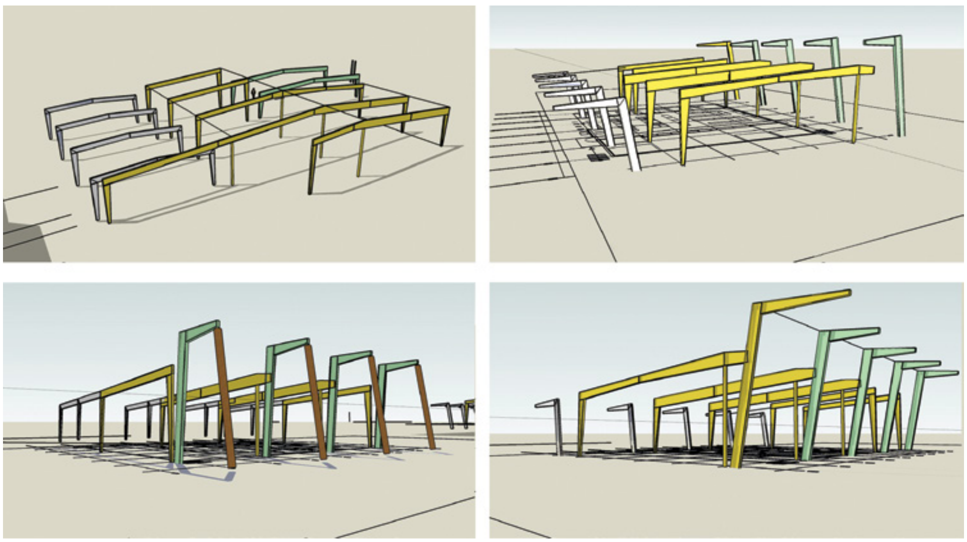


Figure 3.68 Investigation of design alternatives using available steel.

complement the available materials. It wanted to remake the materials into a new, authentic and aesthetically appealing building, but working within the limitations of the available components, and without compromising durability. Several alternatives were explored (Figure 3.68). The final design necessitated inverting components – columns became ribs,

Figure 3.69 The steel during erection.

beams became columns and so on. Any necessary refabricating of steel occurred on site and was surprisingly easily and cheaply achieved. Steel components were placed on saw horses for cutting, fitting, welding and bolting to reshape them to fit the new form and function. The process needed only a fork lift truck and small lifting machinery (Figure 3.69).

The high front canopy and overhang of the new building were a problem due to a lack of appropriate steel and a desire to use softer materials by the reception area (Figure 3.70). Reclaimed cedar hydro poles were identified as readily available – Manitoba Hydro replaces its poles regularly and the old poles are usually still in good condition. Depending on how they are finished (creosote can be a problem) they require little refinishing and, in this case, were used in an as-found condition. Milled cedar from hydro poles and reclaimed oak planks were also used for benches at the base of each pole and for decking in the reception area (Figure 3.71).

The design team was keen to embrace and highlight the history of the reclaimed materials as a reminder of their past use. The steel columns and beams remain unpainted and open to view.

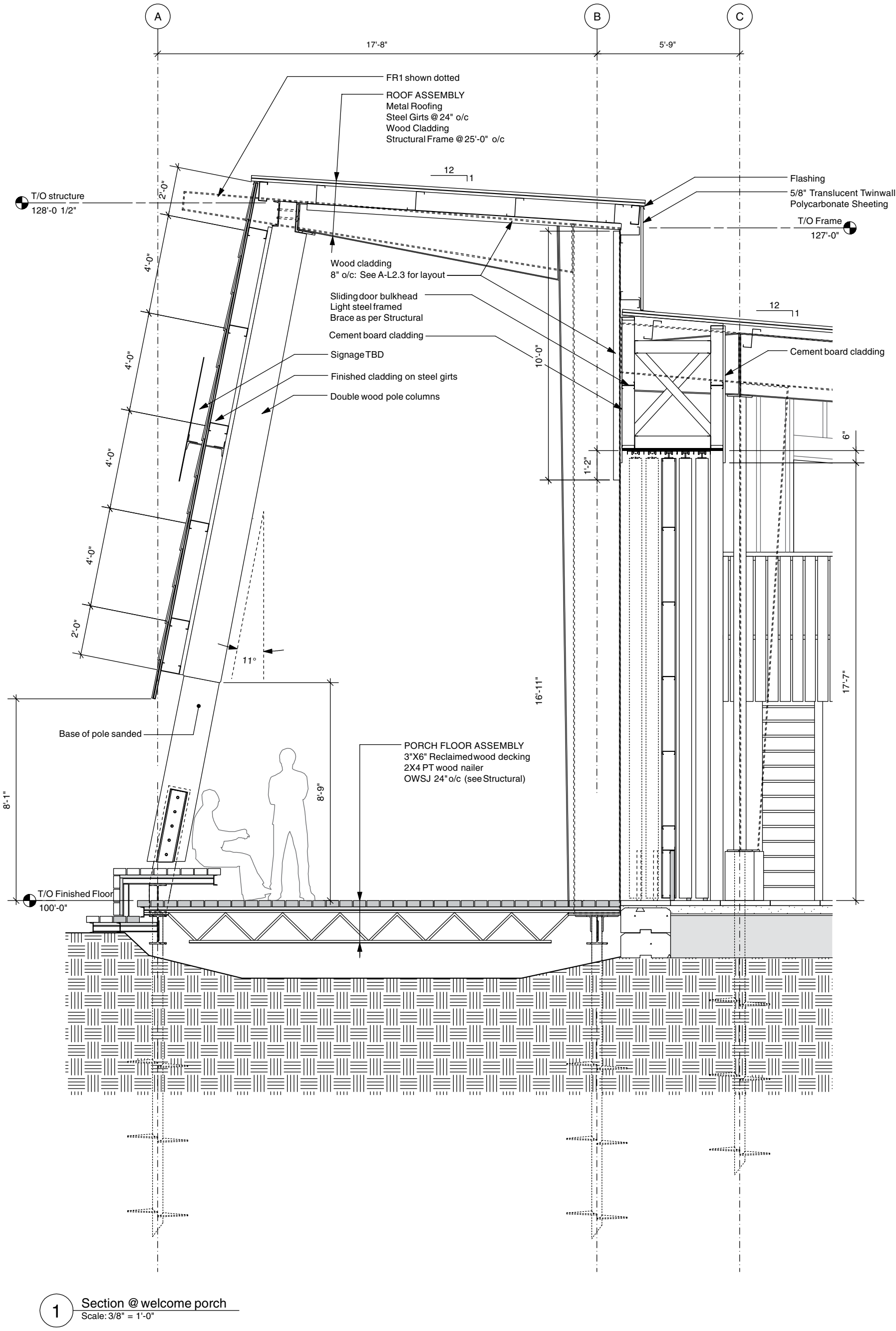


Figure 3.70 Section of the front canopy.

Figure 3.71 The front canopy.

Also, coloured steel cladding was used to animate the façade and show the history of the materials. It was difficult to reclaim thin steel cladding without damage due to the fixings. Thus, about 50% of the wall cladding panels were not reclaimed but purchased new (although produced from recycled steel), a lot of it from end run culls. Another design objective was that the building must be capable of being removed in the future, leaving the site in a clean condition (Figure 3.72). To minimize foundation damage steel screw auger piles were used. Although these are new, they are manufactured with steel having a high recycled content and are reusable, or recyclable. Where reclaimed materials were not available, materials with a high recycled content were chosen. The floor is an interlocking panel system produced from 100% waste or recycled plastic. Wood framing was produced locally and all the connections were done to allow for the material to be dismantled and used again.

Figure 3.72 Detail of column base and flooring from reclaimed wood.

Although not really representative of mainstream construction, due to its unusual unconditioned space requirements, the material reuse aspects of this building form a valuable example, particularly for buildings with intermittent occupancy and where space conditioning is not a priority; for instance, park structures, festival venues, outdoor market-style venues and also some storage buildings. Other more recent structures at the Winnipeg Folk Festival follow a similar design strategy with reclaimed materials. Nevertheless, the overall approach and design process with close collaboration between the parties and a strong commitment to reuse has relevance to many other building types. Economically, La Cuisine shows that such an approach can be cost effective – the cost of construction is estimated to be about half of a building created using new materials. Furthermore, the local sourcing of materials was beneficial to the local economy, with a greater proportion of project funds spent on local labour rather than on new materials from manufacturing companies from afar.

The project illustrates some of the characteristics beneficial to a design team wishing to use reclaimed materials:

- Leadership and commitment of the owner.
- Flexibility during the design process.
- Creativity in the use of components in new situations.
- Ability to see the opportunities presented by the available components.
- The need to act quickly when a source for reclaimed components was discovered.
- Shared commitment of the design and construction team to the goal of working with used materials and components.
- Commitment to working in an integrated way and approaching design and construction as a continuum.
- Tapping the creativity of the various trades.
- A construction manager who appreciates a challenge and is willing to take on abnormal projects.
- A willing, creative and cooperative structural engineer.

The project also highlights some of the barriers to a wider adoption of reclaimed materials and components. These include a lack of infrastructure to supply used materials and components in the industry. Currently, supply and distribution is informal and needs an investment of time and the development of networks to get access to such materials and to develop stockpiles. Secondly, it is more difficult to predict the final outcome of such a process. Such buildings will tend to be more improvisational and, thus, require a client and design team with an open approach, and so may be less suited to some commercial clients.

Element	Source	Processing	Comments
Structure	Steel components from dismantled pre-engineered, steel-framed industrial buildings	Steel components were placed on saw horses for cutting, fitting, welding and bolting to reshape it to fit its new form and function	Design evolved based on available steel components
	Reclaimed cedar hydro poles	Used in an 'as-found' condition	
Cladding	Steel cladding from dismantled industrial buildings	It was difficult to reclaim thin steel cladding without damage due to the fixings	Coloured steel cladding was used to animate the façade and show the history of the materials.
Furnishings	Reclaimed cedar from hydro poles and reclaimed oak planks	These were milled for benches at the base of each pole and for decking in the reception area.	

3.3.3 Pointe Valaine Community Centre

Architect:	Smith Vigeant Architect
Green rating:	LEED-NC Gold
Construction:	2007
Location:	Montreal, QC, Canada
Floor area:	800 m^2 (8 600 sq. ft.)
Use:	Community centre
Owner:	Town of Otterburn Park
Certification:	LEED-NC Gold
Reused components:	Prefabricated insulated concrete cladding panels, bricks.

This suburban community centre (Figure 3.73), built in 2007, illustrates an opportunist approach when a creative architect identifies readily available but used components that can be integrated into a current project. In this case, locally available prefabricated insulated concrete cladding panels that had been removed from a big box store were discovered in storage at a local contractor's yard and were available for reuse for only the cost of transport.

Figure 3.73 Point Valaine Community Centre.

For its new social, cultural and recreational centre the city of Otterburn Park was eager to support a sustainable project as a reflection of the community's values. The two-storey, 800 m^2 (8 600 sq. ft.) building includes a 200 seating capacity meeting hall and exhibition space, offices, meeting rooms and other support space. The building unifies a beach, river walk and picnic area, and at the lower level it provides storage space for canoes, kayaks and recreational items, a workshop, lockers and showers for the users/cyclists. The building has a steel structure with considerable use of prefabricated components, including a structurally insulated panel (SIP) roof with the painted OSB exposed as an interior finish to reduce the use of finishes.

The integrated design approach (IDP) facilitated an open and fluid process of conception, which enabled some flexibility in the final design. Environmental impacts were analysed at several levels, including reduction of ecological footprint over the anticipated 75-year building life. With regard to materials, these were sourced locally where possible and a total of 28% of total project materials were located within an 800 km radius. Materials with a high recycled content were also targeted (15%). Other goals included the use of easily demountable, recyclable materials, so most elements are easily removed for reuse or recycling (with the exception of the foundations) and it is expected that up to 85% of the material used could find a new use. 80% of construction waste was diverted from landfill. As a result of these strategies, the building achieved LEED-NC Gold certification.

During the early stages of the design, Smith Vigeant Architects was open to the idea of reusing components for the building envelope. The client wanted a durable building exterior due to potential issues of vandalism, and initially brick was considered. They were willing to use different materials from a variety of sources and investigated a patchwork design. The team discovered a local supplier who had 13 large prefabricated, insulated, concrete cladding panels in storage removed from a big box store that had been recently dismantled. The panels were only a few years old and in good condition, and could cover 40–50% of the exterior wall surfaces of the proposed building (other exterior materials are high efficient curtain wall system, fibre cement board and wood). The panels were available for just the cost of transport, which was approximately CAN $500/panel (less than 10% of the cost of similar new panels). By the time they were identified the design was fairly well advanced but fortunately only minor revisions were required to accommodate them. The client was supportive of the idea,

especially after the design team calculated the likely cost savings.

The building design required some minor adjustment to suit the width of the panels but no significant changes in design were necessary. The panels had to be cut at the top and bottom to adjust the height and line them up correctly (Figures 3.74 and 3.75). However, the building design included a spandrel strip at 2.7 m height and, coincidentally, this coincided with a strip on the panels. So the architects were able to use this in the external expression of the elevation (Figure 3.78). The external finish surface was kept the same as in the original building but support and anchoring were adjusted. The cost of this was relatively minor. Original cast-in-place hardware was kept at one end of each panel for connection to the new building (Figure 3.76).

Consistent with its environmental objectives, the project aimed to achieve a high level of energy efficiency. Therefore, in this cold climate, high insulation levels were desired. The panels had a reasonable level of insulation (approximately Rsi 4.4 m^2 C/W, R25) integrated but not as much as was originally planned. Nevertheless, the thermal mass on the inside of the insulation was a benefit and the exterior finish was acceptable, so additional insulation was not incorporated (Figure 3.77). The overall building performance was compensated for with improved mechanical systems, including a radiant floor slab with polished concrete finish.

In addition to the cladding panels, salvaged bricks were used for internal partitions within the building. These provided thermal mass and reduced maintenance requirements. The mason identified bricks from a demolished house nearby that was built using lime-based mortar and so readily facilitated deconstruction.

Code approvals were not a problem – the building department was happy to accept the reuse as long as the engineer was willing to approve the construction. However, timing/scheduling was identified by the designer as a key issue. In this case, the panels were in storage and could be made available when needed, but other salvaged materials could not be used as availability did not coincide with the construction schedule. Another problem identified by the architect was that little infrastructure exists in the local construction industry to facilitate reuse and make products easily available, so it is difficult for design teams and contractors to find appropriate materials. Similarly, the contract bidding process can be an obstruction, as

Figure 3.74 Delivery of the used prefabricated panels.

Figure 3.75 Cutting the prefabricated panels on site.

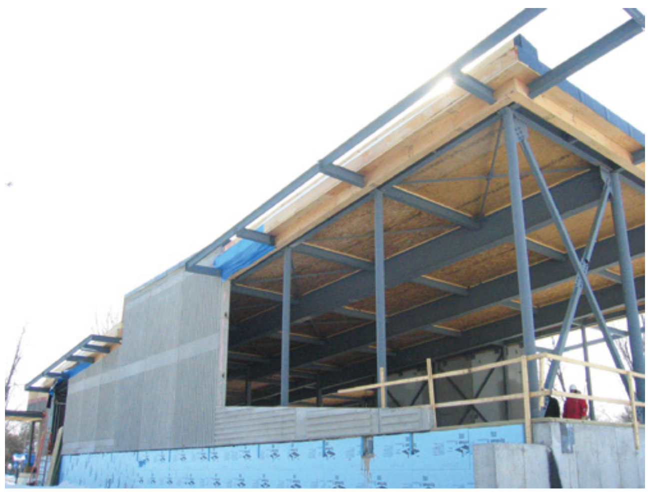


Figure 3.76 Installation of the prefabricated panels.

Figure 3.77 The building interior with the reuse wall panels.

Figure 3.78 The reused concrete panels can be clearly seen on the elevation.

reuse can introduce an additional level of uncertainty and unfamiliarity, which can lead to higher bids or contractors avoiding such projects.

The environmental benefits in relation to the reuse of materials were not quantified for this project. It was estimated that approximately 35 m^3 of concrete was saved but associative carbon impacts were not calculated. Carbon impacts were only considered for operational energy use which show considerable savings compared to code requirements.

Element	Source	Processing	Comments
Facade	Prefabricated concrete panels from deconstructed big box store	The panels were cut top and bottom to adjust the height and line them up correctly	The panels were available for just the cost of transport
Interior walls	Salvaged bricks		The mason identified bricks from a demolished house nearby

3.3.4 Oasis Children's Venture

Architect:	Benjamin Marks and Matt Atkins
Construction:	2012
Location:	Stockwell, South London, UK
Floor area:	200 m^2 (2 150 sq. ft.)
Use:	Office and children's play space
Owner:	Oasis Children's Venture
Construction cost:	£170 000 (£850/m^2)
Reused material:	Timber framing, gypsum drywall, plywood, insulation.

The Segal self-build method is an interesting example of a construction system that was conceived to facilitate both ease of construction and deconstruction, thus permitting material reuse. It originated in the 1960s when architect Walter Segal wanted to create a temporary home for his family in Highgate, London, while they built a more permanent house. Segal designed and built a temporary structure in the garden which could be easily dismantled using standard-sized building components with only paving slabs as foundations. It took only two weeks to build and cost £800. Based on this simple building, Segal subsequently developed a more sophisticated system suitable for self-builders to create their own homes. His approach was to go back to basics, using simple post and beam timber construction inspired by medieval builders, Japanese temples and US kit houses.

Figure 3.79 The Oasis Children's Venture building.

Figure 3.80 The old unused Coin Street building.

He used standard-sized modern materials to avoid cutting and waste, and eliminated skilled wet trades such as bricklaying and plastering; this allowed people with little experience to build houses. It also simplified future adaptation and wholesale dismantling, permitting relocation of the building or reuse of the materials. Segal even developed a system for installing interior plaster drywall and exterior cement board cladding in such a way that these could be removed and reused with little damage.

The Segal method was used for a variety of self-build housing projects in the United Kingdom. In the 1980s, architects Architype designed an office building using the system for the Coin Street Community Builders (CSCB), which is a social enterprise operating on London's South Bank. This 135 m^2 (1 450 sq. ft.) single storey building (Figure 3.80) was vacated in 2007 and was to be removed to make space for a new building for The Rambert Dance Company. In 2011, two week before the building was due to be demolished, the materials were donated to the Oasis Children's Venture, a local charity in nearby Stockwell that provides facilities for children to play in a secure environment. With support from over 100 volunteers over two weeks, and coordinated by architecture students Benjamin Marks and Matt Atkins, the old building was dismantled into its components, which were labelled and moved across south London to Stockwell. The salvaged materials included the timber structure, interior drywall finish, insulation, window frames, the boiler, sheets of woodwool and interior fittings. Other

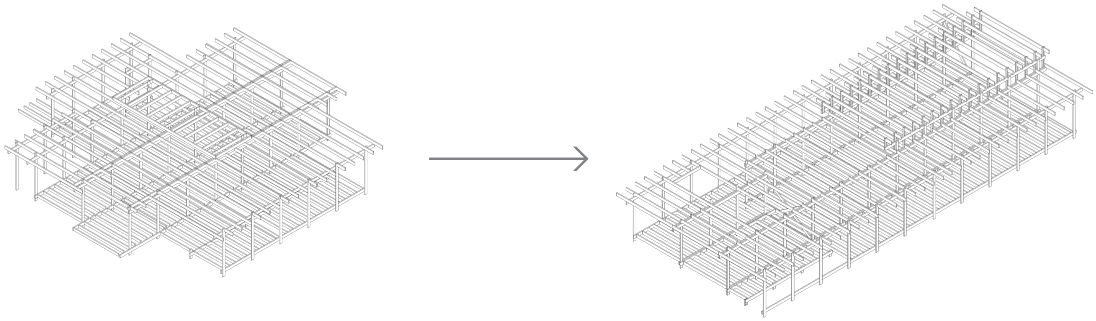


Figure 3.81 Framing transformation.

components, such as the old cement board cladding, roof finish and foundations, proved impractical to salvage and were not reused. The simple constructional logic of the Segal system using bolted and screwed connections allowed the main components of the building to be cleanly and quickly separated and became the key to effectively reusing the material. In addition, materials such as plywood sheets, floorboards and polycarbonate used to make lightweight removable door panels were salvaged from another building that was being demolished on the Coin Street site.

At this point there was no design for the new building, so all the salvaged materials were stockpiled at the new site. Marks and Atkins took on the task of designing a new facility for Oasis using principally the salvaged materials. Rather than merely rebuilding the old building in a new location, which would not have provided appropriate spaces and facilities for the new use, the components of the old building were treated as a resource to be shaped into a completely new building (Figure 3.79). The designers redrew the original building in CAD and used this as the starting point for their new proposals (Figure 3.81). They embraced the principles and the logic of the Segal system and worked with the materials sizes and specifications that were available. The deconstruction process had been instructive for the team to understand the logic of the system and also to observe any problems or details that had not aged well. So the designers were able to adopt many of the same construction details that were used in the original building, but updated the specifications to meet current codes and performance expectations, and revised other details. By adopting the Segal method the new building is also demountable and so the materials and components may have further lives ahead of them.

The interior of the new building comprises a new play space, office, kitchen and ancillary functions (Figure 3.82). A larger open

Figure 3.82 The office area.

area was required for the play space and the 2.4 m (8ft.) floor-to-ceiling height in the old building was increased in this space by creating a clerestory, which altered the building section and introduced natural light. Overall, the internal space is the same size as the old building but the total covered area is larger due to an outdoor veranda that was included. Thus, some additional new construction material was required. Nevertheless, the vast majority of the new building is from salvaged material, giving it a very low carbon footprint. Funding for the project was very limited so the simplicity of the Segal system was a benefit, as it allowed a significant amount of work to be done by volunteers. The modular, dry construction and bolt-together fixings that characterize the Segal method proved fundamental to both the success of the deconstruction and the reassembly by volunteer labour (Figures 3.83 and 3.84).

To meet contemporary building codes, the walls and roof required additional insulation but this was readily integrated without difficulty principally by adding rigid insulation to the exterior of the frame. Some of the original mineral wool insulation could be reused in the floor and ceiling. Glazing was upgraded to modern double-glazing units; however, these could be accommodated within Segal's original window design. The engineer was able to certify that the salvaged timber was structurally suitable for its new use, which was made easier due

Figure 3.83 Raising the new frames.

Figure 3.84 New framing takes shape.

to the use of a lighter weight roof finish than the original building, meaning that the frame was carrying lower loads. However, dimensional variations of the salvaged timbers caused some issues during the assembly process. A new cement board cladding was used, as the original façade was in poor condition and difficult to remove without damage. The new lapped siding was better able to accommodate site tolerances and installation by unskilled labour. In some areas the salvaged character of the materials was featured, such as in the soffit timbers in the

Figure 3.85 Reused light fixtures are integrated.

veranda, which display a variety of finishes dependent on their previous uses and treatments.

The project highlights the importance of considering the consequences of the end of a building's life and the likely life-span at the design stage. Some buildings may be expected to last for a long time, so deconstruction may be less of an issue, but flexibility may be more important. This has been demonstrated by some heritage buildings and much of London's Georgian and Victorian architecture that has accommodated many lives and uses. But many buildings designed today are not expected to last a long time and their construction methods make them difficult to dismantle. The Segal method demonstrates that, if care and thought is put into the design of a building, it is possible to create a system that makes it quite realistic to take the components apart in a way that maintains their value, so that new uses can be found for them. Thus, when the building is no longer an asset, the components continue to have value, rather than becoming a burden.

Element	Source	Processing	Comments
Structure	Framing from old Segal method building	Building deconstructed by volunteers	Segal method facilitates deconstruction through simple bolted and screwed joints
Internal wall lining	Plaster drywall and plywood	Segal method construction features a compression fixing detail to install wall finishes that allows them to be removed undamaged	Care required in storage and re installation
Softwood flooring	Demolition of building nearby		Reused as flooring
Insulation	Mineral wool from walls of old building	Collected in bags and reinstalled in the floor and ceiling	

3.3.5 The Old Oak Dojo

Architect:	Next Phase Studios
Construction:	2013
Location:	Jamaica Plain, Boston, MA, USA
Floor area:	86 m^2 (925 sq. ft.)
Use:	Community meeting space
Reused material:	Timber framing, salvaged flooring, electrical fittings, movie set.

The Old Oak Dojo is a unique gathering place in Boston aimed at dissolving the boundary between public and private and helping to create healthy and resilient communities and engaged citizens (Figure 3.86). It provides a small space for community members to meet, learn, eat, celebrate and play. The building is located on the footprint of an old barn from the early 1930s within the grounds of a Victorian

Figure 3.86 The Old Oak Dojo.

multifamily residence and is built around a 170-year-old oak tree, which gives it its name. The barn was used as a bicycle repair shop in the 1970s but had been abandoned since the 1980s. As a building it was beyond rescue but it was the starting point for and strategy of reclaimed materials used in the new building.

The project had very ambitious environmental performance goals from the start. It was awarded Living Building Challenge (LBC)[h] Certification, which includes a very demanding set of requirements to minimize impact on the environment. LBC requires careful sourcing and selection of preferably local materials to reduce toxicity as well as decrease waste generated through transport and construction. Although LBC encourages reuse of materials and components, it does not require the level of reuse that was achieved in this project. Nevertheless, the architect, Next Phase Studios, was able to adopt an approach that focused almost entirely on using locally reclaimed materials. It benefited from good connections with building materials reuse networks, particularly the Boston Building Resources Reuse Center, which was able to assist with providing much of the material for this small project.

To be LBC certified, a building cannot use components that include constituent materials that are on the LBC '*Red List*'. These are materials for which there are significant environmental and health concerns and include materials such as PVC, mercury, formaldehyde and lead. LBC requires evidence that these materials are not used in any of the components in the building. The certification process is quite onerous and makes material and component selection challenging. This can make selection of reclaimed materials and components more problematic, as it is not always possible to establish their full history and composition.

Nevertheless, Next Phase Studios proposed that the project should source the majority of materials from locally deconstructed buildings. The client embraced this idea and participated in identifying suitable materials. The first strategy was to keep the design simple and flexible to maximize opportunities for integrating reclaimed components. The small size of the building allowed the use of salvaged timber for the structure; this is possible to find locally, is flexible and often appropriate

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[h] LBC is a demanding set of requirements including net zero energy and water use, a healthy indoor and outdoor environment and careful sourcing and selection of materials to reduce toxicity as well as decrease waste generated through transport and construction (http://living-future.org/lbc).

Figure 3.87 Timber from a movie set was used in the building.

for secondary use. The design team developed an initial outline design and worked closely with Boston Building Resources Reuse Center and other sources to identify appropriate materials. Much of the structure of the building came from materials used in a movie set that had been salvaged by the material reuse networks (Figure 3.87). This provided relatively new and good condition engineered timber components, including LVL and TJIs beams, and Microlam components, as well as FSC-certified timber. It was also helpful that the original manufacturers could be identified for these materials and this assisted with establishing their specifications.

The design team was easily able to adapt the design of the building to match these reclaimed materials, which became the structure of the building. For example, the roof was originally intended to be a series of smaller roofs with multiple pitches but was transformed into a long shed roof to take advantage of the larger engineered timber beams. Other minor adaptations of the design were needed to suit the materials and, in some cases, the structure was probably a little overspecified, by using what was available. Purchasing the salvaged timber was significantly cheaper than buying new but some additional labour was required. The architects estimate that the total material and labour budget was lower than if all new materials were used. However, additional costs for the project were mainly due to the

Figure 3.88 Reclaimed timber floor.

effort required in establishing compliance with the LBC Red List of materials.

Additional reclaimed materials came from a variety of sources, including reused material networks and local knowledge of demolition projects. Roof timbers from a pool in Watertown became decking for the stairs. Floors from a paper mill in Lawrence provided salvaged antique heart pine T&G flooring (Figure 3.88). A house that was deconstructed nearby provided millwork that was used to create kitchenette shelving, drawers, countertops and cabinets (Figure 3.89 and 3.90). Also, timber from the old garage was used to create entrance cubby-holes. All the doors were from previously used sources, except the Nanawall glass door system, which was an important design feature. Even smaller components, such as door knobs, ceiling fan, countertops, sink and pendant light fixtures were sourced through the reuse networks. The team found that most components for a small building such as this were possible to find from reclaimed sources, and storage space on site made it easier to collect these components and keep them until required. The team believe that no significant compromise to performance or

Figure 3.89 Cabinetry removed from a local house.

Figure 3.90 Shelving made from recovered cabinetry.

durability had to be made due to the reuse strategy (Figure 3.91).

Where reclaimed components were not possible the team tried to choose local and recycled materials. Thus, insulation used recycled cellulose, new lumber was sourced locally from Maine and is FSC-certified mixed. Similar care was taken in the waste diversion aspects of the project.

Due to the unusual nature of the project – both the LBC certification and the focus on reuse – the architect and client chose a design/build approach to realize the project where the design and construction team are the same entity. Next, Phase Studios chose to manage the project construction itself – so it had someone on site much of the time to make decisions as necessary. This allowed it to manage the non-typical aspects of the project and gave it far more control of the materials choices than would be the case in a typical project. It also allowed more care in minimizing waste on site and virtually eliminating any waste going to landfill.

The state of Massachusetts has taken a progressive attitude to reducing construction and demolition waste, setting recycling

Figure 3.91 Cladding from reclaimed timber.

targets and banning some types of construction waste from landfill. This was a benefit to the project, as it has led to the establishment of new organizations that are working to find value in waste. These '*matchmakers*' identify materials and components that are coming to the end of their current operational life but have potential for new uses. They connect potential users of these resources with their current owners, thus saving materials from landfill. This has generated a growing market for salvaged construction materials. To make more widespread use of reclaimed materials, architects need to understand these networks, which in the past often started as local enterprises but are now beginning to work at national level, sharing information about materials that are available. The digital age also makes this type of exchange easier to facilitate and a more general acceptance of purchasing from networks and Internet sources is making this form of exchange more common.

Next Phase Studios has commented that realizing the objectives of this demanding project was possible due partly to its small scale, and additional costs and design time were more associated with the LBC Red List compliance rather than using reclaimed materials (Figure 3.92). However, for larger projects sourcing would be more challenging and would need far more

Figure 3.92 The finished building.

planning, and be done ahead of time. At present this still feels like a 'boutique' approach – of interest to some progressive clients but less so for mainstream corporate clients, except perhaps for a special space such as an entry lobby or board room.

Element	Source	Processing	Comments
Structure	Timber components from a movie set purchased by material reuse organisation	Dismantling, storage and transport	Some minor redesign of the structure to accommodate these components was necessary
Raised garden beds	Sourced through the reuse networks	Dismantling, storage and transport	
Flooring	Floors from a paper mill	Reclaimed by a timber company	
Furnishings	Timber components from a deconstructed house nearby	Timber was used to make new millwork & furnishings	
Internal furnishings and fittings	Sourced through the reuse networks	Remilled and remanufactured	
Plumbing fixtures	Sourced through the reuse networks		Sinks, counters and faucets
Electrical fittings	Sourced through the reuse networks		Ceiling fan and pendant light fittings

3.4 SECONDARY USE OF NON-CONSTRUCTION MATERIALS

3.4.1 Pocono Environmental Education Center – Tyre Wall

Architect:	Bohlin Cywinski Jackson (BCJ)
Construction:	2005
Location:	Dingmans Ferry, PA, USA
Floor area:	720 m^2 (7 750 sq. ft.)
Use:	Environmental Education and Visitor Center
Owner/Operator:	National Park Service/Pocono Environmental Education Center
Construction cost:	$2 000 000 ($2 660/m^2)
Reused material:	Waste car tyres from the National Park.

It is well known that dealing with the large quantities of discarded consumer and industrial waste products creates significant environmental and resource use concerns. A variety of recycling initiatives has been launched by various organizations to develop alternative second life strategies for some of the most ubiquitous consumer products, yet high levels of circular use are still rare. However, some of these products have characteristics that make them potentially adaptable for use as components in buildings, and can sometimes perform equally well or better than purpose-designed products.

Vehicle tyres are one such product that has attracted interest from designers and product developers to look creatively at their potential for interesting architectural solutions. Examples include the work of Refunc in Europe, which has created a series of installations with waste tyres, and Michael Reynolds, who invented the Earthship house concept which uses tyres rammed with earth for external walls (see Figure 2.4). The Pocono Environmental Education Center at Dingmans Ferry in Pennsylvania designed by Bohlin Cywinski Jackson explores the architectural potential of using shingles fabricated from waste car tyres (Figure 3.93).

Bohlin Cywinski Jackson approached MooRoof, a Canadian company that has developed a patented process to cut old tyres into strips and install them as roof and wall shingles, to provide wall cladding for the centre (Figure 3.95). In addition to using a ubiquitous discarded product, a significant advantage of tyre shingles is that they are expected to last much longer than typical cladding shingles used in North America and carry a 50-year warranty. The MooRoof system was used as a central feature and educational tool on the front facade of the building, which is located within National Park Service land and is primarily a visitor activity centre and teaching tool for children. A primary goal of the building's design was to demonstrate sustainability using the

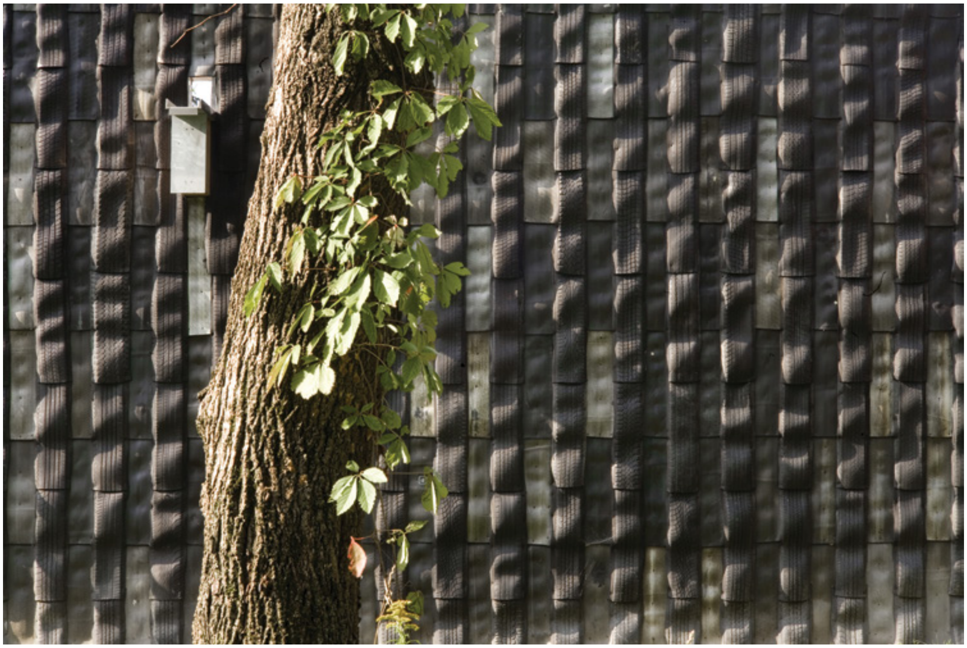


Figure 3.93 Recycled tyre call cladding at the Pocono Environmental Education Center.

features of the building to broaden understanding of society's interdependent relationship with nature.

The first view visitors see on approaching the facility through a forest is of the undulating tyre-clad north wall (Figure 3.94), which was a central feature of the design strategy for the building. The dark north wall contrasts with the bright, sunlit, south-facing main activity space of the building. From the start Bohlin Cywinski Jackson had conceived this wall clad with a manufactured recycled rubber shingle, but when construction began the intended product was no longer available. Richard Moore of MooRoof was then contacted to install the tyre shingles. The process involved the manufacturing of the shingles on site from discarded tyres retrieved from a nearby river and other locations in the National Park, and the remainder from a local disposal site (Figure 3.96).

The process of creating shingles out of old tyres used proprietary equipment developed by Moore which removed the tyre beads and sidewalls, resulting in 900 mm (36 in.) long strips that are 300–400 mm (12–17 in.) wide, depending on the tyre used (Figure 3.97). The strips are arranged in alternating rows so that one row faces in and the next faces out (Figure 3.98). In this building the tyres were screwed directly to a plywood

Figure 3.94 Entrance elevation.

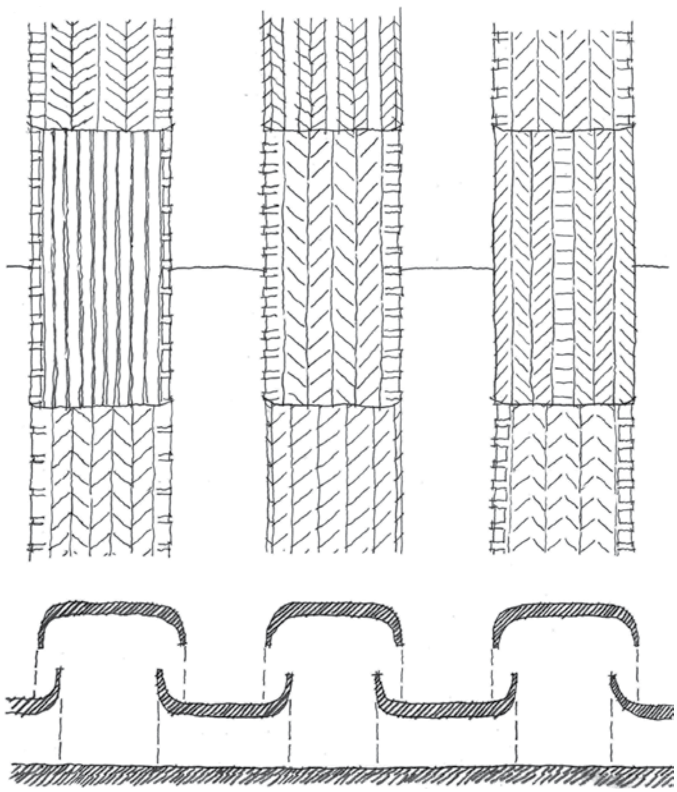


Figure 3.95 Sketch of the tyre cladding detail.

Figure 3.96 Tyres were collected locally.

Figure 3.97 The tyres were processed on site.

Figure 3.98 Tyre strips installed on the building.

Figure 3.99 Tyres are screwed to the sheathing.

sheathing with an air/water barrier in between (Figure 3.99). No furring strips were used. This created a vertical pattern with the tyre tread visible on every second strip. The shingles are overlapped and screwed down along their edges for a tight seal. The result is a very tough wall that can withstand the climate extremes at this location and the high-impact use to be expected from a hands-on learning environment. (MooRoof claims that an item as sharp as an axe will bounce off the shingles due to the reinforcement within them.) Tyre shingles are also claimed to be more wind resistant than asphalt shingles, because of their greater weight and stronger attachment, and have good sound absorption qualities. This unique solution provides a long-lasting, maintenance-free skin that also promotes the reuse of discarded resources, challenging visitors to understand the effectiveness of circular resource systems.

Figure 3.100 The passive solar south façade.

The building incorporates numerous other sustainable design features (Figure 3.100). Its form is a large south-facing shed sited to minimize the clearing of mature trees and to preserve wetlands, oriented to take full advantage of natural ventilation and solar gain, with abundant natural light and views of the forest. The tyres were part of a comprehensive strategy of careful material selection that included an exposed fly-ash concrete floor slab, ground-face concrete masonry units and a timber structural system. Reclaimed and recycled materials were chosen wherever possible without sacrificing performance. The most obvious of these is the building's unique tyre shingle wall.

Element	Source	Processing	Comments
Cladding	Waste tyres	Proprietary system to cutting shingles from used tyres	Creates a unique and long lasting façade or roof

3.4.2 Big Dig House – From Highway to Housing

Architect:	John Hong (formerly of SsD now Project: Architecture)
Construction:	2006
Location:	Lexington, MA, USA
Floor area:	300 m^2 (3 400 sq. ft.)
Use:	Single family house
Owner:	Paul Pedini
Reuse material:	270 tonnes of concrete and steel from highway dismantling.

Large infrastructure projects often use a variety of durable materials for short periods, for example as temporary structures, and often with little consideration for what they could be used for after the temporary use ends. Yet there is considerable potential for such materials to have second uses, particularly if pre-cycling – designing with consideration for future use – was practiced more widely.

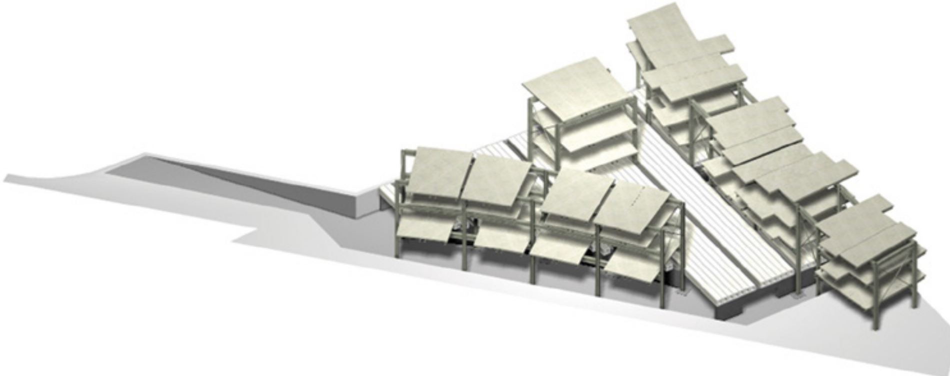
The Central Artery/Tunnel Project in Boston known locally as the '*Big Dig*' was a huge infrastructure project that rerouted a major

Figure 3.101 The Big Dig House was built using highway components.

Figure 3.102 Inverset components used in a highway.

highway (I-93) running through the centre of the city into a tunnel and replaced it above ground with a series of parks. During this process the highway was temporarily rerouted and this required the use of provisional raised roadway structures constructed from Inverset prefabricated panels (Figure 3.102). These are a system of composite steel and concrete panels designed for fast bridge construction. During the Big Dig project, lots of highway waste materials, including many Inverset panels that had been temporarily used, were collected across Boston, taking up valuable storage space (Figure 3.105). Land was leased to store them and there was a limited budget for their disposal.

John Hong (formerly of SsD now of Project: Architecture), an architect working in Boston, noticed these materials in a storage depot and contacted the demolition company dealing with the Inverset panels to enquire about their availability. He teamed up with engineers working on the Big Dig to explore the potential for reuse of the discarded panels as components of a building system. Their first proposal was in collaboration with one of the contractors for the Big Dig which also had a real estate development branch and had the know-how and equipment to take on an innovative project.



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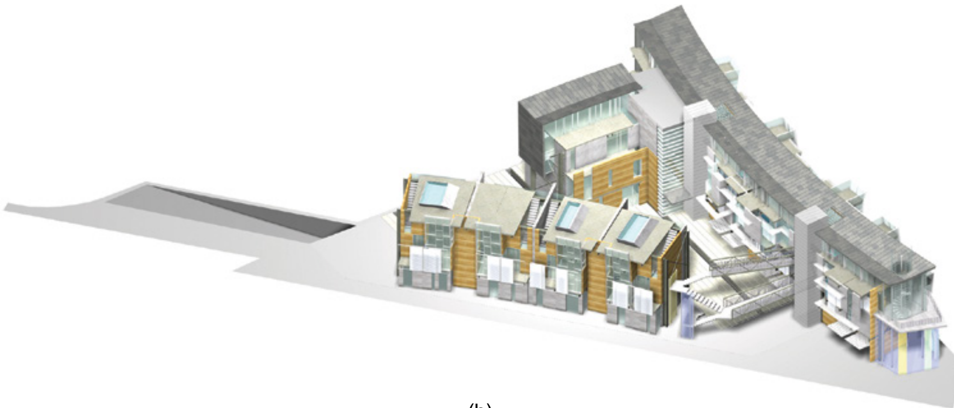


(b)

Figure 3.103 Design proposals for the initial unbuilt project for a multi-unit 'Big Dig Building'.

The initial scheme was for a small multi-unit residential development on land owned by the contractor (Figure 3.103). The project used the opportunities offered by the unique character of the discarded Inverset highway panels. They are designed for HS20-44 highway specifications and can withstand 12 kpa (250 psf) loading, which is many times greater than the 2 kpa (40 psf) required for residential construction. Taking advantage of the ability of these large-scale highway components to carry heavy loads and span long distances allowed the architects to explore options that are difficult to achieve in typical low-rise residential construction, and to create subtle spatial arrangements. This included the integration of long span underground parking, water-filled trombe walls, playgrounds introduced into upper level units to provide immediate access to the outdoors and the ability to incorporate full-scale landscapes on roofs and balconies. Also, heavy loads, such as libraries, could be readily supported and long

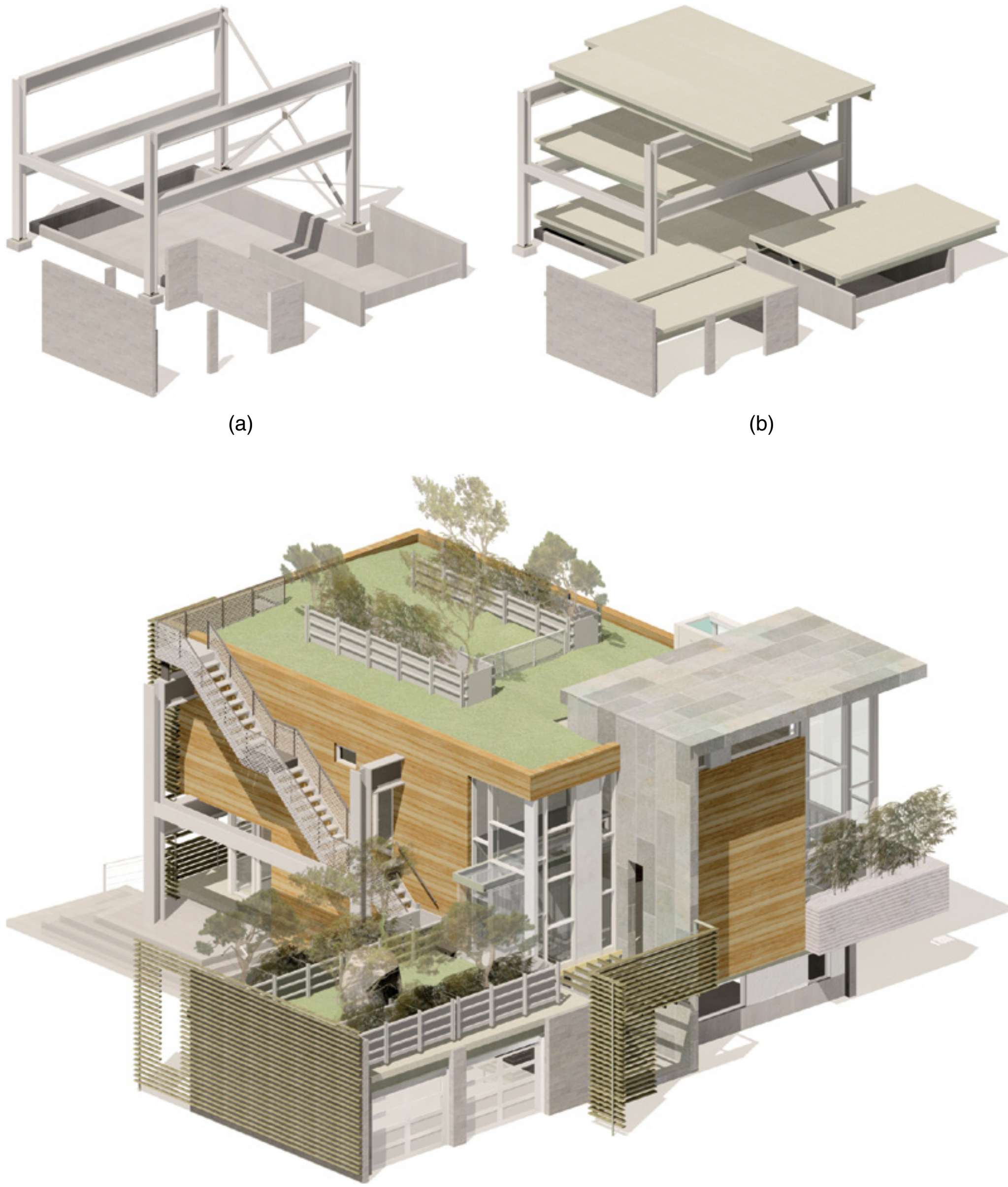
spans enabled connections between inside and outside to be more readily achieved. Another benefit was the prefabricated nature of the design, so the structure could be quickly and economically assembled, making its use on difficult, urban sites more realistic.

Unfortunately this project was shelved when the owner of the company passed away. However, the vice president of the company, Paul Pedini, was interested in using this approach for his own project, which became the Big Dig House (Figure 3.101). This was a 300 m^2 (3 400 sq. ft.) detached single family house, constructed as a prototype building that demonstrates the potential for reusing these infrastructure materials (Figure 3.104).

The structural system for the house included 17 Inverset panels, each weighing about 13 tonnes, supported by a steel structure, comprising in total over 270 tonnes of steel and concrete discarded from Boston's Big Dig. There are only limited ways that the panels can be assembled and little flexibility in their use, so it was necessary to accept the logic, rules and restrictions of the material. Since the roadway for which the panels were originally used was curved, each panel is trapezoidal to deal with the road condition for which it was designed. Thus, the house had to accommodate this slight curvature and has few right angles. Also, the height of the highway was greater than typical residential floor-to-ceiling heights. This allowed interesting spaces and details to be created, including a roof garden with over 1 m (40 in.) of soil to grow large plants, and with a retaining structure and railings from steel formwork previously used as road barriers.

One of the recurring issues with reuse of any components is establishing their level of performance. In this case it was obvious that the Inverset panels were previously used for much higher structural demands of a highway. However, even though they were greatly over spec for a building they did not have the necessary tests data to show that they met structural requirements for use in buildings. The engineer had to go back to first principles to prove to the building department that they could meet structural requirements.

Another recurring issue with reused components can be use of toxic finishes from the previous use. In this case, the panels were required to undergo environmental tests to check for any pollutants and off-gassing issues to establish they were safe. Some panels had too much oil on them to be used and had to be discarded. Also, the exposed steel integrated into the inverse panels was coated with lead-based paint when used for the highway, and this had to be sand blasted off. In fact, this, along with transport of the panels to site, was the most significant costs



(a) (b) (c)

Figure 3.104 Schematic of the Big Dig House construction.

of reuse. Conversely, little fabrication was necessary, only some minor drilling of new holes. Otherwise the material was left in its original form, so savings in structural material and in speed of construction were achieved.

The site for this house is located in an area that has very specific architectural requirements, so the planning approval process took a long time, and the municipality required considerable reassurance about the architectural character of the house. The municipality was also concerned about the potential damage to the roads from the large trucks delivering these bulky, heavy materials. However, the engineers were able to demonstrate that using standard flatbed transport trucks, which are designed to distribute the load, would not lead to greater point loads on the roadway than regular traffic. Once on site, the panels required the use of a large crane to lift the heavy materials into place and a specialist infrastructure crew to assemble the components (Figure 3.106). Although this had cost implications, these were offset by the fast speed of construction – the structure was erected within 21 hours.

The architect wanted to highlight the highway structure from the exterior and interior (Figure 3.107) to make it obvious that it was recycled – he wanted the house to be a teaching tool. But this led to problems with steel penetrating the envelope. To address the potential condensation on the steel inside the building where it penetrates the envelope, the designers proposed to warm the steel with radiant loops. This functions only when it is cold outside, but clearly has a significant energy penalty. In addition to the structure, a concrete cistern previously used for roadway construction was reused under the building to collect rainwater for green roof irrigation. The architects also wanted to use waste timber that had been sunk at the bottom of a river bed for many years, but timing did not permit this.

The client for the Big Dig House did not want the building to cost any more than regular construction. This project had a unique cost breakdown, as there were non-typical costs for transport (amounting to $10 000) and for paint removal. Considerable cost savings were generated since the Inverset panels were considered to be garbage, so they were available for no cost (other than transport). The architect was able to demonstrate overall cost savings due to lower labour cost for the structure compared to a stick-framed house and from the speed of construction. Reusing the panels also saved the government the disposal costs they would have had to pay. However, the extra design and testing costs had to be absorbed by this small, one-off, project. Such an approach would be far more effective with greater savings for larger projects. The architect estimated that a 30% saving in structural costs would be possible for a bigger project. Also, if the process of reusing these panels had been considered from the start of the Big Dig project, many buildings could have used these components and much waste and disposal cost could have been saved. A national register of infrastructure materials that are available for reuse would be another way to make such components readily available.

Figure 3.105 The Inverset panels in storage.

Figure 3.106 Assembly on site.

Figure 3.107 Interior featuring tall spaces and highlighting the structure.

Such '*pre-cycling*' approaches of thinking about a component's future life at the design stage are an important aspect of the circular economy.

Element	Source	Processing	Comments
Structure	Discarded Inverset composite panels used for temporary highway	Removal of paint	Crane required Extra transport costs
	Steel components from highway bridge	Removal of paint	Thermal bridging issues
Landscape	Railings from steel formwork previously used as road barriers		
Water cistern	Highway deconstruction		

3.4.3 Kaap Skil, Maritime and Beachcombers Museum

Architect:	Mecanoo Architecten
Construction:	2011
Location:	Oudeschild, Texel, The Netherlands
Floor area:	1 200 m^2 (12 900 sq. ft.)
Use:	Museum building with exhibition spaces, public areas and offices
Owner:	Maritiem & Jutters Museum, Oudeschild
Construction cost:	€2 900 000 total buildings costs (€2 400/m^2)
Reused material:	Cladding made of hardwood piling from the North Holland Canal.

The starting point and inspiration for this project by Mecanoo Architecten was the local tradition of reuse of materials and objects washed up on the shores of the island location. During the golden years of the Dutch East India Company in the seventeenth and eighteenth centuries, the Reede van Texel (Texel's offshore anchorage) served as a harbour and departure point for expeditions to the Far East. Situated at the island of Texel in the Waddenzee off the coast of The Netherlands it was a suitable location for provisions and water to be brought on board and maintenance work and small repairs to be carried out as ships waited for favourable conditions for departure to the Orient. All this shipping activity also meant that for hundreds of years a considerable amount of debris, driftwood and lost cargo from stranded ships and shipwrecks was washed up on the shores of Texel and used by the people of island as building materials.

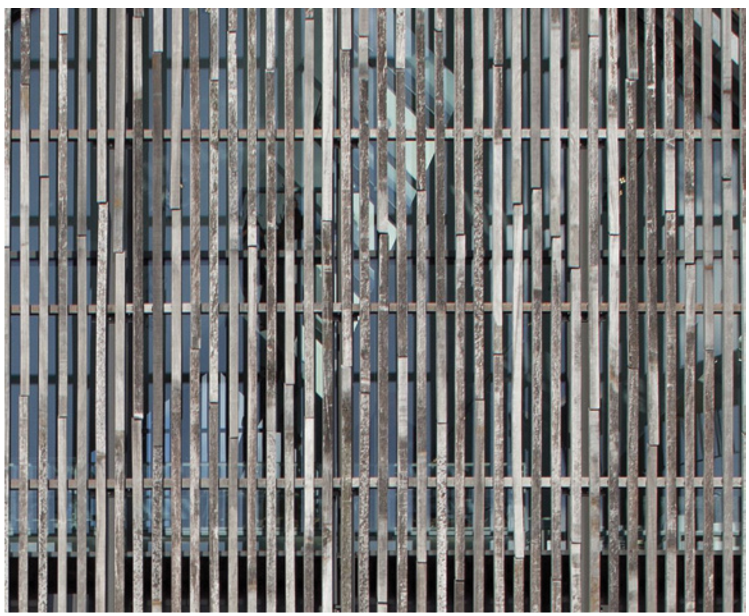


Figure 3.108 Detail of the elevation.

Figure 3.109 Elevations and sections.

When designing an extension for the maritime and beach-combers museum Kaap Skil on the island (Figure 3.110), Mecanoo Architecten worked with the local community to develop a strategy for this modest but striking museum building that reflects their history and traditions. The site in the village of Oudeschild was surrounded by small-scale residential and commercial buildings, and the community was keen that the new building should be carefully integrated with the existing village fabric, but at the same time become a centrepiece for the community. The museum form proposed by Mecanoo created four playfully linked gabled roofs that not only reflect the rhythm of the surrounding rooftops but also resemble waves rising above the dyke and visible from the sea (Figure 3.109). The architects investigated alternative strategies for salvaged material as inspiration for the design and initially proposed a multicoloured glazed façade using waste glass that is often washed up on the island's shore. The local community was keen on the strategy of reusing salvaged materials but less keen on a fully glazed design. The architects developed a close dialogue with the community through workshops and meetings to understand their hesitations and expectations.

After further research into suitable facade materials that would provide aesthetic quality, longevity and reflect the circular material traditions of the location, the architects discovered that wood piling in Dutch canals is replaced on a regular cycle of 25–30 years. They contacted a contractor in the Province of Noord-Holland (which Texel is part of) who was commissioned

Figure 3.110 The form and materials of the Kaap Skil Museum were chosen to integrate it into a village on the island of Texel.

by the Department of Public Works to replace the 25-year old wood piling from the North Holland Canal. These piles were made of large size (approximately 350 × 100 mm or 14″ × 4″) untreated Azobé wood, which is a strong, durable and tough timber often used for railroad ties, groynes and bridge planking. After many years under water the piles were often in good condition and suitable for a second use with a beautifully weathered white, grey, rust red, purple and brown surface.

The local community embraced the idea of using this material for an outer screen of vertical slats with a layer of glass behind (Figure 3.108). The wood piles were transported to Texel and sawn into strips to create the louvres by the local sawmill of Pieter Dros, generating 10 km worth of 50 × 50 mm (2 × 2 in.) wooden battens. The unsawn edges were deliberately featured by placing them on the most prominent side of the façade. The

Figure 3.111 Elevation.

vertical wooden battens make reference to ship masts and cover both the front and the rear side as well as the roof of the building (Figure 3.111).

The textured façade of old timber provides a strong identity for the building with views from within to the North Holland skies while creating a rhythmic play of shadow and light inside (Figure 3.112). The 70 mm spacing allows daylight to filter through to a ground-floor cafe and a first-floor gallery, creating a captivating play of daylight and shadow with variable transparency depending on the angle of view. In some conditions the sun and shadow can make the space feel like an underwater space with light filtering through the surface. Curators for the museum embraced the design concept, rethinking how to present the displays and proposed innovative exhibit designs with artefacts for the underwater archaeology exhibits and beachcomber collection displayed in mobile cabinets made from steel frames and glass (Figure 3.113).

Figure 3.112 Interior full of interesting daylighting effects.

Figure 3.113 Interior with exhibition items.

This project relied on a very collaborative design process. The architects working closely with the community developed a high level of trust and openness. This was central to the success of the project, as the community became champions for the design and advocated for its success. The architects observed that without strong commitment from the client, who had ambitious goals for an innovative approach, and support from the community, it would be difficult to realize such a project. Warranty issues and code approvals often create significant barriers for material reuse that can hamper many creative solutions if there is no flexibility of approach by authorities. Also, since such an approach inevitably does not follow standard processes, it tends to create controversy and more work for the design team. However, if established supply lines for reused components are developed (as exist in The Netherlands for materials like second-hand bricks) the process of circular design will become easier.

The wooden façade of Kaap Skil is an interesting example of an architectural concept that emerged from a local tradition of reuse and the significance of the building would be lost without such a material strategy. The visitor's experience of the building is enriched by the way the old material contributes to a unique space, embracing the architect's interest in time and change and its effect on people, place and purpose.

Element	Source	Processing	Comments
External timber cladding	Azobé wood piling removed from Dutch canals	Cut into smaller sections close to the site	Azobé wood is a strong, durable and tough timber. Can be hard to work with

3.4.4 Waste House – UK's First Permanent Building Made from Rubbish

Architect:	BBM Sustainable Design
Construction:	2014
Location:	Brighton, UK
Floor area:	85 m^2 (920 sq. ft.)
Use:	Demonstration house
Owner:	University of Brighton
Reused material:	Salvaged timber and plywood, vinyl exhibition banners, denim clothing, carpet tiles, plasterboard (drywall) offcuts, polystyrene waste and insulation offcuts.

The Brighton Waste House is a project initiated by BBM Architects in association with the University of Brighton in the United Kingdom to demonstrate the potential for using rubbish as a construction material and to establish appropriate applications for unheralded materials. Starting with the ecological principle '*that there is no such thing as waste – just stuff in the wrong place*', the project aimed to demonstrate that many under-valued materials that are commonly referred to as waste have the potential to become valuable resources. There have been many small structures built of waste but the challenge here

Figure 3.114 The finished Waste House.

was to create the first permanent building to meet current planning and building codes in the United Kingdom that is constructed predominantly from waste, surplus and discarded material. Over 85% of the material used in the project was gathered from the construction and other industries, or from household waste.

The design team, headed by Duncan Baker-Brown, wanted to prove that previously used materials, and organic low carbon materials, can compete effectively with their more established high energy, high carbon counterparts to create high performance buildings. It wanted to demonstrate circular materials systems to achieve an energy efficient, low carbon house by employing innovative prefabrication techniques using waste as the source material, and applying building physics principles to lightweight construction, insulation performance and materials energy storage. A further objective was to prove that a contemporary, innovative, low energy building can be constructed almost entirely by inexperienced young people studying construction trades, architecture and design. To this end, over 300 students worked on the project, which was initially fabricated in the workshops of City College Brighton and Hove, and then assembled on a site at the University of Brighton's Faculty of Arts at Grand Parade campus by students and apprentices between May 2013 and April 2014.

The design approach was focused on finding appropriate ways to create the building's major elements using waste but without compromising performance. The foundations of the building consist of ground-granulated blast-furnace slag and support a framework comprising salvaged plywood beams, columns and timber joists rescued from a nearby demolished house (Figure 3.115). Six hundred sheets of second-hand and/or damaged plywood were used for structure and infill cassettes. This created walls with 400 mm (16") deep compartments that are filled with a variety of waste products, such as denim offcuts from jeans and jackets, DVD cases, video cases and tooth brushes (Figure 3.116). These are packed into the spaces to trap air pockets and act as low grade insulation. In addition, 7.2 m^3 (250 cu. ft.) of polystyrene from old packaging was used as wall insulation. The team wanted to lock away toxic plastic waste to draw attention to the fact that most plastics end up in ocean gyres and cause considerable damage. The walls include transparent sections, '*truth windows*', built into the walls to display the construction. The insulating properties of these materials are being measured by sensors built into the walls as part of a research project by the University of Brighton.

On the outside of the wall, 250 m^2 (2 700 sq.ft.) of seconded/returned insulation products from Kingspan Insulation provide

Figure 3.115 The structure was assembled from salvaged timber.

(a) (b)

Figure 3.116 The walls were insulated with various discarded materials such as packaging chips and denim clothing.

an insulated sheathing layer and are also used for the floor and roof insulation. Internally, discarded vinyl exhibition banners with taped joints form a permanent air/vapour control membrane that wraps around the house (Figure 3.117) and the walls are lined with cast-off sections of drywall that were either damaged or leftover sections from other sites (Figure 3.118). These are used to create an aesthetic pattern that does not hide but rather celebrates the character of the smaller drywall sections.

One of the most distinctive features of the building is the two thousand used carpet tiles that create the rain-screen cladding. These tiles are used with their fire-retardant, waterproof underlay facing outwards, providing weatherproof cladding, while the soft carpet layer faces inward (Figure 3.119). This gives the house its exterior appearance of a '*scaly surface of rubbery black shingles*'. The carpet tiles are installed on battens to create a ventilated cavity behind, but with a large overlap that hides the fixing. The design team developed appropriate details for dealing with junctions and openings, including curving the tiles around the corners of the building. Their long-term performance when exposed to the weather and UV light will be monitored by the university. The roof consists of 65 m^2 (700 sq.ft.) of rubber membrane made from old Pirelli car tyres.

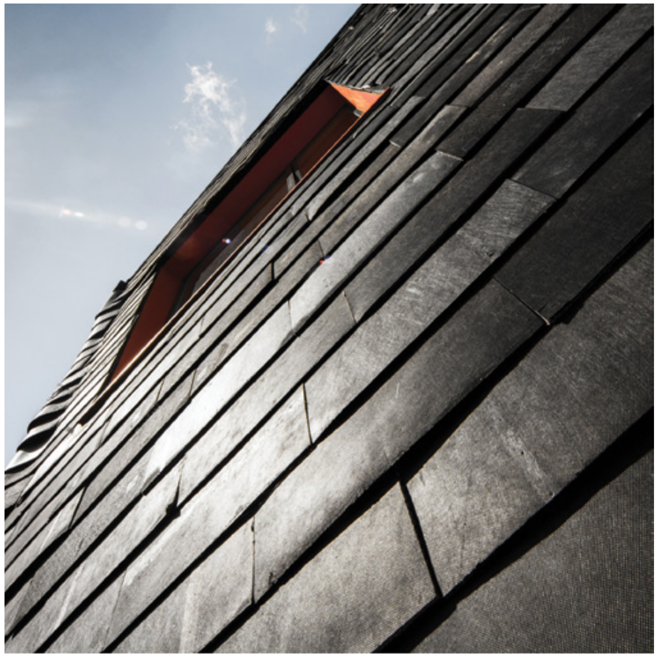
Internal walls provide some thermal mass by using ten tonnes of chalk spoil from a local construction site; this was compressed using a technique normally employed to build rammed earth walls to make a wall that flanks the staircase. Also, waste blockwork was used internally. Wood came from various sources, including damaged new stock from a retailer and residents' sheds. Also 50 mm × 50 mm (2″ × 2″) softwood timber that is used throughout the building was sourced from skips from City College and Brighton Wood Store, and 2000 second-hand bolts were used for fixings. The interior surfaces were finished with paints from New Life, a local supplier that reprocesses waste water-based paint into a premium grade emulsion.

Many materials were obtained on the Freegle website – a free local reuse and recycling service developed from the Freecycle Network. These include the kitchen and some of the insulation material. The project team showed how creative thinking can lead to innovative uses for available materials. For example, sealing around windows and sound proofing of the first floor was achieved by using 500 cycle tyre inner tubes. A few elements, including the triple glazed windows, the breathable house-wrap membrane for moisture control and wiring and plumbing fittings were new, as it was felt that performance would be compromised with reused components.

Figure 3.117 Vinyl exhibition banners installed here as the vapour control layer shown before the drywall was installed.

Figure 3.118 Offcuts of drywall were used to create an interesting internal finish.

(a)



(b)

Figure 3.119 (a) Carpet tile cladding corner detail. (b) Old carpet tiles used as cladding in the Waste House.

The resulting building is a permanent design workshop and at the same time a live research project that will be used by students from the university's Sustainable Design MA course and will be available as a community resource for hosting sustainably themed design workshops and events. The project aims to create a debate about the huge potentials for creative material strategies within the circular economy and to encourage creative thought while highlighting suitable solutions. It demonstrates that a creative and informed approach can avoid most new materials and provide options for many discarded materials. However, as a model for future housing it also highlights the lack of infrastructure and expertise to enable more widespread implementation of such approaches.

Element	Source	Processing	Comments
Structure	Salvaged plywood beams, columns and timber joists rescued from a nearby demolished house	Six hundred sheets of second-hand and/or damaged plywood were used for structure and the infill 'cassettes'	Walls with 400-mm deep compartments were created from plywood
Insulation	Denim offcuts from jeans and jackets, DVD cases, video cases and tooth brushes	These are packed into the spaces to trap air pockets and act as low grade insulation	
	Polystyrene from old packaging was used as wall insulation		Freegle website
	Seconded/returned insulation products from Kingspan Insulation	These provide an insulated sheathing layer	Also used for the floor and roof insulation
Interior lining	Plasterboard (drywall) offcuts left over from other sites	The walls are lined with cast-off sections that had to be cut to fit	An aesthetic pattern celebrates the character of the smaller drywall sections
Air/vapour barrier	Discarded vinyl exhibition banners	Creates a membrane with taped joints that wraps around the house	
Cladding	Used carpet tiles	Installed on battens to create a ventilated cavity behind, but with a large overlap that hides the fixing	Appropriate details for junctions and openings were developed, including curving the tiles around the corners of the building
Internal walls	Chalk spoil from a local construction site; waste blockwork was also used internally	This was compressed using a technique normally employed to build rammed earth walls to make a wall that flanks the staircase	
Fixings	Second-hand bolts		
Sealant	500 damaged cycle tyre inner tubes	For sealing around windows and sound proofing the first floor	
Kitchen	Freegle website – a free local reuse and recycling service		

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IMAGE CREDITS

Figures 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8 & 3.9 By M.V.D. Burg, courtesy of RAU; figures 3.10, 3.11, 3.12, 3.13, 3.14, 3.15 & 3.16 Courtesy of Brooks Freehill and Mike Moore of tres birds workshop; figures 3.17, 3.18, 3.19, 3.20 & 3.21 Supplied by Larry Wolff, WLC Architects Inc; figures 3.22, 3.23, 3.24 & 3.25 By Dror Baldinger, FAIA; figure 3.26 Courtesy of Overland Architects; figures 3.27, 3.28 & 3.29 By Author; figures 3.30, 3.31, 3.32, 3.33, 3.34 & 3.35 Courtesy of K20 Architecture; figures 3.36,

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4 MATERIALS INVESTIGATIONS

Various industry groups have approached reuse by investigating the opportunities offered by particular materials – examining how to establish circular infrastructures and construction systems for those materials. This chapter describes four very different initiatives that researched how circular systems for reuse could be established at the material/component level.

4.1 NORDIC BUILT COMPONENT REUSE

The Nordic Built Component Reuse project[a] set out to explore new practices for reuse of dismantled building components and materials, resulting in visions of new ways to organize, tender, trade and build with them. The aim was to devise and prototype new systems from discarded building materials that: are beautiful, apply reversible construction principles, are marketable and are possible to manufacture through processes that are effective in cost and energy. By establishing a strong architectural identity as well as a viable business model for reused and upcycled components, the intention was to move the boundary between waste and value, and inspire and assist the development of the circular economy in the Nordic countries.

Demolition practices in Nordic countries today are efficient in terms of separating construction debris and minimizing landfill. However, the project partners felt the Nordic construction industry was poorly prepared for conversion towards a more effective and careful use of these waste resources to capture their potential value. They observed a widespread reluctance of industry professionals as well as building users to incorporate second use materials. The challenge was to find new ways to access this value and find industry acceptance.

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[a] This project was a collaboration between Vandkunsten Architects (Denmark), Genbyg.dk (Denmark), Asplan Viak (Norway), Malmö Högskola (Sweden) and Hjellnes Consult (Norway). This section is a synopsis of its final report, http://vandkunsten.com/wp-content/uploads/2016/11/NBCR-20161107-web.pdf.

Resource Salvation: The Architecture of Reuse, First Edition. Mark Gorgolewski.

The transformational journey from waste materials to valuable new components was investigated through a variety of aspects: technical/practical, environmental, commercial and cultural. Using the Scandinavian SfB building component classification system, a matrix was used as a generator for possible transformations between the original, first generation function of a component and its potential second generation function. In total, twenty different prototypes for construction systems were studied and five key prototypes were developed and analysed in detail. A variety of product stages were considered, including sourcing materials, rehabilitation and processing, design integration, construction and marketing.

A variety of investigative tools were used: full size mock-ups were created to explore details, renderings and design explorations were used to illustrate aesthetic potential, extensive workflow charts assessed practical implementation and life cycle assessment (LCA) was carried out to quantify environmental benefits.

The five key prototypes focused on the following: concrete, clay, metal, wood and windows. These were chosen based on interviews with industry experts and the following criteria:

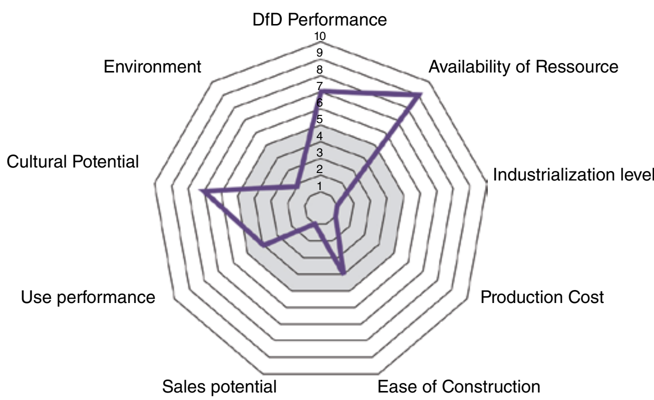
- availability: volume;
- preparedness for off-site industrialization: risks, technology;
- production costs: labour hours, resources, time, process complexity;
- sales potential: attractions, price, competing solutions;
- ease of construction (on site): risks, difficulty;
- in-use performance: including maintenance, risks, requirements, possible reactions;
- cultural performance: experience, identity, architectural motifs, materiality;
- environmental performance (LCA):
- DfD performance: future disassembly process, reuse potential.

The five key prototypes are shown in below:

Concrete
Cutting larger concrete units into smaller modular paving and façade elements displays the aesthetics of weathering and exposing concrete aggregate (Figure 4.1). The complexity, energy intensity and cost of cutting concrete meant that the environmental and business case for this prototype was weak (Figure 4.2).

(a) (b)

Figure 4.1 The concrete wall cladding prototype.



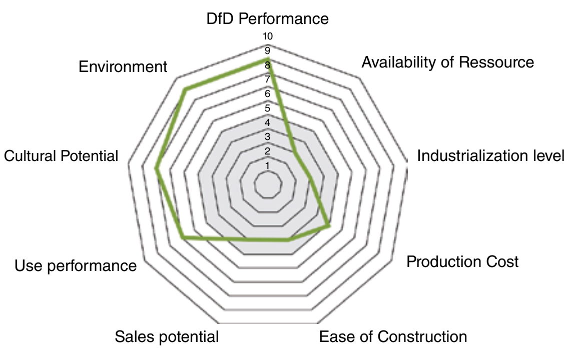
Concrete/
Assessment of Prototype Performance
The assessment of the selected concrete system is less than promising. 6 out of 9 parameters are assessed to be lower than new brick walls made from clay bricks or light concrete bricks. In fact, with 1's for Industrialization Level, Production Cost, Sales Potential, and 2 for Environment

Figure 4.2 Performance diagram for the concrete prototype.

Clay

Old roof pantiles were used to create a new façade system designed for disassembly and with a customized mounting system (Figure 4.3). Though the process is time consuming and availability of pantiles is currently inconsistent, the tiles do weather beautifully like brickwork, which adds to the cultural value and acceptability of the concept, and the environmental analysis is positive (Figure 4.4).

Figure 4.3 The clay wall cladding prototype.

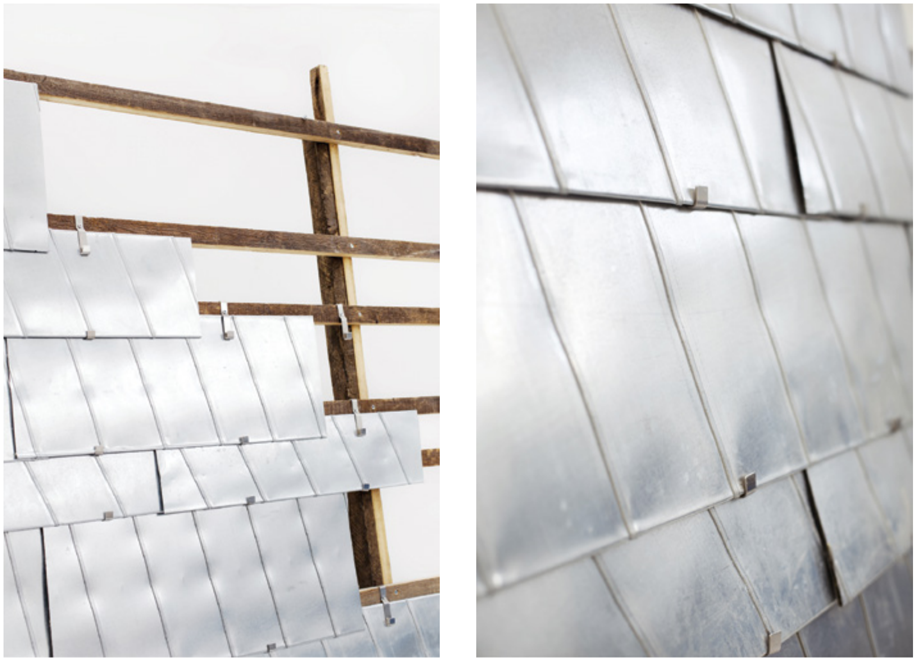


Brick/
Assessment of Prototype Performance
The assessment of the Pantile facade is not promising for a commercial breakthrough.
Four out of 10 parameters are assessed as lower than for a traditional cladding system from traditional cladding bricks or a steel facade.

Figure 4.4 Performance diagram for the clay prototype.

Metal

A new façade system was proposed using rolled metal ventilation tubes and an existing mounting system for slate (Figure 4.5). The aesthetics of the metal surface appears culturally well known and the concept has a strong story – two parameters that add to a strong assessment of the concept. Furthermore, the alteration of tubes to sheets is simple, which results in a positive LCA (Figure 4.6).



(a) (b)

Figure 4.5 The metal façade prototype.

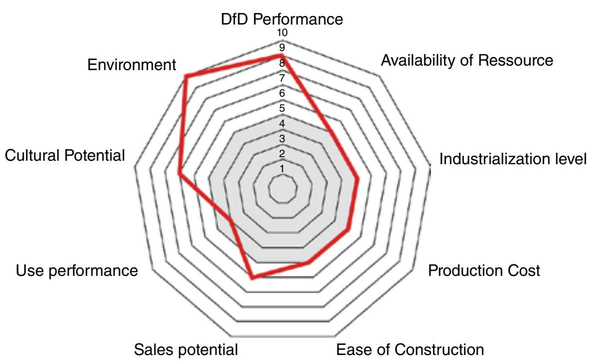


Figure 4.6 Performance diagram for the metal façade prototype.

Steel/
Assessment of Prototype Performance

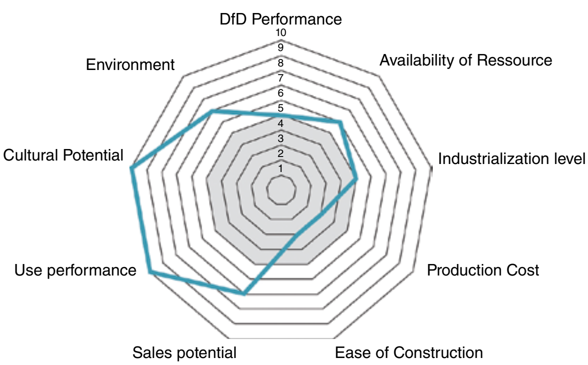
The assessment of the Spiro-facade can be labeled as the least negative as only in Use Performance with a 4 is assessed to be slightly lower than a new product.
At 5, the concept is assessed to be comparable with new product systems for Availabilty, level of industrialization, Production Cast, and Ease of Construction. At 6, Sales potential is a little higher than conventional products and at 7, Cultural Potential is markedly higher than conventional cladding sysytems.

At 9 and 10, Spiro Wall is assessed very high environmentally, in terms of LCA and Design for Disassembly Performance.

The cultural potential includes aesthetics. Here, the Spiro Wall has a very familiar look with a novel twist and possible variety as well as subtle narrative of its former use.

Windows
This system creates a façade screen with reused glazed windows supported by metal profiles (Figure 4.7). It is possible to adapt window elements to a metal support system and to adjust their size by cutting the wooden frame. By using simple wedges to fasten the frames to the metal profile, the new façade screen is fully reversible with beautiful detailing and a positive LCA (Figure 4.8).

Figure 4.7 The reused window façade screen prototype.



Glass/
Assessment of Prototype Performance
The assessment of the selected Glass prototype is very positive in terms of cultural potential, use performance, sales as well as environmental performance (LCA).
DfD, Availability, Industrialization are comparable to new Products.
Cost of production and ease of construction are assessed to be low at this stage, These parameters can be improved and the high merchantability suggests that there is a niche market for this delicate system

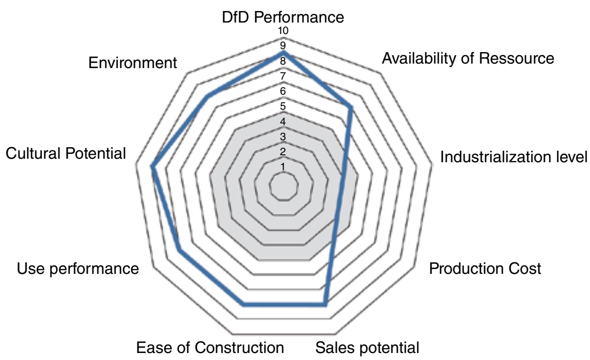
Figure 4.8 Performance diagram for the window façade screen prototype.

Wood

The new 'Nordic Wall' is a double-sided, stackable building block for interior partitions and decorative panels. The sandwich components fit together with a tongue and a groove; they have a core of standard fire doors and cladding in a variety of wooden surfaces from old floors or façades. The LCA shows positive environmental benefit.

(a) (b)

Figure 4.9 The Nordic Wall prototype.



Wood/
Assessment of Prototype Performance
The assessment of the wooden Nordic Wall is positive over all.
5 indicates a traditional solution with new components.

Economically, the concept is estimated to be a little below traditional component (new drywall) in terms of industrialization level and production cost.
All other parameters are estimated to contain a high potential.

Figure 4.10 Performance diagram for the Nordic Wall.

The overall findings of the project suggested the following problems, failures, risks and shortcomings:

- Feasibility – Commercial feasibility was the highest risk of the project. In fact, only the the Nordic Wall has developed into a marketable product by Genbyg. One reason is that a stable delivery is hard to maintain. This challenge has led to a new business model that is based on custom made-to-order and system principles rather than fixed products.
- Failure – In creative and innovative processes that have shaped this project, successes emerge from trial and error – and failures are inevitable. Hence, some concepts failed and were ruled out by poor cost evaluations, others by the environmental evaluation, even though they lived up to other quality parameters for becoming a marketable product.
- Logistics – Handling the odd size waste materials and managing the workshop logistics proved a challenge for the team.
- Technology – This became an unexpected challenge, as it was not clear to the team which technologies were feasible for use on a production line. Furthermore, some of the technologies may not exist yet or have not yet been applied for the purpose. In such cases, possible technological scenarios that could be pursued in further projects were envisioned and illustrated.

4.2 STORYWOOD

The concept of StoryWood[b] (proposed by the Delta Institute) is interesting in the context of urban mining. StoryWood is wood from urban sources, with a '*compelling history and unique provenance that sets it apart from other building materials*'[1]. It is timber material that has been mined from reclaimed wood and trees harvested in urban areas that has a history.

StoryWood highlights the fact that such materials have a unique and interesting past and a story to tell. The value of the wood component depends on how its story is expressed through its end use. So rather than trying to make such materials mimic mainstream, new materials, designers should understand these stories, feature them and make them transparent. In this way the richness of the wood's story gives a competitive advantage and can add value to projects.

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[b] This section is based on information from the Delta Institute's *Toolkit for using StoryWood*, www.delta-institute.org.

In order to tell the story of any material, the supply chain needs to be transparent and understandable. Stories about any forest product start with the origins of that wood: the tree from which it was sawn and how that tree was harvested or the building from which the wood was reclaimed. The stories of mass-produced products are not told, because their supply chains are not transparent. When a material's supply chain is transparent or documented, designers can evaluate whether the material meets their priorities based on its extraction and production, sustainability, support of local workers, or interesting story.[1]

A transparent supply chain reveals the three variables that give a material the potential to tell a story: its source, the proximity of where it came from and its sustainable stewardship. Woods from different sources and different species have different stories to tell; the benefits and challenges associated with each type vary. Use of StoryWood can also support social and economic sustainability goals, including job creation, local business and community cohesion.

The Delta Institute has created a *Toolkit for Using StoryWood* to help architects, designers and developers understand the value

Figure 4.11 Storywood – wood with a history can take many forms.

Figure 4.12 The Recycled Cottage designed by Juan Luis Martínez Nahuel, in Chile, features local reused eucalyptus and rauli from a 1970s house.

of this concept. The toolkit aims to help designers navigate the universe of unique wood products and '*identify, evaluate and share the most interesting parts of a certain type of wood's back story, and, more specifically, it will help to align material choices to achieve LEED certification*'.[1]

The *StoryMaterial* concept can be applied to other materials, such as bricks coming from urban mining and even industrial steel, encouraging designers to think of these materials in a different way to new materials from primary sources. The value of the material's story depends on how its history is captured and expressed through its end use. The uniqueness of each story gives a competitive advantage, which has led designers, such as Reclaim Detroit, Cleveland's Rustbelt Reclamation and Chicago-based groups Rebuilding Exchange and Icon Modern, to build StoryWood into their brands. However, the concept is more relevant to featured components in buildings and less so for residential scale structural framing that is usually hidden within the building.

4.3 REUSE OF STRUCTURAL STEEL

A Eurofer survey of European Union member states in 2012 estimated that construction steel has a 96% recovery rate; 91% is recycled but only 5% is reused.[2] There is significant potential for energy and financial savings if steel building components are reused rather than melted down and recycled. The Building Research Establishment (BRE) in the United Kingdom has calculated that reused steel typically has only 4% of the carbon emissions of new steel.[3] It is estimated that reusing just 10% would reduce UK emissions by 77 000 tCO_2e (Table 4.1). Furthermore, the reuse supply chain will demand new skills and create new employment opportunities. Overcoming the barriers to this could kick-start a market worth of 25 000 tonnes/year, 10% of current UK scrap, with a potential value of £12.5 million. There are also potential macro-economic benefits, as currently around 70% of UK steel scrap is exported whereas a larger reuse market would retain greater economic value within the UK.

Table 4.1 Embodied carbon comparison for 1 kg of steel.[4]

New steel, kg CO_2e	1.53
Recycled steel, kg CO_2e	0.4 kg CO_2e
Reused steel, kg CO_2e	0.03

Two recent Innovate UK projects aim to explore the sustainability benefits offered by steel reuse and identify pathways to overcome barriers:

- *Circular Economy Business Models; Re-use of Structural Steel*.* The aim of the project was to propose a new business model for steel reuse.[5]
- *Supply Chain Integration for Structural Steel Reuse*.** The aim was to address supply chain issues by examining the practical and economic feasibility of establishing an online information portal through which the supply and demand of reused steel are mapped to stimulate a reused structural steel market

The research indicates that, although technically viable, there are significant barriers both on the demand and supply side to wider reuse of steel. Three types of successful and cost-effective scenarios of steel reuse were reported:

1) Recovered sections reused in new design (reduced transport and material costs).
2) Refurbishment of structure *in situ* (with strengthening).
3) Relocation of entire structures to new site.

A radical rethink is necessary around the design and delivery process, as well as a shift in culture necessitating new and

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* Project led by a the Association for Sustainable Building Products (ASBP) in collaboration with Cleveland Steel and Tubes, Steel Construction Institute, Ellis and Moore, UCL ISR and Cullinan Studios.

** Project led by the Steel Construction Institute (SCI) in collaboration with ASBP, University of Cambridge and the National Federation of Demolition Contractors.

Figure 4.13 Steel truss joists recovered and reused in a building in Montreal.

Figure 4.14 This *in situ* steel structure in Toronto was stripped down to its frame and refurbished into a new building.

effective communication lines. Central to the challenge of making reuse more common is the need to share information about steel reuse between the demand side (the client and its design team) and the supplier side (the demolition contractor). For instance, architects and demolition experts may need to work together and develop a common language. A series of online surveys and semi-structured interviews with UK construction industry members indicated that barriers to reuse are largely systemic and need to be dealt with first to increase reuse rates.[6] This requires a coordinated approach across the construction supply chain. The following barriers were identified:

- Economic/cost – There is a perception in industry that reuse of steel is more expensive than new steel, and this was confirmed by analysis. But the differences are small and subject to the varying price of new and scrap steel. This gives hope that this difference could be overcome with larger-scale operations and improved infrastructure. Since 2000 the average difference between the price of new steel beams and steel scrap has been £313/tonne, with a minimum range of £187/tonne. Therefore, steel reuse should be profitable if the total cost of reconditioning, testing, deconstructing and additional transport of the reclaimed steel is between £187/tonne (in the worst case) and up to an average of £313/tonne. This provides an opportunity for the right business model, although the margins are tight. Successful, cost-effective examples of reuse are able to eliminate one or more of the cost components (e.g. testing, transport, re-fabrication).
- Availability/storage – Given the low volume of steel that is being reclaimed for reuse it is inevitable that supply is currently limited. Both supply and demand need to be stimulated and a means of sharing information is needed. Although stockists could hold reclaimed steel, currently this does not mesh well with their usual operations.
- Traceability and certification - Information concerning the provenance of the reclaimed steel and its mechanical and chemical properties is clearly important for designers to be comfortable using the material. In future BIM may provide a mechanism to make this readily available but for today more onerous methods of identifying historical steel characteristics are necessary, sometimes requiring testing. A database of all buildings Tekla files (structural models) would make the steel more easily traceable when a building is deconstructed. The requirement for CE marking under the Construction Products Regulations is a particular concern for all second use materials.
- Lack of demand/incentive – There is a lack of legislative incentive to reuse structural steel and together with an uncertain economic justification there is little incentive for

clients to pursue reusing structural steel other than for principled reasons, to reduce embodied carbon, or for corporate social responsibility reasons.
- Lack of supply chain integration – Construction projects usually have a long life (sometimes hundreds of years) and little connection between the demolition contractor (potential supplier) and a new building client (with its professional advisers). These need to be connected so that information on supply (from deconstruction) can be connected with the demand from the designer.
- Automated demolition and health and safety – Current demolition is automated and destructive for reasons of cost, time and health and safety. Technically it is quite feasible for more deconstruction to occur as long as project plans, schedules and budgets accommodate these activities.

Four mechanisms to overcome these practical barriers are proposed:

1) Creation of a database of suppliers of reclaimed steel – A web-based database of suppliers providing a material exchange facility is a method to overcome availability concerns. This will create a repository of construction steel information to facilitate future reuse of steel if/when the legislative and economic climate make reuse viable or a requirement.
2) A demonstration of client demand – If demolition contractors perceive a demand and a viable economic model they are more likely to deconstruct steel for reuse. Growing awareness of the significance of embodied carbon, material efficiency and the circular economy means that more clients are interested in reuse. These two need to be connected.
   A website portal for sharing information about structural steel reuse, with a knowledge centre that addresses technical information and where reclaimed steel sections can be sourced and traded, can provide clients and demolition contractors with confidence to embrace reuse.
3) Technical guidance and education for the construction industry – Detailed guidance is needed on the process of designing with reused steel, including procedure for testing, with a list of suitable test houses.
4) Government leadership – Various levels of government can influence industry in many ways, such as: incorporating design for deconstruction objectives into local planning regulations, requiring a pre-demolition audit to ascertain what materials could be salvaged, specifying a percentage of all steelwork to be reused, fiscal incentives, public sector procurement rules, initiating a registry for suppliers of reused steel, information sharing, awareness raising and recognition for projects leading steel reuse.

A Reusable Buildings Network (RUBN) has been created by the partners to collaborate on overcoming barriers. The network is developing rules of thumb for reuse in new construction and refurbishment and simple check lists for designing for deconstruction and reuse.

4.4 REBRICK PROJECT[c]

Manufacturing bricks requires large amounts of energy and material resources, and currently at the end of their first use bricks are typically crushed to become waste to landfill or are downcycled to site fill. This happens despite the fact that many types of bricks can easily last for several centuries. One of the problems with the way we currently use bricks is the strength of the cement-based mortars that make it difficult to deconstruct brick walls without damage to the bricks. Developing an automated way of cleaning bricks for reuse can significantly contribute to resource efficiency. The REBRICK project was a European collaboration to address this by:

- developing and modifying existing brick cleaning technology to fulfil regional requirements;
- exploring the market possibilities for reused bricks in Europe;
- marketing the use of reused bricks to key stakeholders in Europe.

The project demonstrated a new approach to what was previously demolition waste, potentially saving energy and resources (Figure 4.15). Danish companies Gamle Mursten (meaning Old Brick) and Scan-Vibro in collaboration with D'Appolonia SpA from Italy developed a new patented technology that consists of an automated process for sorting of demolition waste, a vibration-based system that both sorts the demolition waste and cleans mortar from old bricks without using water or chemicals, thus constituting a very environmentally friendly process. The technology exploits the reuse potential of used bricks, maintaining a higher value use for the material than just crushed aggregate. The Danish Environmental Protection Agency estimates that each reused brick saves 0.5 kg of carbon dioxide emissions compared to typical new bricks. The bricks are more expensive than the cheapest bricks on the market but cost competitive with good quality bricks, and are particularly sought by designers who want a less machined appearance.

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[c] REBRICK is a part of the Competitiveness and Innovation Framework Programme (CIP), an initiative of the European Union, and received a public grant partial funding for demonstration from the EU. This summary is based on project reports, http://www.gamlemursten.eu/

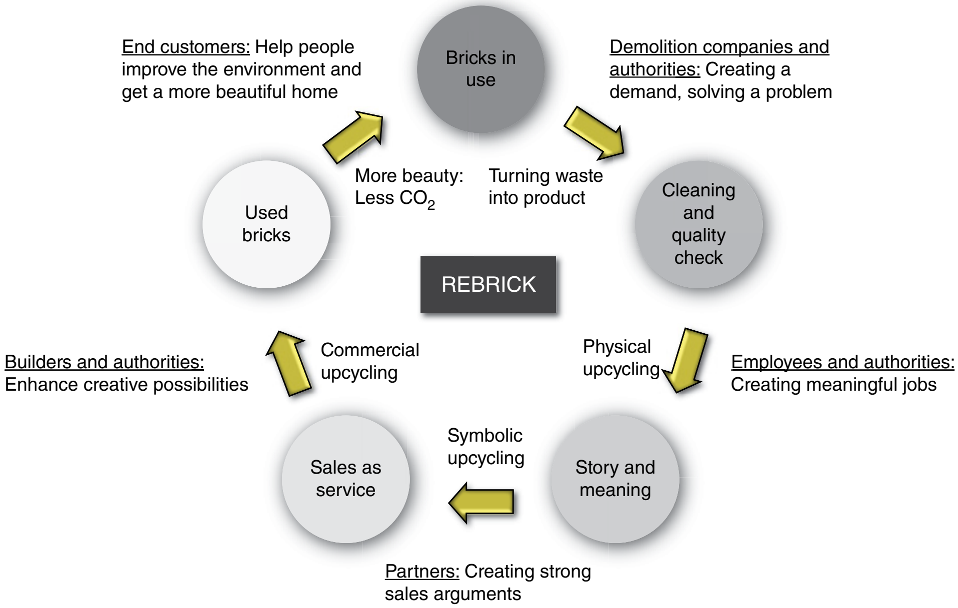

Figure 4.15 Diagram of REBRICK value stream.

Since there is no harmonized European standard for reused bricks, the REBRICKS have been approved for CE marking based on a European Technical Assessment (ETA), which is a voluntary process, providing information declaring the essential characteristics of a construction product where the product is not covered by any harmonized European Standard.

The process starts with mechanical separation of the brick from other demolition materials. At local recycling centres bricks now have their own dedicated containers. When a container is full, it is taken to the Gamle Mursten factory, where whole bricks are then separated from damaged bricks by an automated system. Whole bricks are cleaned by a vibration-based rasping technology process and then sorted manually after visual inspection of characteristics, quality and colour. Cleaned bricks are placed on a conveyer system and an automated system stacks and wraps them ready for transport to a new construction project (Figure 4.16).

In addition to developing the patented technology, the REBRICK project aimed to demonstrate commercial scale application for various European markets. Initially, full-scale demonstration was implemented for the greater Copenhagen area with a capacity of 4000 bricks/hour to demonstrate the technical ability to produce reusable bricks within market specifications. Bricks from the agricultural University in Copenhagen and from the former

(a) (b)

Figure 4.16 Brick recycling process.

Carlsberg plant were the first to be processed. The facility now receives brick waste mainly from Copenhagen and Zealand (Figures 4.17 and 4.18). By 2017 three factories were in operation in Denmark processing 4.5 million bricks/year, selling to northern Europe. The old bricks typically originate from buildings from 1900 to 1955 that are being demolished.

Figure 4.17 These town houses on Brygge Island, Copenhagen, designed by Vandkunsten were built using 640 000 yellow machine scrubbed brick that came from Værløse airfield and Hunsballe Seed facility in Slagelse.

Figure 4.18 Interior of the town houses on Brygge Island, Copenhagen.

The production can be customized to different regional requirements within Europe with differences in labour costs, brick weight and mortar types. Bricks with a low-to-modest cement content in the mortar can be processed. Furthermore, the machine can be disassembled and the entire production facility can be moved to another location in a matter of weeks. Hence, it is technically possible to temporarily locate the facility close to large demolition projects.

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IMAGE CREDITS

Figures 4.1, 4.3, 4.5, 4.7 & 4.9 by Kristine Autzen, courtesy of Vandkunsten; figures 4.2, 4.4, 4.6, 4.8 & 4.10 Courtesy of Vandkunsten; figures 4.11, 4.13 & 4.14 By Author; figure 4.12 Courtesy of Juan Luis Martínez Nahuel; figures 4.15, 4.16, 4.17, 4.18 Courtesy of Gamle Mursten

5 PRACTITIONERS

This chapter describes the experiences of four organizations that have considerable expertise of working with reuse of materials and components and have developed business models based on the circular economy. They all responded to a list of questions about how they are able to put reuse into their core activities from a design and construction perspective, and how this affects their process of creating buildings.

5.1 ROTOR

Rotor is a new type of organization that offers a variety of services and initiatives to address material flows in the construction industry. Based in Brussels, Belgium, it develops critical positions on design, material resources and waste through research, exhibitions, publications and consultancy. On a practical level Rotor handles the design and realization of small architectural projects and acts as a supplier of reclaimed materials. Below Rotor explains its approach to maximizing material reuse.[a]

How do you work to maximize material and component reuse in the built environment?

Members of Rotor are actively developing a range of services aimed at facilitating the reuse of building materials and components, and have established a variety of relationships with designers. For some projects, Rotor acts as the principal designer, directly appointed by the client. In other cases, it is appointed as a consultant to the design team. Rotor has also put in place various initiatives to improve the availability of second use materials, and finally sometimes it merely acts as a supplier of second use materials.

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[a] This section was prepared with assistance of Michael Ghyoot of Rotor, http://rotordb.org/

Resource Salvation: The Architecture of Reuse, First Edition. Mark Gorgolewski.

Projects where Rotor acts as the principal designer are typically for the design of interior spaces, which allows it to control the whole process and trajectory of the elements from their source to their new destination. For example, when hired to design Parodi's bookshop interior, Rotor started to compose a palette of distinctive elements that could answer all the specifications for this space. It used ceiling elements taken from a bank headquarters building (Figure 5.1), which had been in storage for a few months, and created shelving elements in the showroom (Figure 5.2). The small holes in the melamine plywood that were originally for acoustic purposes could be easily used for a discreet fixture system that allows the books to be displayed according to the needs of the shop owner. Also for this project, it discovered a unique canvas representing mountains that had been used as decor for a spectacle at the Brussels Royal Opera. This provided a distinctive wall covering, far better than what was available through wallpaper catalogues (Figure 5.3).

When acting as a consultant, Rotor's role is to help the design team to integrate reclaimed elements into architectural projects. Usually, it is directly contracted by the client for this role. Depending on the stage of the project when it becomes involved and the conditions of the project, this can be a more or less ambitious operation. In some cases, the role is limited to advice on a few reused materials that could possibly be included in their project. In other cases, reuse strategies are fundamentally integrated into the design strategy by involvement throughout the whole design phase. This consultancy service can also provide technical tests (for example for the remanufacturing of elements) and mock-ups.

An example of this is a design proposal for an architectural competition for the MAD fashion Centre in Brussels conceived in a joint team with the architecture office V+. The aim of MAD is to regroup the offices and workshops of organizations that foster Brussels-based design and fashion talent. V+ and Rotor worked together to develop a project that is radically conservationist. Instead of demolition, as was suggested by the brief, it proposed to preserve the building volumes and make as much use as possible of what is already there. The project displays a high level of tolerance towards the existing and combines this with high standards for anything new that is to be added. The end result is a proposal that is far richer than could be realized with a design from scratch (Figure 5.4).

Some of Rotor's initiatives do not deal directly with designers but try to craft a general framework that makes implementing reuse strategies easier for all in the construction sector. For example, Opalis (http://opalis.be) is an online database presenting all the major resellers of second hand construction elements in

Figure 5.1 Ceiling elements salvaged from a bank building.

Figure 5.2 Ceiling elements reused as shelving components in Parodi's bookshop.

Figure 5.3 Wall covering reused from the Brussels Royal Opera in Parodi's bookshop.

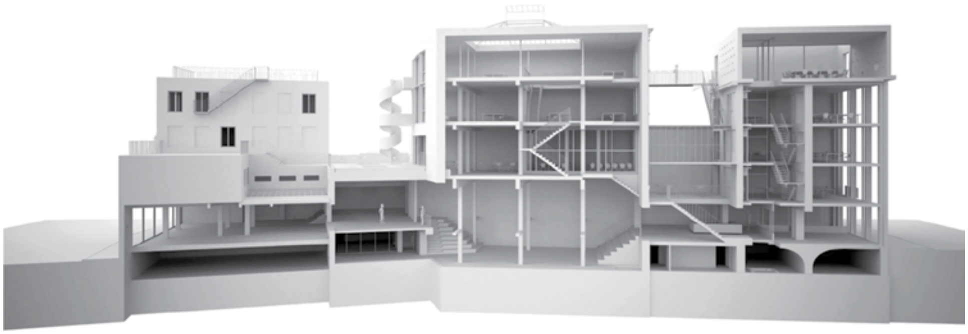

Figure 5.4 Proposal for MAD Brussels for a design and fashion talent incubator.

Belgium. Rotor staff visited each organization and the services and the materials they offer are documented on a specific web page. Opalis is a way to make the existing salvage sector more visible and to help designers, contractors and owners find professional partners to source (or to resell) reclaimed components of high quality.

In the same category of initiatives is the Vade-mecum, which is an initiative that sets out comprehensive legal and practical guidelines and creates document templates for public authorities who wish to encourage the reuse of building materials in public works. Working with a legal expert the team carried out a thorough investigation of the legal framework of material reuse in public works based on Rotor's hands-on expertise acquired over many years of salvaging building components. It presents different options for public bodies to divert construction materials to the second use sector during demolition or renovation of their estate. The Vade-mecum proposes a step-by-step method to organize the identification, reclamation and transfer of reusable materials in accordance with public procurement legislation. For each step standard templates for contractual documents and details of appropriate schedules are provided for use by the relevant public authority for different procurement strategies.

Finally, Rotor also acts as reseller of reclaimed components that it dismantles or acquires during demolition works. This is the core business of *Rotor Deconstruction*, a spin-off organization launched in 2014. In this case, Rotor act as a supplier of materials and often provide advice about the best way to use the available reclaimed components. This way of working has allowed some exemplary projects to occur, conceived and realized by others, using reclaimed materials supplied by Rotor.

How do you present the idea of material/component reuse to clients?
Most Rotor clients already know that they want to use reclaimed materials and components, so the discussions are rather about the right choice of element or the best way to use them. Sometimes, it is necessary to moderate the enthusiasm of some designers or clients to use reclaimed components whatever the problems. Rotor takes a pragmatic approach and feels that it is better for the reuse sector to avoid a dubious proposal rather than have to deal with the consequences of a bad decision.

How does the design and construction process have to adapt?
Rotor believes that circular material approaches require re-examination of the practice of design and the relations between the different actors involved in a project: the client, consultants, contractors, the trades. Design becomes quite different when elaborating a project around something that is already there. The designer has to adapt their ends according to the means. Of course, questioning the way the material economy is organized can be seen as an obstacle, for it takes people out of their comfort zone and can make things more complicated, less streamlined and places more responsibilities on actors who are already very busy. While taking these concerns seriously, Rotor sees reuse as an opportunity to reflect on typical practices and to question how things work – or do not work.

In its projects the process varies considerably depending on circumstances. In more ambitious projects it is necessary to develop a specific design that responds to the requirements of particular components. In this case the reused elements are primary and the design has to adapt to suite their characteristics, which need to be understood at an early stage in the process. Sometimes the project has to adapt to an important component with a non-standard shape or dimension. Second-hand window frames are an example of this; instead of producing a new frame according to the dimensions specified by the designer, the size has to be adapted according to availability. At other times, inspiration comes from the eloquence of the material. Some used materials come with a story, a strong narrative that the designer might want to expose in a new project – either to show it off or to conceal it in the general narrative.

In some cases, it is possible to replace a new material by an exact reclaimed equivalent, for example door latches, sinks, paving and so on. Sometimes it may even be difficult to determine whether it is new or reused. This can occur with little impact on the design and substitution can occur late on in the process. In the Abattoirs de Bomel project in Namur, Belgium, a

Figure 5.5 The cafeteria of Bomel reuses furniture from a former Générale de Banque.

renovated 1940s former slaughterhouse, different elements from nearby deconstruction sites were gathered and used in a cultural centre. A sort of copy–paste strategy was implemented for these elements. For example, elements of the cafeteria at the headquarters of the former Générale de Banque, which was under demolition at the time the project was being designed, were used for the new Bomel cafeteria (Figures 5.5 and 5.6). The storage cabinets for the centre came from another dismantled Brussels office building. They were carefully numbered, disassembled, trucked and re-assembled, and sometimes transformed, on site.

How do you find and secure salvaged materials/components?
Although there is an element of good fortune in the process of finding appropriate used materials and components, Rotor believes this aspect is not entirely based on luck, as it largely depends on awareness of opportunities and possibilities. Some items have a strong affinity for reuse, but it is still necessary to pay attention to discover them and make good use of them. One way to cultivate such an attitude is to carefully survey the resources found in a client's estate. It is a strategy used in many of Rotor's design projects. Many clients, particularly those with a portfolio of buildings, have a stock of unused elements, a reserve of not-yet-discarded items that could be reused. When the specifications of the project are more demanding, the focus

Figure 5.6 Ceiling elements from the Générale de Banque used in the cafeteria of Bomel.

of research is extended to look for elements in different places: on the second-hand market, on the Internet, in deconstruction projects and so on.

Rotor has arrangements with some real estate developers who own large office spaces in Brussels. When changes to a building or interior spaces are scheduled a survey of reusable elements is carried out and Rotor arranges to remove the useful components. This reduces disposal costs for the owner. Other organizations contact them because they have heard of their activities and services. Rotor also remains attentive to buildings due for demolition and proactively establishes contact with the owners. However, it is sometimes difficult to match supply and demand. It often tries to sell components directly from the site using its network of contacts, to avoid additional handling. Nevertheless, it has found that stocking elements is a way to broaden the window of opportunities and provide more time for a material to find a new destination. But maintaining a stock has an additional cost that has to be carefully taken into consideration.

What are the cost implications?

Costs are a complex issue. Reuse strategies are not necessarily cheaper than using new materials. Practically, reuse is often

not so much about getting a cheaper alternative that meets the same requirements as getting a product of higher quality, or with more personality, for the same price. For instance, instead of using anonymous standard bathroom sinks made '*we-don't-know-where*', it may be possible for a project to use a series of aesthetically appealing bathroom sinks produced locally in the 1950s.

However, Rotor strongly believes that the economics of reuse are totally different to using new elements. Even if the final price for the client may be roughly equivalent, how the money has been spent can vary greatly. For instance, in Rotor's projects the cost of raw material is often low compared to a more typical approach. Also, less time is spent choosing elements from a catalogue or creating virtual simulations. But more labour is required due to all the deconstruction and remanufacturing operations and the logistics involved with identifying appropriate used components.

Secondly, the economics depend on the type of component and its characteristics. For example, new ceramic toilet bowls are so cheap to produce that it is hard to compete with a salvaged equivalent (because of the cost of labour involved in the dismantling and the remanufacturing operations, and also maybe because of the negative connotation a reused toilet can provoke). Other elements are much harder to compare with an equivalent on the market today. For example, exotic woods that were largely used in the 1950s and 1960s, and which are now endangered, have no current direct new equivalent and have an individuality value. Reclaimed solid oak flooring can compete well on cost with equivalent new solid oak flooring, but not with cheaper plywood and chipboard based floors. Someone looking mainly for a cheap floor would not buy the reused oak floor, yet someone looking for a high quality floor might find it worth the price.

How do you maximize the potential opportunities that reuse offers?
Rotor believes that the reuse of construction materials and components has the potential to stimulate local economic initiatives and provide interesting and meaningful jobs. It also provides an alternative to destructive ways of dealing with resources – an alternative that takes into account the intelligence and energy embedded in them. Yet, reuse still has to find its place in the context of conventional (de)construction practices. This process will take time. In comparison, the development of the recycling sector in Belgium took two decades to become established (and is still evolving); it required considerable effort in research and development, adaptations of the legal context, technology transfers and development of new entrepreneurial activities and new business models. Today, in Europe there is

positive political climate to develop reuse practices in the construction sector but there is no reason to think reuse can occur in an instant. It may be necessary to start quite modestly and to extend progressively the spectrum of potential reuse materials.

Rotor often considers a '*reusable*' component is a previously used component for which there is a demand. However, this definition puts the accent on the demand factor. But demand may vary according to different factors: technical (can it be reused?), commercial (are all the operations worth the final price?) or more subjective (is there someone according value to it, willing to acquire it for a specific price?). None of these factors are fixed. But all of them need to be addressed to expand the range of reusable materials. For example, Rotor recovered a stock of L-shaped, white, melaminated plywood boards from an office building where they were used as radiator covers (Figure 5.7). Initially they had no demand for these. But they were able to generate a demand by creating various solutions, meeting differing needs. In the Belgian Pavilion of the Venice Biennale in 2010, they were assembled in pairs to make small portable benches. At the Abattoirs de Bomel project, they were stacked on each other to make office cupboards (Figure 5.8a), but also cut in thin slats to be used as corner ties to support shelves (Figure 5.8c), used vertically to make the corners of a desk (Figure 5.8b) or in the design of a rolling counter. In yet another project, they were used to make small stools. In every situation, the fact that these elements were readily available gave another dimension to the design phase than if starting from scratch.

How do you deal with codes and performance issues?
The materials Rotor deals with are mostly interior elements, which are subject to less rigorous code and performance requirements. Nevertheless, Rotor has explored performance questions and their implications for the reuse sector in several research projects. For instance, Rotor is working on a study concerning the necessity for a CE-marking for second use material. Although European regulations about the commercialization of construction products remain silent on this specific aspect, it is possible to interpret that reused materials do not need CE marking. What is needed, though, for technical and commercial reasons, is an assessment of the performance of these types of products. There is still a big question on how to organize this assessment and according to which protocols.

What are the most common barriers that you encounter to material reuse?
An obstacle often encountered is the organization of public procurements. In these projects designers are required to

Figure 5.7 L-shaped melamine plywood components salvaged from an office.

(a)

(b) (c)

Figure 5.8 Various new uses for the melamine ply L-shaped components.

specify neutral elements not to distort the principle of concurrency and to permit any provider to propose a solution as long as it meets the general requirements. The problem is that reused components are rarely so generic. They are often hard to describe in such a neutral way due to the fact that they are very specific, situated and hard to substitute by another component.

What needs to happen to make material reuse more common?
There are two complementary aspects to this: firstly, what should the reclaimed material sector do in order to find a broader audience and market for its products; and, secondly, how should conventional design and construction practices be adapted in order to be able to integrate reclaimed components? Both need to be addressed and need different responses.

Some of Rotor's projects such as Opalis, Vade-mecum (see above) and their research reports try to address the first aspect of the problem. They seek ways to professionalize the reclaimed materials sector in order to meet the requirements of mainstream industry. However, more work is needed; in particular, there is a need to document the technical characteristics, establish new commercial channels and to guarantee stability of supply.

When acting as a designer, Rotor aims to address the second category and examine conventional design practices. Mostly its projects have unique contexts, where the requirements of mainstream industry are less pronounced. In the role of interior designer it has been able to convince clients to give it free rein to manage the project budget and split this between materials and labour according to specific project needs. Thus, Rotor is able direct resources to finding appropriate materials, propose design/build strategies and manage the construction process. This makes its process very distinct and perhaps difficult to scale up, but the features of flexibility in budgeting, materials choice and timing are important.

Rotor feels that it has started to collect the low-hanging fruit – the construction elements that can already be reused without major difficulties – in the hope that these actions will demonstrate that reuse is indeed sensible and provides a good basis to progressively aim at higher fruit. In the long term it is working towards a time when the two aspects will coincide, that the construction industry will embrace more reuse strategies and the second use materials suppliers will develop, in parallel, processes and strategies to meet this demand.

5.2 MILESTONE PROJECT MANAGEMENT

Gerry Humphreys of Milestone Project Management in Winnipeg, MB, Canada, has developed a reputation for a construction process which is participatory, integrated, socially responsible and extensively uses salvaged materials and components. His building projects are usually community-based, high performance buildings that have a low environmental impact and are award winning. This section describes his approach to maximizing material reuse.[b]

How do you work with designers to maximize material/ component reuse?

Working on many projects with reused materials over fifteen years, Milestone has learned that once the concept of a building project is formulated and the drawings are well underway, the advantage of using salvaged/reclaimed material and components diminishes and is at best token but usually non-existent. To be successfully and seamlessly integrated, materials from deconstruction (and other salvage) have to be introduced at the concept design stage and requires strong client commitment. In the past, the pyramidal organization of project delivery with the architect as prime designer often restricted material reuse, particularly if the architect was not keen on the idea. Today the process is often changing to recognize the value of integrated design. Although the architect plays a key role, the client, various consultants, construction manager and, possibly, the community, all share the same communication level and are involved in an open dialogue allowing material reuse to be openly discussed and the ideas of all participants can be captured. This strategy has often been adopted when dealing with green buildings, where it is accepted that shared knowledge benefits good design, and helps facilitate material reuse.

This template for project delivery was firmly imprinted when Milestone became the construction manager for the Mountain Equipment Coop retail store in Winnipeg, Canada (Figure 5.9). The client wanted equal communication across the board, so rather than one prime contract with the architect it created a number of individual documents to contract separately with the architect, each of the consultants and the construction manager. This allowed each team member an unimpeded voice at the

[b] This section was prepared with assistance of Gerry Humphreys.

Figure 5.9 Mountain Equipment Coop in Winnipeg.

table and facilitated a process that allowed considerable reuse of materials on this 2 800 m^2 (30 000 sq. ft.) building that was completed within budget and on schedule, receiving numerous awards.

How do you present the idea of material/component reuse to clients?

One of the biggest hurdles when approaching a client about the second use of reclaimed materials, especially when they are just embarking on their *new* building project, is getting past negative words like *waste*, *garbage*, *discarded* and *salvage*. These types of expressions reinforce the impression that materials are substandard, not adequate and will give the client a poorer-quality building. This conversation has to change to a discussion of sustainability, good economics, high social values and what is good for the earth in general. Milestone's clients have typically already heard terms like *green building* and *sustainable building*

and they have a general understanding of what that means. They also know that both government and private funders in Manitoba favour buildings that use local and used material, as this typically generates local employment that benefits the community.

How does the design and construction process have to be adapted?

Milestone is normally hired for a project prior to the design team being selected. This allows the clients to set their goals, purpose and mission, and to establish a preliminary construction budget without any preconceived vision of the physical building. When the design team is ultimately hired there is an established reference guideline that lays out the client's mission statement and wishes; it also includes environmental goals, such as what percentage of reused materials they would like included, the recycled content of any new materials and a statement on the future deconstructability of the building. Clarity about resourcing building materials at the preliminary stage can add intelligibility to the design. For example, is there a building on the site (or nearby) to be deconstructed? Can this be a source of materials? Is there a local (or other) source of quality recycled material and what does it have to offer? Investigations are needed to establish what materials/components are present and how they can fit in. These types of questions give a quick assessment of the stock of materials and components that are available for incorporation at the concept design stage. The resulting initial design undergoes a preliminary construction estimate that takes into consideration any included reused material. The balance of the budget estimate assumes that the remaining materials will be new (off-the-shelf). This process establishes an agreed budget and design concept. The team then moves on to finalize the construction drawings. At this stage the different layers of design are reconsidered to look for further opportunities to incorporate used materials/components. Each design decision is questioned specifically regarding materiality:

- Is there is an equal or better reused material/component available and is it the same cost or more economical than conventional?
- Can the design adapt easily to this replacement using the reclaimed material/component (instead of new)?
- If a reused material/component is not available does the new option contain a high recycled content and can it be built to be recycled at the end of the building's life?

Large structural components (beams and columns) are often readily available from salvage. The engineering consultant will know exactly what span and size is needed for beams, joists and columns (if new), and can easily perfom substitute calculations for reused structural components. Next, landscaping, interior

partitions and exterior envelope elements are considered. Finally, the focus shifts to finishes, architectural details, historical details, hardware, furniture and fit-out.

How do you find and secure salvaged materials/components?
Milestone sources reclaimed materials and components a number of ways, including from: salvage yards, demolition tenders, government demolition, websites, salvage companies and, especially, word of mouth. When self-deconstruction is not available, sources as close as possible geographically are used. Coordinating the timeline for delivery to the project site is important, as double handling and storage can add unnecessarily to the overall budget.

The following five steps are used to help identify what happened to materials that come from a deconstruction project:

1) Identify reclaimed material/components with potential to fit directly into the new build (substitute for new).
2) Identify materials/components not required and find other markets. This could mean selling with funds used for the benefit of the project, trade for materials needed, or possibly subuse – for example as formwork or hoarding.
3) Can materials be modified in dimension for reuse? For example, can a 50 × 200 mm (2″ × 8″) timber be ripped into two 50 × 100 mm (2″ × 4″) timbers and use on site?
4) Can materials be modified in form (back to base composition or fibre) and be reused? For example, can scrap wood be mulched and used in landscaping or can concrete be crushed and used as fill?
5) Finally, identify any remaining material unsuitable for recycling and destined for landfill (minimize).

When project deconstruction is not available as a source for materials in a new project:

- Can a *new* item be replaced with a *reclaimed* similar item from the marketplace (economically)?
- Can a *new* item be replaced with an equal but different type of *reclaimed* material from the marketplace? For example, can a new steel column be replaced with a reclaimed wood column that can structurally do the same job and is available?
- When it is necessary to purchase a *new* material does its composition contain a high recycled content?
- When required to purchase *new* material can that material be deconstructed and reused or recycled at end of the building's life?

Sometimes reused materials and components can be purchased in a similar way to new construction materials from regular suppliers.

However, many reclaimed material are '*a material of opportunity*' and have to be purchased when available and not necessarily in the proper sequence of the construction timeline. In anticipation of this, the project estimate typically includes a petty cash line that allows for immediate purchase of available items and quick re-imbursement back to the account. A practical example of this is the West End Cultural Centre in Winnipeg (Figure 5.10). The project budget included an allowance for medium grade hardware, doors and interior storefront. An opportunity arose to get higher grade hardware, doors and storefront from the deconstruction of a provincial courthouse in Calgary (Figure 5.11). A crew was sent to remove the required items, which were transported to Winnipeg for installation in the new project (Figure 5.12). This generated substantial savings in the budget line from having to purchase these same items new. These types of innovations helped the project achieve LEED Silver certification.

On a practical level the best advantage is in structural materials. These include steel and timber beams, joists, columns, cast iron columns, brick and face stone. Under the guidance of a skilled and creative structural engineer these reclaimed materials can be intermixed and swapped to suit the project. Winnipeg has a large stock of steel-framed, timber-framed and load-bearing brick buildings that are being decommissioned and deconstructed, and there are a number of salvage companies that will reclaim material when asked.

What are the cost implications?
It is a common misconception that reclaimed materials increases costs. In fact, it is usually design inflexibility and lack of communication that add to costs. Cost tracking for the Mountain Equipment Coop project showed that reused materials reduced the overall costs even when additional labour was considered.
A construction management contract allows strict control of the project budget. The flexibility of this type of contract in an integrated design atmosphere allows for all parties to be continually aware of costs and for close control by the design team and client. An example of this type of approach was the La Cuisine food service structure at Birds Hill Provincial Park (see section 3.3.2). This project had a limited fixed budget and a design requirement that the building had to be built with as much reclaimed or recycled material as possible. The award winning building met all the programme requirements and was built within the construction budget using reclaimed materials because of a flexible and communicative design team and careful budgeting.

How do you maximize the potential opportunities that reuse offers?
Deconstruction and material reuse, besides being environmentally sensible choices, offer many opportunities outside of what is normally considered in a standard construction process. The

Figure 5.10 West End Cultural Centre, Winnipeg.

Figure 5.11 Storefront removed from Calgary courthouse.

Figure 5.12 Storefront of the West End Cultural Centre in Winnipeg which reuses components from a Calgary courthouse.

mechanics of taking a building apart to preserve material integrity requires a high degree of labour. This can offer creative opportunities for the benefit of the project and community. Milestone has consistently used deconstruction as an employment stepping stone with on-the-job training for people who have had the misfortune to end up in a circle of poverty. Labourers are screened and selected through a local street-side drop in centre (Figure 5.13). They are provided with basic personal safety equipment (usually donated from local builders supply stores) and given an outline of site and personal safety by workplace health and safety officers. They are then employed through the project *site work* budget and given on-site training in the process of deconstruction. The best part of the programme is that they are told to observe other trades and consider if they may like a particular type of work. The other trades are then approached to ask if they would be willing to allow such a worker to work with them for a week for free (the programme will pay their wages), with the provision that if the worker likes the trade and the contractor likes the worker they will hire them. In this way unemployed labourers find employment and are replaced with other unemployed persons. When this programme was first started it had a 20% success rate for people transitioning across to full employment. More recently, that rate had progressively increased to nearly 80% and

Figure 5.13 This hospital building was deconstructed by Milestone using trainee labour.

has attracted the attention of the Province and social agencies leading to grants to offset running cost.

How do you deal with codes?
For projects that involve deconstruction and reuse of materials, Milestone invites building code officials to participate in the integrated design process and their comments are considered and incorporated, which helps to earn their confidence. Typically, their participation is just in the first design charrette and then they are aware of the objectives and prepared when permits are applied for.

Any code issues regarding structural materials and members are dealt with by the structural engineer. Using steel as an example, tables are usually available even for older sections and when in doubt the engineer can always beef-up sections, add stiffeners, make adjustment details and modifications under their project seal. Outside certification companies and material testing are occasionally used as required to prove the quality of components.

Durability is achieved in the same fashion as new. The organic and manufactured characteristics of the components are generally no different, whether they are new or reclaimed. Old steel has to perform the same as new steel. Old or first growth timber can actually be better than the grading of today, but regardless must perform as new. A rule of thumb used for timber is that reclaimed should be one grade and one dimension greater than new for the same performance. For example, if a 50 × 300 mm (2” x 12”) new SPF joist is required then a reclaimed 50 × 350 mm (2” x 14”) Douglas Fir joist can replace it.

What are the most common barriers that you encounter to material reuse?
The most common problems or barriers that Milestone encounters are still ones of visual perception. Milestone rarely gets any stated concerns regarding reused materials or components that are to be used as structural assemblies. For the most part these type of components are buried within the fabric of the finished building. If structural components are to be purposely exposed, it is usually to feature the material. Typically, problems with design and satisfying clients are related to the visual aesthetics of reclaimed materials, making them look contemporary and up to date. Good design, open client communication, creativity and direct consultation with the applicable trades can usually accomplish acceptable solutions. For example, in a recently completed extensive rebuild of a century-old church in Winnipeg the massive interior was converted into a four-storey affordable housing project (Figure 5.14). The former church interior was deconstructed,

Figure 5.14 The interior of this former church in Winnipeg was deconstructed and converted to new uses.

requiring removal of an abundance of heavy carved, ornate and plank oak, all reclaimed for reuse. The former church congregation space was reduced to around one tenth of its former original floor plate and set up as a leased space in the corner of the same building. A design charrette connecting the church congregation, interior designer, construction manager and carpentry trade helped to create the new more modern and comfortable congregation space. The salvaged materials were successfully integrated into a contemporary sanctuary that still respected a traditional environment.

Fortunately, most Milestone clients are agreeable to the idea that design can be sculpted to accommodate the available materials. When reclaimed materials are presented as just another building resource in the same fashion as any new material that is locally available, the design conversation rarely goes off track. In reality, all building construction requires designers to take into consideration which materials are readily available within the local environment. That is why steel or heavy timber buildings are not usually seen on the African savanna; these materials are not readily available there. It is an important realization that high quality reclaimed and repurposed building

materials are just another resource on the palette of locally available materials.

What needs to happen to make material reuse more common?
As with all concepts that challenge conventional practice any new idea, to be fully adopted, requires acceptance by parties that are at the forefront. Designers should add a category to their resource catalogue for reclaimed, recycled and recyclable materials. Universities and colleges need to have environmental consequences as part of their academic criteria and clearly understand that there is a design option for reclaimed, recycled and recyclable material. If design professionals learn this early and consistently, this will translate to their everyday work (and change old design thinking).

Governments should lead by example and realize the power they have in what they do and not just in what they say. For example, government-sanctioned demolition should be redefined to harvest as much quality material as possible by selective deconstruction and have demolition only as the option of last resort. Harvested materials should be offered via brokerages or through websites. Also, governments, as tenderers of massive amounts of publicly funded or compensated projects, should include in their Request for Proposal (RFP) requirements that deconstructed material from their sizable resource be incorporated into new projects. This material could be offered at minimal to no cost as the dollars spent have already been absorbed in the deconstruction. This would ultimately lower the overall cost of new construction on public and government compensated projects.

5.3 LENDAGER GROUP

Since its creation in 2011 in Copenhagen, Denmark, Lendager Group has worked as designers, producers and strategists on circular design solutions, applying its thinking to buildings, products and strategies that enable resources to be circulated at their highest possible utility and value. This has given it considerable experience with creating competitive, long lasting, innovative, circular solutions and reducing waste. Its ideas for maximizing material reuse are explained here.[c]

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[c] This section was prepared with assistance from Anders Lendager, Malene Køster Lasthein and Ditte Lysgaard Vind from the Lendager Group, http://lendager.com

How do you work to maximize material and component reuse in the built environment?
Lendager Group's projects all aim to accelerate the transformation towards a circular economy. Using tools such as life cycle assessment (LCA), life cycle costing, mapping of material flows and value creation it demonstrates that sustainable and circular approaches are consistent with growth, aesthetics, cost reduction, healthy citizens and reducing environmental impact. It is constantly looking for opportunities to push the boundaries of sustainability and circular design thinking within the built environment. Its work is inspired by the concept of '*upcycling*', a process whereby the value of discarded materials is increased through a reuse or recycling process, ideally also creating products with a longer lifespan than the original (see also Chapter 2.5). It applies this thinking at a variety of scales, from the building component, to whole buildings, to urban areas. The group has three principle areas of activity:

1) Architectural design and urban metabolism projects that focus on circular approaches: working on the design of buildings and cities using readily available waste materials, upcycling these to a higher value.
2) Strategic consultancy and analysis for companies that are interested in resource efficiency: analysing new ventures and delivering tools for companies and municipalities to realize their potential within the circular economy.
3) Developing upcycled building components and materials from locally available industrial waste steams or salvaged construction materials: this is often done in partnerships with manufacturers or waste handlers and has expanded beyond the building industry to other sectors.

How do you present the idea of material/component reuse to clients?
Lendager Group is able to show evidence of the cost competitiveness and environmental benefits of its projects; this is a powerful tool that attracts clients to its work. One of its early projects in 2012 was Upcycle House (Figure 5.15), a pioneer affordable, contemporary, single-family home built in Nyborg, Denmark, from cyclical materials at no additional cost to a typical family house. The interdisciplinary design team used creative sourcing and undertook a wide-ranging search for suitable materials that had a previous life and could be reused (Figure 5.16). When using reclaimed materials was not feasible due to performance or cost, it found materials with a high recycled content. The materials were considered from four different aspects:

1) Lifespan and durability.
2) CO_2 reduction – LCA calculation.
3) Economics – cost compared to typical solutions.
4) Availability – local supply.

Figure 5.15 Upcycle House is built from upcycled and reused materials and components.

Figure 5.16 Upcycle House interior finishes are mainly reused.

The finished project consisted of 90% upcycled materials and 8% directly reused components. Only 2% of materials were new and these were mostly fixings and small items. The LCA study showed that this approach led to an 86% reduction in the embodied carbon emissions from constructing the house. Furthermore, the house is expected to meet a demanding operational energy requirement (an Energy Class 2015 house with an energy use of 32 $kWh/m^2/yr$). So performance was not compromised by the materials strategy. This makes a compelling case to potential clients.

This way of working has become part of the DNA of Lendager Group and it has been able to continuously show, through its projects, that transforming to a circular economy can be done without compromising on aesthetics or economics. As awareness grows of the immense amount of wasted resources in Denmark, government policies are increasingly embracing circular thinking. This is creating a clientele for this type of work. Lendager Group has been approached by various local and international clients interested in applying circular strategies to both large and small projects. These include some large investors who have approached the group to use its expertise to scale-up circular thinking.

An example of a larger project that embraces this approach is the proposed Resource Row Housing project in Copenhagen for a private developer. This is a residential development proposal for 52 row houses and 56 apartments. Using a similar upcycle approach, this project features cross-laminated timber (CLT) floors, reused brick cladding and walls between units made from recycled concrete aggregate. Other aspects of the project include a sharing community that will include communal bikes, cars and tools, and agricultural spaces that allow each unit to grow a significant amount of food on the roof of the building. LCA calculations suggest that this development will have an 80% reduction in lifetime carbon emissions compared with a typical development. This project illustrates that clients and investors who need to satisfy strict economic criteria can embrace a circular approach as a fundamental part of the DNA of their projects, and calculating life cycle impacts can be used as a tool to inform their decision making.

How does the design and construction process have to adapt?

The upcycling process currently requires innovation and research to develop appropriate materials and components that are acceptable to the industry and to integrate them into buildings. Lendager Group involves different types of professionals in all parts of the value chain, so that they all work together through the entire process. For example, the demolition contractor used to be the last

person to take part in the building's lifecycle, only when it had to be torn down. But now, for circular projects, the demolition contractor is the first person called and becomes a creative partner to maintain the value of available materials. Also, the contractor needs to be on board with an appropriate site management strategy with on-site storage and efficient management to minimize double handling and processing. Currently, each project is different, with its own business plan, partnerships and objectives and requires a flexible and innovative approach. As this way of working becomes better understood and upcycled products become established, a more consistent method of practice will develop. Carrying out LCA studies on projects to measure and identify the environmental benefits of alternative approaches helps to build a strong case.

An example of the development approach currently used by Lendager Group is a collaboration on an extensive research and design exercise to create *Upcycle Wood Panels* (see http://lendager.com/en/upcycle-en/upcycle-wood-panel/) (Figure 5.17) with partners Genbyg, BurnBlock and Teknologisk Institut. These panels use waste wood from window frames, doors, floors and old scaffolding wood that can be traced back to its source. The window frames and doors were split, cut and planed into regular

Figure 5.17 Upcycle Wood Panel in the Copenhagen Towers II.

sized strips, which were sent to be fireproofed (using organic and non-toxic fire retardant) to be able to comply with the fire regulations for indoor cladding. The wooden stripes are mounted on a back plate to create a varying surface.
The mounted wood is then treated with natural stain that is toned with natural pigments. The finished panels are 500 mm (20”) wide and come in varying lengths up to 6000 mm (20’) without any visible seams. These panels were originally developed for the Copenhagen Towers II, a high rise building in Ørestad, Copenhagen, designed by Foster and Partners, where 60 000 linear metres (200 000 linear ft.) of wood was used to create about 2 000 m^2 (21 500 sq. ft.) of panelling. Now that this project has demonstrated the functionality and beauty of this upcycled product it will become far easier for other designers to specify it since it is to be made available as a product from project partner Genbyg.

How do you find and secure salvaged materials/components?
Lendager Group’s view is that suitable materials are all around us. It starts a new project by looking at the resources available in and around the construction site. There is a constant coalescing in its process of material, idea and design, and one of the ways its process differs from others is the fact that material will often come before the design idea.

For example, when it looked at a site in the Amager district of Copenhagen, it found 3 000 tonnes of concrete waste from the former paint factory on the site. This could be used for the new 8 500 m^2 (91 000 sq. ft.) Pelican Self Storage warehouse facility that was proposed for the site (Figure 5.18). In Denmark today, up to 95% of all concrete is simply crushed and used as low value road aggregate, yet concrete manufacture is responsible for about 5% of all worldwide greenhouse gas emissions. In this project Lendager Group was looking for a higher value way to use the concrete. It developed Denmark’s first circular building site and a unique recycled concrete that makes it possible to pour new foundations, ground decks and walls using 65% recycled aggregate, and to cast elements from defective castings using 80% recycled materials. Altogether, these efforts achieved a reduction in carbon emissions of just over 95% (Figure 5.19).

In addition to working with construction waste, Lendager Group has discovered that waste from outside the building industry can be upcycled into building components; for example, plastic waste. In 2012, Europe alone sent 9.6 million tonnes of discarded PET plastic bottles to landfill. Through months of research, asking how this global challenge could be turned into a potential business, Lendager Group discovered a felt material

Figure 5.18 Rendering of the proposed Pelican Self Storage project using recycled concrete.

(a) (b)

Figure 5.19 Experimenting with recycled concrete wall panels for the Pelican Self Storage project.

Figure 5.20 Acoustic panel made from recycled PET plastic bottles.

made from discarded PET plastic bottles. Using this material it designed acoustic ceiling panels (Figure 5.20) that are used on the ceiling of the café, the canteen and the foyer of the Copenhagen Towers II.

What are the cost implications?

Lendager Group was created from a frustration that sustainability objectives were often lost as a building project progresses and value-engineering leads to cost cutting. So a major part of its work is to continuously push the bar for circularity in the build environment and, at the same time, showcase that it can be done without compromising on cost, as well as quality and aesthetics. It has been able to demonstrate in its projects that costs are not a barrier to reuse. For example, the Upcycle House was constructed at a similar cost to a traditionally build house and was sold to a family on same conditions as any other house in the area. Also, the various upcycled products developed by Lendager Group for the *Copenhagen Towers II*, including the acoustic panels made from old PET bottles and the Upcycle Wood panels, were delivered at no additional cost to comparable products.

However, it recognizes that distribution of the budget for a circular project is likely to be very different to typical projects. Resources are usually redirected to research, analysis, sourcing materials, testing and prototyping, and often extra labour, but material costs may be lower. In addition, there are potentially local economic benefits. For example, the Upcycle Wood panels for the *Copenhagen Towers II* created 28 local jobs

for the five months it took to process all of the upcycled materials.

How do you maximize the design potential opportunities that reuse offers?

The Resource Row Housing project illustrates how sourcing materials, and researching how to maximize their value, can lead to unique design solutions. In this case Lendager Group identified that Denmark has about 60 000 abandoned rural houses in locations where people are moving away to larger cities. These houses are being gradually demolished and provide a large potential resource of materials. Built mostly in the 1960s, they feature brick façades with cement mortar which makes it difficult to recover the bricks. Lendager Group has proposed to cut 1 m^2 (10 sq. ft.) panels of brickwork (Figures 5.21 and 5.22), which are then reinforced and transported to Copenhagen to be reused in the new project (which may house some of those immigrants from the rural houses into the city). These panels of brick become the aesthetic driver for the new project (Figure 5.23). Economic analysis has shown that this approach should be achievable at no additional costs and an LCA indicates reduced environmental impacts.

How do you deal with codes and performance issues?

Performance issues are often addressed by research, prototyping and testing. For example the 100% reused aggregate concrete at the Resource Row Housing project (Figure 5.23) is causing some concern for satisfying building codes and the engineers are required to undertake some additional testing to demonstrate that 60–80% reuse of aggregate will perform satisfactorily (typical 20% recycled aggregate is accepted).

What are the most common barriers that you encounter to material reuse?

Lendager Group has identified and works to address the following barriers that need to be addressed to make circular material use more established:

- More innovation is required.
- Governmental rules regulating against a certain percentage reuse through quantitative materials measurement should be removed.
- Upcycled materials should be valued and measured based on the same metrics as virgin materials.
- Cultural behaviour and perception of old materials needs to change – there is little understanding for the urgency for lack of resources.
- Business cases need to be made for circular businesses.
- An infrastructure for reuse of materials needs to be established.

Figure 5.21 Brick panels being cut from old houses.

Figure 5.22 Recycled brick panel.

Figure 5.23 Resource Row housing using salvaged brick panels.

What needs to happen to make material reuse more common?
One of Lendager Group's concepts is *Ressource City*, which aims to demonstrate a comprehensive vision for a circular industry. It proposes a strategy for the city of Næstved, Denmark, to create an industrial cluster that facilitates cooperation and knowledge between companies, research institutions, public institutions and citizens working with upcycling. The project starts with the existing resources of Næstved, important recycling businesses, a derelict industrial area and a wish to reuse existing resources, and shows how to create the groundwork for development, growth and creation of jobs within a new circular economy. This is the long-term goal, to create and industry and infrastructure based on circular systems.

5.4 SUPERUSE STUDIOS

Superuse Studios (previously 2012 Architects) is an interdisciplinary design and research practice based in Rotterdam, The Netherlands (with an office in China), which for many years has focused on cyclical resource systems with the goal of turning cities into interconnected networks of materials flows and processes. It has developed a variety of tools and methods to intervene in material flows, maximize material reuse and create what it calls '*superuse*' in the built environment. Its design projects show the creative potential that circular approaches offer. Its ideas for maximizing material reuse are explained here based on discussions with founding partner Jan Jongert.[d]

How do you work to maximize material and component reuse in the built environment?
Superuse Studios takes inspiration and knowledge from industrial ecology and aims to demonstrate the potential of resource-based design, creating new value from what is currently discarded. The business model is based on several types of activities: assisting other companies in finding second use resources, a design practice where it can directly experiment with second use materials and research projects to increase

[d] http://superuse-studios.com

knowledge of resource flows and reuse potential. The firm uses a variety of research and representation tools to continuously develop, communicate and analyse the ecological design possibilities of second uses for materials and components at all scales. These include urban metabolism studies, material flow analysis, Sankey diagrams and its own tool, called a harvest map (Figure 5.24), discussed below.

It stresses the difference between '*closed*' and '*open*' cycle systems. Examples of closed cycles are companies that take back their product after its lifespan expires for remanufacture (sometimes using rental contracts). These tend to be dominated by large, established companies, combining sustainability ambitions with controlling production and protecting their supply of raw materials. This usually requires investment of large amounts of capital and centralization, which leads to large, multinational operations with limited local benefit, locking in resources (and preventing consideration of alternative uses) and indistinguishable products and services.

Superuse Studios is more interested in open cycles, which make the potential use value of used materials publicly accessible. In open cycles knowledge about the materials that are cycling around is shared, making exchange between different production processes possible. This provides more

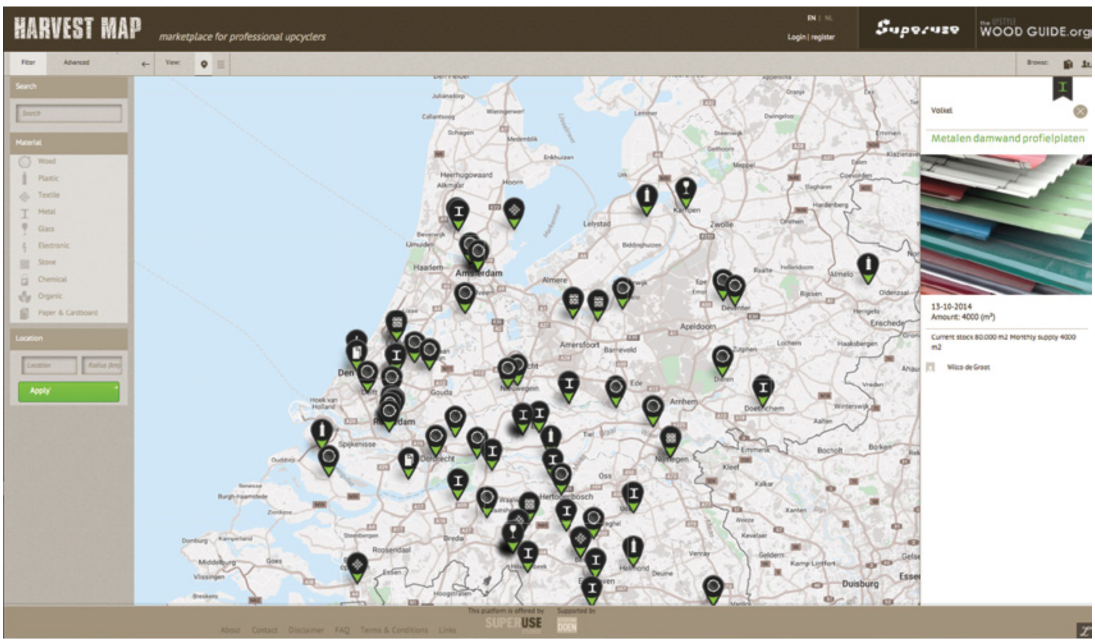

Figure 5.24 Harvest map for The Netherlands showing potential sources of used materials.

opportunity for designers to add value and create unique, locally resourced and appropriate solutions. Open cycle interventions are often smaller operations in niche markets, working locally, intervening in existing materials flows. Open source sharing is common among them and clients or customers are often personally involved in the development of new products. New, small-scale technologies also ensure that production is often no longer a huge investment. Examples of open cycle innovators in other industries include mushroom company Rotterzwam, which is developing a waste-free process chain with 12 different products and services (including mushrooms, compost plants, enzymes for a water treatment company, lubricants and ingredients for odour control) all based on Rotterdam coffee waste.

Mapping of urban material flows allows points of intervention to be identified. These are termed '*cyclifiers*', which are resource recovery and reuse mechanisms that short-circuit the existing flows. They plug into locally available, unused (or under-used) resources, addressing the various layers of urban flows by acting as metabolic processors. This process is referred to as '*superuse*' – a design strategy that takes local materials and components considered as waste or of little value and creates new functions in buildings, interiors and products. An example of a flow that Superuse Studios identified and was able to redirect is discarded wind turbine blades, which are replaced at regular intervals due to stresses. It was able to use these large sandwich polyurethane components as elements in a the Kringloop Zuid Recycling Centre and also in the Wikado childrens play park in Rotterdam (Figure 5.25).

How do you present the idea of material/component reuse to clients?

For Superuse Studios its approach is partly from conviction and every year, with increasing interest in the circular economy (and recent EU legislation), it finds more partners that share it. To them it seems logical to use what is already there and anything that prevents that seems incongruous. For instance, it is inconsistent to tax labour instead of resources and materials, as this has the impact of exporting labour to China, importing products and creating waste.

However, Superuse Studios is not dogmatic about reuse and superuse and looks for what is appropriate in each project and for each client. One project may have 30% of superuse materials, another 50%. It is more important to develop the general approach and knowledge about second use, establishing local connections and networks, and to be able to learn afterwards what did and did not go well, and how to improve. Every project is dependent on circumstances and the ingredients that have to be worked with – budgets, time constraints, location and so on.

Figure 5.25 Wikado childrens play park in Rotterdam uses old wind turbines.

That makes these projects vulnerable to all sorts of things that are changing, so a flexible mindset is necessary for this sort of practice.

How does the design and construction process have to adapt?
Since 1997, Superuse Studios has radically revised its design process as architects and developed its own expertise, as other consultants and contractors did not have the necessary knowledge for superuse. It describes the architect as needing to be a craftsman able to combine analytics, envisioning and execution skills, in order to show what is possible. Rather than start with a spatial form and then find the most appropriate materials, it now starts by exploring the materials available in the local vicinity of the project. This requires a lot of research, understanding material flows: which ones are present, how they behave, what tools are needed to understand how they work and how to intervene in them. This becomes the starting point for matching new uses for old materials.
It compares this to cooking - you can come up with a recipe and then buy all the ingredients, or you can be inspired in the kitchen by what is left from previous purchases, and thus create a new dish.

Working backwards forces the designer to look at the entire construction chain from another side. The role of traditional

suppliers becomes very different. Rather than doing business with the sales departments of supplier companies, now Superuse Studios tend to do business with the production department and the waste processor.

Projects that are managed in a more traditional way have extended lines of communication, which can make a circular materials approach difficult, requiring an intermediary manager to translate such ideas to a client or contractor, and get agreement. This often leads to suboptimal solutions. Superuse Studios prefers the organizational structure of an integrated team.

How do you find and secure salvaged materials/components?
Superuse Studios has a commitment to open cycles, which require public knowledge of available materials (so that their value can be maximized). So it has developed various open source web-based tools that can be used for sourcing materials. One of the most helpful tools is the '*harvest map*' (www.harvestmap.org). This is an online graphical tool that is effectively a library of available second use materials in the locality of a building project (Figures 5.24 & 5.26). It includes information on available and soon-to-be-waste materials nearby and connects potential buyers with suppliers. For a designer, the harvest map becomes a regional material catalogue that can be used to assist the design team and also to communicate material choices to the client. A harvest map offers the ability to link larger corporations to small businesses and also in closed cycles to keep information lines open. Superuse Studios believes that a broad cultural shift will only happen if large companies open their resource flows to others, so that they can connect back to local stakeholders and be able to continue to adapt flexibly to changing circumstances.

A harvest map was used for the Kringloop Zuid Recycling Centre (Figure 5.27), which is a regional recycling centre and thriftstore in Maastricht, The Netherlands. About 75% of all materials came from buildings that had been taken down in the neighbourhood. For example, the harvest map identified apartment blocks being demolished to make way for a road and this provided resources such as window frames. Other materials used include discarded wind turbine rotor blades, shipping containers and colourful waste steel sheeting discarded from an order by a steel factory in the neighbourhood.

The harvestmap.org online platform for The Netherlands includes more than 250 common material flows. It identifies known sources, helps other designers to find materials and supports new circular entrepreneurs to start their own facilitation companies.

Figure 5.26 Harvest map showing sources for materials used in the Villa Welpeloo.

What are the cost implications?

The cost implications depend on many factors, including the building system used, scale, availability, transport and so on. For example, if the structure consists of modular precast concrete panelling, it is usually relatively easy and cost effective to take down and reuse, or superuse it. A material has a much lower price if its economic value has been depreciated. This, in turn, can be an investment in the project. Some materials even have a negative value, where one does not pay but is instead paid for accepting them. Superuse Studios is working to find the right scale where the use of low or negative

Figure 5.27 Kringloop Zuid Recycling Centre.

value materials can be used as way to invest in and start projects. So, in effect, cost is a design issue. If superuse is done with minimum adaptations and transport cost can be kept low, and if the scale is big enough, it can be cost effective. In some projects, like the Kringloop Zuid Recycling Centre, cost savings can be up to 30%

How do you maximize the potential opportunities that reuse offers?
Rather than accepting recycling as a normal route for materials at the end of life, Superuse Studios looks at used materials and components to see if they can be used either for their original use or for some other use (if not, they can always still be recycled). Both reuse and superuse can be appropriate strategies depending on the particular situation. When a façade is taken out of a building it will often be appropriate to reuse it as a façade for another building. But with superuse there is an additional creative challenge, and it adds a second aesthetic layer to the work. The key to superuse is to connect different systems – understanding that functions can change, like turning a bottle into a brick. The creative spark is to recognize that an object can have an even better performance in its new function compared to its original one. It is about discovering better, longer-lasting uses than the original design. Some products are designed to last maybe 4–5 years, or even three months, like

the metal ribs of a cheap umbrella. But if these are used for a lighting fixture, for instance, they can last for many years. The material already had a life and a function, so when it is superused there is an effect of separation. There is a design challenge every time to determine what level of recognition of its original use is appropriate.

Superuse Studios' collaboration with Van Gansewinkel, one of The Netherlands' main waste collectors and processors shows the benefits of partnership and connecting different material flows. Both organizations recognize that more value can be generated by looking for more creative solutions than merely recycling. So Van Gansewinkel started selling second use materials and components to the construction sector, generating profit for all parties involved. For example, one of the waste streams of a Dutch truck plant consists of steel plate with uniform punched holes. Normally, Van Gansewinkel transports this scrap to the steel processing industry to be melted and recast. The owner gets the scrap price and Van Gansewinkel is paid for transport. Superuse Studios identified the potential to remanufacture this material according to its design and use it on building sites. In this chain the truck industry receives double the income from its waste product, van Gansewinkel becomes a supplier instead of just a transporter with a greater profit, Superuse Studios receives a small fee for mediation and design, and the customer gets a unique product that is 20–30% cheaper than if it would be made new.

How do you deal with codes and performance issues?

Superuse Studios is cautious about performance and safety when using old materials and components and has a conviction not to be dogmatic about how to do things. Since the material costs are often low, it may be acceptable to use more material than if a new material were used; for example, employing larger components when a structure uses old steel with less defined characteristics. This would be a team decision involving the client, contractor and other consultants in an integrated design approach. For Villa Welpeloo in Enschede, The Netherlands (Figure 5.29), the quality of the steel salvaged from old industrial machinery was not known, so the structural consultant assumed the worst type of steel specification when calculating the structural integrity of the building. Most likely its real performance is better, but for safety reasons the worst case was assumed.

Figure 5.28 Cable reels which are deconstructed and the timber used for cladding.

However, some materials may perform better when they are older. For example, wood over fifty years old will often stay straight and hardly warp. In other cases, processing can improve materials qualities. An example of this is the timber from common large cable reels that Superuse Studios has used in their projects (Figure 5.28). This low grade softwood is heat

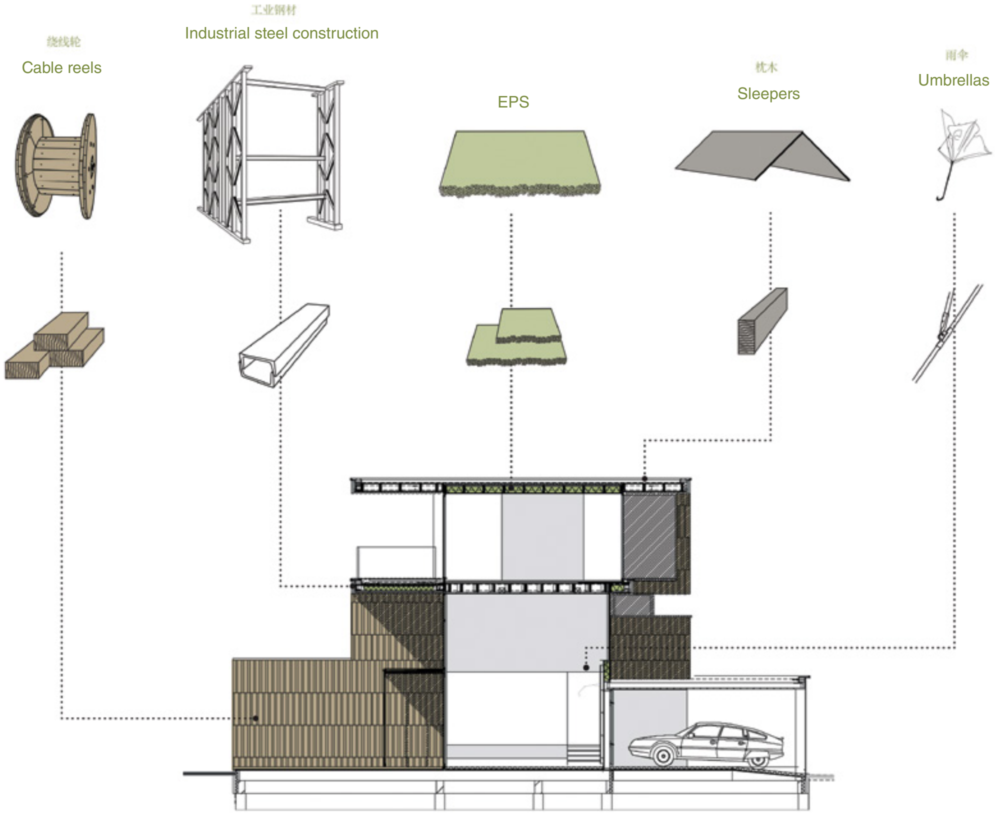

Figure 5.29 Schematic of the Villa Welpeloo in Enschede, The Netherlands which indicates material sources.

treated and conditioned using waste heat from a cogeneration plant, upgrading it into a material suitable for use as a building cladding with dimensional stability, increased durability and one that does not need any additional chemical coatings. This material was used as a cladding the Villa Welpeloo (Figure 5.30).

What are the most common barriers that you encounter to material reuse?

Labour cost is decisive as to whether a material is reusable or superusable or not. If the price of disassembly and transport costs exceed the price of a new product, reuse or superuse is not plausible. In Europe, currently, labour is expensive and materials are often cheap due to imports from countries with low labour costs. This can make reuse and superuse difficult to justify economically. For example, a client installed new lighting

(a)

(b)

Figure 5.30 Villa Welpeloo in Enschede, The Netherlands, uses heat treated cable reel timber as cladding.

in its rental office only one half a year ago but was unable to rent it out. Everything was stripped out again, including the lighting, which still had the foil wrapping in place, but the resale value of the lighting components on the secondary materials market barely justified the effort.

However, for some high value components, such as old timber and heritage components, the dismantling process and labour time is worthwhile due to the quality of the component.

What needs to happen to make material reuse more common?
The biggest needed change is a tax shift from labour and added value to resources and depreciation. There is a movement called '*Ex'tax*' (http://www.ex-tax.com) that aims to change this regime, predicting an immediate benefit for increased jobs, product quality and reduction of waste by increasing taxes on natural resource use and reducing taxes on labour.

IMAGE CREDITS
Figures 5.1, 5.2, 5.3, 5.4, 5.7 & 5.8 Courtesy of Rotor; figures 5.5 & 5.6 By Jean-François Flamey, provided courtesy of Rotor; figure 5.9 By author; figures 5.10, 5.11, 5.12, 5.13 & 5.14 Courtesy of Gerry Humphries; figures 5.15 & 5.16 By Jesper Ray, courtesy of Lendager Group; figures 5.17, 5.18, 5.19, 5.20, 5.21, 5.22 & 5.23 Courtesy of Lendager Group; figures 5.24, 5.26, 5.28 & 5.29 Courtesy of Superuse Studios; figure 5.25 By photographer Denis Guzzo, courtesy of Superuse Studios; figure 5.27 By photographer Fernando van Teijlingen courtesy of Superuse Studios; figure 5.30 By photographer Allard van der Hoek, courtesy of Superuse Studios

6 IMPLICATIONS FOR DESIGN

Scarcity pushes us to see resources as part of a network of social and temporal relationships, into which the designer intervenes………Design becomes concerned with the temporal life of objects, with what comes before and after the instant of completion…..design under conditions of scarcity takes on an ethical dimension because the construction of scarcity often leads to an inequitable distribution of resources. (Jeremy Till[1])

In *The Science of the Artificial*, Herbert Simon describes design as '*the process by which we devise courses of action aimed at changing existing situations into preferred ones*.'[2] If we wish to create a more ecologically grounded built environment, based on circular approaches, we need not only to design buildings that perform better with regards to resource use, but, more fundamentally, to devise a system and infrastructure that will achieve this. Two aspects need to be addressed:

1) From the demand side, the building procurement and design community needs to review and adapt conventional practices in order to increase demand for, and effectively integrate, reclaimed materials and components.
2) From the supply side, the reclaimed material sector needs to revise its processes and marketing to improve security of supply, information, standardization, and communications, so that it finds a broader audience for its products.

Both aspects need different responses and appropriate processes. This chapter explores the characteristics of how the design process needs to change. It is clear from the many projects reviewed in this book that there are significant differences to the design process if a circular system that values used resources is a goal. These are based on availability, supply chain, ownership, detailing and information. The situation may change as the supply of used materials and components improves and knowledge of how to make use of them becomes more

Resource Salvation: The Architecture of Reuse, First Edition. Mark Gorgolewski.

Figure 6.1 Salvaged baseboards and crown mouldings were mounted in vertical strips inspiring beautifully patterned, corrugated walls and screens at the NRDC office renovation in Chicago by Studio Gang.

common. However, the different characteristics and patterns of availability need to be recognized and accommodated. Also, the different supply chain requires design teams to be more flexible and to develop their proposals around available reclaimed materials and components (Figure 6.1), rather than the traditional process of designing the main features of the building and then identifying the components that will meet the required specifications.

6.1 DESIGN PROCESS CHARACTERISTICS

By proposing a building made from materials at hand, the project introduces an entirely new paradigm for a project delivery process that has not changed substantially in the last fifty years. It radically alters the way a building is both conceived and made: form follows availability. (Jeanne Gang[3])

The previous chapters of this book highlight the experimental nature of working with used materials. As design teams adopt strategies to increase use of reclaimed materials and

components, it is likely that the standard project management stages typically used by architects may need to be adapted to facilitate a process better suited to circular strategies. From the various sections in this book some key characteristics have emerged. These are discussed here.

Strong Commitment and Setting Goals

As using reclaimed materials and components is still more difficult than using of-the-shelf components, a successful project needs commitment from the entire design team and client. Setting and committing to clear goals with defined targets early on in the process can help to unite the team, avoid conflicts and guide the design through the development stage through to the more detailed specifications. If structural reuse is expected the structural engineer needs to be committed. Having someone on the team with experience of previous projects that feature reuse is also helpful. Without previous experience target setting can be difficult. The level of reuse targeted can be based on the following criteria:

- Smaller projects can have more ambitious targets due to the relatively small volumes of reclaimed materials currently available.
- Previous experience of the design team and contractor with the use of second use materials.
- The amount of flexibility in time available during both design and/or construction phases.
- Client commitment.

The team should agree a decision making process with criteria (or a protocol) for making decisions about types of reuse, which may include technical, aesthetic, economic and environment considerations.

An Integrated Design Team

Experience suggests that design teams that use an integrated design process (IDP) gain a clear benefit and a greater likelihood of successfully reusing materials and components. A decision making process that involves the whole design team, and profits from the creativity, expertise and ideas of all the participants, is more likely to succeed. The process may require the team to revise its normal working practices, include additional expertise such as demolition consultants or reclaimed materials brokers and be prepared to take the initiative when it comes to overcoming unpredictable hurdles that may present themselves. Collaboration and enthusiasm are both important. Involving trades, suppliers and contractors is also helpful. Possible additional design team members may include:

- salvage materials broker/consultant;
- demolition consultant;

- construction manager;
- materials scientist;
- specialist trades.
- industrial ecologist.

Flexible Approach to Process and Timing
Since availability of reclaimed materials and components is currently less predictable, flexibility and tolerance to alternatives by the project team and owner are important. This allows opportunities to be grasped when they present themselves, even if it is not at the appropriate time in the schedule. This is assisted by an integrated design approach. The design team needs to be prepared to revisit decisions when new material opportunities arise.

Material availability may occur early or late in the process. For early materials they may need to be secured/purchased and stored before construction has started, so the client needs to put into place a mechanism to make this happen. This may include early commitment of funds. Involvement of the management contractor at the design stage can help with this. Materials that become available later may involve late changes and some redesign. The design and construction teams should be prepared for this. Building flexibility into the structural design and particularly the depth for accommodating the structure can allow adjustment of the design to suit component availability later in the process and the ability to accommodate components with small variations in specification. This requires appropriate contractual procedures to be used, as the final materials may not be specified at the time of tendering.

A further aspect of timing is the need to connect supply with demand (Figure 6.2). For example, if materials are coming from a demolition site elsewhere, when will demolition occur? And will the materials be available at the time needed for the new project? Until suppliers begin to store significant amounts of reclaimed materials and components, coordinating timing between projects will be necessary. From the time something is schematically designed until it is constructed is usually many months or years. This means that to design for the use of a specific reclaimed component is to take risk about its availability if it is not procured or reserved during the design process.

New Relationships
Sourcing reclaimed materials and components requires designers to foster new relationships with organizations they may not traditionally be in touch with. This can improve their choices when used components are desired. Designers can benefit from developing working relationships with:

- Local salvaged material handlers who may have access to useful materials.

Figure 6.2 The University of Toronto Scarborough Campus Student's Centre featured reused steel taken from a local demolition which required careful coordination of the two projects and nearly failed due to scheduling issues.

- Demolition contractors who are aware of buildings that are up for demolition and could be deconstructed.
- Materials brokers.
- Industries with waste streams that may have value in construction.
- Contractors of infrastructure projects who may need to dispose of materials that have a construction use.
- Specialist reclaimed materials procurement consultants who are emerging in some locations and can take on the task of identifying particular used materials. Their experience can reduce the risks of disruption or delay.

Material and Tectonic Centred Design

A market for salvaged materials and components needs to develop in each country with regular availability and easy exchange though websites, suppliers and other market mechanisms. Until this happens, the starting point for designers will often be identifying an inventory of potential second use materials and components, and developing their design ideas around their tectonic characteristics. This can be seen as a restriction or a positive inspiration for creating meaningful

ecological architecture suitable for the circular economy. Jeanne Gang suggests that used materials should not be seen as a straight replacement for new, but rather their particular features offer unique solutions that need to be explored.[3] For many of the projects in this book, the design concepts were inspired by the reclaimed materials and components that were identified as locally available.

Opportunistic

The creative ability to see the opportunities presented by available materials and components (and to look for *materials of opportunity*) helps to increase the possible scenarios of reuse. A simple and flexible design helps to maximize opportunities. For structural design, the size and length of the available members can be used to determine the bay sizes in the new structure, thus maximizing structural efficiency from the available components. This approach requires that the available components are identified early in the design process and that they are purchased or reserved to prevent the salvage contractor from selling them elsewhere. If the intention is to reuse all or part of an existing building in situ, the search for a suitable building will need to commence at the pre-design stage of the project.

Other areas to look for opportunities are in the labour cost for processing reclaimed materials. Several projects have used not-for-profit youth training programmes or government job reskilling programmes as a way of providing economic opportunities for the less fortunate and lowering the cost of material reprocessing.

Design–Build

Ken Shuttleworth of Make Architects suggests that architects getting involved on site and working very closely with construction teams is necessary to innovate and advance knowledge of the circular economy.[4] In many of the case study projects in Chapter 3, the close collaboration between the design team and construction team benefited from a formal design–build process, with the two teams working as one. Also, the practitioners featured in Chapter 5 all connected design and construction very closely in their processes. Often in such projects the boundary between design and construction disappears, as construction decisions and materials purchasing may occur well before work starts on site, and, conversely, design revisions need to be made late on in construction if materials become available. In typical procurement processes used today these may be practices to avoid but with reclaimed materials opportunities can be lost if the process cannot adapt to suit them. Design–build management of the process has often been found to be appropriate, and even extending this

to deconstruct–design–build can give greater control of the materials supply chain.

For example, tres birds workshop (see Chapter 3.1.2) is a Colorado-based design firm that has established the capability to take on deconstruct and build roles. This allows it to be nimble and make a quick decision when an opportunity to get used materials arises. When working on the Posner Centre, the opportunity arose to remove components from the Hewlett Packard Technology Center in Colorado Springs that was being demolished due to structural problems. Within two weeks, it was able to see the demolition site, get client approval for the used components and extract them. As a result, a variety of components were salvaged for reuse.

Research and Experimentation

Due to the innovative nature of most reuse projects, they may require considerable additional research by the design team at the front end of the project to identify, locate, inspect, choose, adapt and prototype appropriate materials and components. Responsibility for identifying reclaimed components needs to be clearly established – who is responsible for sourcing a particular component? Often the starting point is a research process about available local material sources and the opportunities and limitations to their use. This may require audits of locally available suppliers and demolition projects. Investigation on how materials have been used in the past and what possibilities exist may follow. Sometimes mock-ups and tests are required to prove performance and aesthetics.

The design team may need to establish procedures for assessing and grading sourced materials and components to ensure they meet functional requirements and regulatory standards. This may require protocols and weighted analysis using agreed criteria to assist with selection and to convince the client of the appropriateness of a material. The process may require visual inspection, structural or other testing, prototyping and possible refurbishment. This helps to ensure approvals and successful inspections, as some municipalities are often unfamiliar with and, therefore, hesitant to allow the use of reclaimed components.

Aesthetic Concerns

Many old buildings, often with worn material surfaces and imperfections, are seen as full of character and uniqueness. However, materials with similar characteristics in new buildings are often regarded suspiciously, as unacceptable, poor quality, tacky and second best. Some reused materials such as structural steel components are usually buried deep in the building

Figure 6.3 This clay tile wall panel created by the Nordic Built Component Reuse project features the imperfections of the reused pantiles (see Chapter 4.1).

envelope and not apparent, so aesthetic imperfections are unimportant. But many reclaimed material and components have unique aesthetic characteristics and when exposed they can become distinctive and inspiring architectural features.
For example, the Pocono Environmental Centre (Chapter 3.4) and the Kaap Skil Museum (Chapter 3.4) expose the uniqueness of old materials, and this is what makes the projects successful and popular. The concept of Storywood (Chapter 4.2) highlights the uniqueness of old wood.

The culture of newness is gradually changing and creative architectural solutions inspired by old materials can assist with

Figure 6.4 At the University of Toronto Scarborough Campus Student's Centre the old markings and brackets were left in place to identify the steel as reused.

this process. Reuse of materials and components offer an opportunity to celebrate their individual qualities and characteristics and to reinvent and transform them in a creative way to reveal their uniqueness (Figure 6.3). Often visible scars and features of the old material are left intact and used in a decorative way to highlight the heritage of the material, and celebrate its reuse (Figure 6.4). Many interesting projects accept the damaged character of a material and develop an aesthetic approach that embraces this. This is common with reused brick, old stone, old timber, so why not other materials.

Economic Flexibility

The economics of material reuse is complex. Many in the industry assume that it will be more expensive (particularly for larger projects), but the reality seems to be varied. It is

important for the client to understand that projects that use reclaimed materials and components typically have a unique cost breakdown significantly different to a regular building project, as there are non-typical costs. But the overall costs need not be higher and can sometimes be lower. Some of the cost issues include:

- The split between labour and materials is likely to be significantly different. Typically, materials costs go down, as reclaimed materials are often cheaper than new (except for special, heritage and unique items), but more labour is needed to process and prepare them. Since labour is generally expensive, keeping the extra costs under control is important.
- There can be additional design team costs. This can be due to additional research, testing, sourcing and redesign to suit the project. Value-based fees, where fees are based on the time/effort/material put in by the designer, may be appropriate.
- There is likely to be greater uncertainty over cost early in the process until key components are sourced and secured.
- Deconstruction is generally more expensive and time consuming than demolition, but provides useful resources at the end of the process.
- Transport, storage and double handling can add significantly to costs. For this reason local materials and components are often the most cost effective, except for specialist items. Additional handing and off-site storage can add considerably to costs. It is preferable to avoid moving material several times with the associated loading and storage costs. The highest savings often occur for projects that focus on reuse of what is already on site.
- The cost plan should include sourcing, deconstruction, refurbishment, transport and testing/verification costs while remaining flexible to allow for market fluctuations in supply and demand.
- Securing materials can require early purchase by the client directly, so establishing a budget structure that allows this is important. For example, as a designer–builder, tres birds workshop often has to directly purchase items that it may use on a future project. If the team waited for the right project to come along before purchasing, then many reclaimed items would no longer be available.
- In some countries (such as the USA) a powerful tool to encourage deconstruction (and therefore reuse) are tax credits. If a building owner disposes of salvaged materials and components through a non-profit organization (such as Habitat for Humanity ReStores), it can claim tax credit for the resale value of the donation.

Knowledge Based

Many organizations that have successfully created a business model around designing with reclaimed materials and components have developed a knowledge base and built a database of locally available sources. Many of the pioneers (see Chapter 5) operate an open source policy as they see their work as opening up the market for more circular practices. Warranty and market confidence are significant issues for reuse and can prohibit interesting solutions and prevent creative reuse. Establishing a common knowledge base helps to grow confidence in this approach.

Building Information Models (BIM)

Building information modelling can be valuable tool both for work flow modelling and also for storing information about component characteristics (materials passports) for future reuse.

Processing, Transport and Storage

Processing, handling and storage can add significantly to cost. It is important for the client to understand that materials may have to be acquired early in the process (whenever available, for example from a demolition nearby) and this will necessitate storage. An appropriate location may be required (preferably on site). Careful planning and the involvement of the main contractor in this process can alleviate some of the drawbacks. Timing can be important; for instance, when to move materials so as not to double handle them. Transport may be an additional cost if it is determined that additional processing or storage is required away from the site. Again this requires coordination with the main contractor, or supplier, and can have a significant impact on costs. This highlights the importance of having the construction manager at the decision table.

6.2 PERFORMANCE ISSUES

Performance is often mentioned as a concern or barrier to reuse. In this section various aspects of performance are discussed.

Codes and Standards

One of the major concerns about reuse revolves around their performance and acceptability for code compliance. However, codes and standards are often not an barrier, although they can lead to more work to demonstrate compliance, sometimes requiring alternative compliance paths. Most codes permit reclaimed materials and components if they can be shown to comply with the requirements and relevant standards. The emergence of performance or objective based codes makes it easier to develop innovative solutions and has helped to

provide paths for acceptance of non-standard materials. There is often reasonable freedom given within such codes for designers to prove equivalency. However, problems sometimes occur when departing from the familiar prescriptive process. The alternative compliance process places the onus on the design team to prove equivalency and challenges building department officials leading to inconsistent interpretation and varying attitudes and requirements. From the designer's and client's point of view this can result in uncertainty about what may be required and can act as a deterrent to taking an alternative design approach. Some projects featuring reuse have involved building code officials in the project at an early stage so they have a good understanding of the project objectives.

In Europe there is concern about how the requirement for CE markings may become a barrier for some types of reuse. A CE marking indicates that the product meets all the legal requirements and can be sold throughout Europe. It is not currently clear how reused components should be dealt with by the CE system and it has been proposed to create an annex to standards EN 1090: 1 and 2 to address this.

Structural Performance

Clearly engineers will only be happy to specify used structural components if their characteristics can be established with confidence. This includes the physical, mechanical and chemical properties. Also, insurers will not be willing to accept materials where their performance is uncertain. Usually there is less of an issue if the structure remains in place, as with adaptive reuse, although strengthening and adapting to meet new code requirements for seismic or snow loads may be required. The situation becomes different when salvaged structural components are reused in a new building and for a different use. In that case there are a variety of guidelines for establishing structural performance, particularly for timber and steel, which are the most likely structural materials to be reuse.

For example, there are established procedures published by the Steel Construction Institute in the United Kingdom for identifying the characteristics of old steel.[5] If the age of steel components is known and they can be inspected then a good estimate of structural characteristics can be made. Sometimes additional testing may be required. Portable non-destructive testing equipment to establish chemical and mechanical properties is available. From historical and dimensional information it is often possible to identify the codes and standards that were adopted in the original design, and thus to estimate the expected performance of the component. Additional safety factors are often used.

Figure 6.5 CK Choi building in Vancouver reused heavy timbers from locally dismantled buildings.

Without extensive damage, heavy timber generally has the mechanical and physical qualities that allow it to be reused in structural applications, but it will need inspection and grading, usually by an engineer. Also, old wood is dry and can have properties superior to current sawn products and has a desired heritage character (see Chapter 4.2). There are many examples of reuse of heavy timber components, such as in the CK Choi building on the University of British Columbia campus in Vancouver, Canada, where approximately 65% of the heavy timber structural components were salvaged from the Armouries Building nearby (Figure 6.5).

Due to the limited research on the properties of used lightweight timber there is some hesitance to reuse stick built framing lumber. Most codes do not allow uncertified or ungraded lumber to be used in structural applications in residential buildings. Although the material can be evaluated by a licenced grader or an engineer who can render the material to be suitable for use as a structural component, this is currently usually not economical. There are no established grading rules for stress grading

Box 6.1 Timber Reuse Study

A US Forestry Service study[8] tested over 1000 pieces of framing timber 50 mm × 150 mm (2″ × 6″) 3 m (10′) long, 50 mm × 200 mm (2″ × 8″) 3.6 m (12′) long, and 50 mm × 250 mm (2″ × 10″) 4.2 m (14′) long, from four different locations and building types in the United States. All the tested components were from buildings constructed in the early 1940s and the timber was used as studs, floor and roof joists, stringers and rafters. The components were visually graded as Select Structural (SS) or No.2. Over 90% of the components collected were Douglas Fir. The bending strength of the old timber was found to be about 25% lower than new timber. Mean stiffness was about 10% higher. Nail holes affected the strength when they were closely spaced or created further splitting, especially when they were located at the high-stress tension edge.

Box 6.2 Laminar Studs[9]

A research project by Bruce Johnson investigated the use of reclaimed medium and short length offcuts of 50 × 100 mm (2″ × 4″) and 50 × 150 mm (2″ × 6″) framing timber to create laminar studs for non-structural uses. Material was sorted into 900 and 1200 mm 3′ and 4′ lengths and jointed with sandwiched joints created by two short 600 mm (24″) members nailed to the side of the main members to form mechanically fastened laminate studs of typical stud lengths of 2 350 mm (93″). Fastener location and the area of laminar plate were load tested and systematically revised in order to achieve a satisfactory deflection of no more than Length/180 as per Section 5 of the US HUD Residential Structural Design Guide. *It was proposed to use these in non-load-bearing wall conditions.*

reused framing timber.[6] However, the US Forest Service has carried out research into structural applications of reclaimed lumber to investigate appropriate rules and guidelines for stick built lumber to be reused structurally (Box 6.1). When regrading, often a conservative approach is taken and the grade is considered one degree lower than that of freshly sawn lumber. This can be regardless of whether any significant damage is present. Davis suggests that it is most appropriate for reused framing timber to take loads in the same way as their original construction (compression members reused as columns and bending members reused as beams).[7] A new web site created by the Building Materials Reuse Association provides useful resources for timber reuse (www.reusewood.org).

Precast concrete buildings could, in principle, sometimes be deconstructed for reuse, but many precast elements have a cast-in-place topping and connections to other structural elements. The *in situ* concrete makes it difficult to recover the original precast elements without damage.

So the suitability of reclaimed components for structural use currently needs to be considered on a case-by-case basis, dependent on the available information. Generally, the closer the new function is to the original the more likely it is that it can be structurally used. Also, standard components and sizes, and simplicity and flexibility in structural design approach, are likely to be helpful.

Thermal Performance

There is little information on reuse of reclaimed thermal insulation. Also, there is less interest in reusing old insulation products due to difficulty with getting sufficient volumes of high quality used insulation that is necessary for modern low carbon buildings, and because there are several viable alternatives available for new insulation materials that are made from waste materials. These include cellulose insulation that uses old newspapers, and cotton and wool insulation products that use old clothing and spare wool fleece. Nevertheless, some companies do offer reclaimed or left-over board insulation in volumes suitable for small projects.

The performance of reclaimed air-based insulation materials, such as glass fibre, mineral fibre and expanded polystyrene, is largely dependent on its physical condition. If it has been extracted from its previous use in a largely undamaged form it should function satisfactorily. However, some high performance foam insulation materials may degrade over time as the gases in their pores may leak out. Over a long period of time the performance of these maybe closer to the air-based insulants.

A few projects have experimented with using any material that traps air in small pockets as an insulation material. For example, the Waste House project (see Chapter 3.4.4) uses old cloths, packing beads and tooth brushes to fill wall cavities. Such methods are likely to provide a reduced insulation performance compared to established insulation products but may, nevertheless, be useful ways to use some discarded materials.

Durability

Sometimes it is assumed that used materials will not last as long as new materials. Concern about how well old materials will last, and their ability to maintain performance, need to be considered on a case-by-case basis. The long term performance of a component is a characteristic of its material properties, the way it is integrated into a building and the maintenance regime. Visual inspection and, if necessary, selective testing can establish if there are any concerns. As has been noted, some old materials, such as older timber components, can be of higher quality than what is currently available new. In fact, mechanical stiffness of older reclaimed solid wood products tends to be higher than their virgin counterparts because the wood has more time to dehydrate, if kept in a dry environment.[8] Also, other components have additional heritage value that may justify reconditioning to improve durability and extend their life. Where and how a material or component was previously used is also significant. For example, damage of exterior cladding varies depending on which face (north, south, east, or west) of the building it was located.

Environmental Performance

One of the major reasons for reusing materials and components is the potential environmental benefits, which are generally regarded as greater than for recycling. Reuse can potentially reduce new resource extraction, save on embodied energy and carbon, and reduce waste. Various studies have demonstrated that there are environmental and economic benefits that favour a shift away from recycling to reuse. In the United Kingdom, the BRE showed that reused steel has only 4% of the CO_2 emissions of new steel.[10] The REBRICK project (see Chapter 4.3) claimed that each reused brick saves 0.5 kgCO_2 emissions. A US Environmental Protection Agency study showed that waste reduction efforts resulting from reuse of components can generate energy and greenhouse gas emissions savings of over 60% greater than recycling.[11]

However, an uncoordinated supply chain can lead to higher costs and environmental impacts. Research also indicates that bottlenecks, such as limited supply of reused components due to insufficient deconstruction, lack of technical feasibility to

reuse and limited market demand, can invert the situation.[12] Thus, there is a need to address barriers in the supply chain and increase knowledge of technical issues relevant to reuse. The designer's role in the process is important to reduce bottlenecks.

Life cycle assessment (LCA) is often used as a tool to quantify environmental benefits. LCA is a complex calculation process, which quantifies the inputs and outputs of a process or product, and assesses their environmental impact in a series of categories. The ISO 14040 series of standards was developed to provide an established framework and guideline to perform LCA studies.[13] This is a complex process and there is some discussion about how to factor in recycling and reuse into LCA calculations, and where to set system boundaries for reused components. Furthermore, reused materials are usually localized but the data used in these calculations usually relies on industry averages, which may not truly reflect the local conditions. However, tools such as Athena Impact Estimator[14] One Click LCA, Talley (a plug in to Revit) and the ICE materials database[15] make it possible for design teams to carry out LCA calculations of building projects.

A simplified analysis can look at only energy and/or carbon emissions resulting from the supply process. Since there is a growing interest in reducing embodied carbon emissions, this type of calculation is more common and some designers are using embodied carbon analysis in their decision making, which makes reused components more attractive.

Box 6.3 Environmental Product Declaration (EPD)

Environmental performance of components and materials is now often established through an Environmental Product Declaration (EPD). This is an independently verified and registered document that communicates transparent and comparable information about the life cycle environmental impact of a product. An EPD does not imply that a product is environmentally superior to alternatives but merely declares its environmental impacts so they can be compared. EN 15804–2012, Sustainability of construction works, environmental product declarations, core rules for the product category of construction products, *applies the LCA process to construction EPDs.*

The accepted way of conducting a LCA for a reused product in EN 15804 is to set the system boundaries between the two product systems (the original product and the reused product). All the original manufacturing impacts are allocated to the original product. The impacts for the reused product start from the moment the original product is discarded (thus they ignore any of the impacts of the original extraction, manufacturing and waste generated in that process). Thus, for a reused steel beam the original manufacturing would be ignored and the impacts associated with the reused beam would start from the moment the original beam is discarded. This methodology is not consistent with the way the steel industry calculates its life cycle impact.

Contemporary questions around different aspects of scarcity in the built environment mean that this is a good time for architecture to embrace a new, materialist mode of practice. (Jon Goodbun and Karin Jaschke[16])

Materiality and Tectonics

Stewart Brand talks about buildings being pushed around by three irresistible forces – technology, money and fashion.[17] To that we can also add the natural forces of the climate. Architecture, by nature, is susceptible to time: rust, rot, discolouring, mould. Brand also talks about '*age*' (representing a presence of history) as being the single most loved characteristic of buildings – people prefer old buildings to such an extent that many building are designed to look artificially old. However, the marks and imperfections that reveal the history of materials in an old building are often not appreciated in a new building context. In new buildings we have an expectation of perfection for material surfaces and shapes; this reduces individuality and leads to loss of variety and material choice. Material characteristics, such as irregularity, discolouration and unevenness, can add beauty and character, both in a new building context as well as in old buildings. An aesthetic of reuse is beginning to emerge with emphasis on recognizing and exploiting the uniqueness of old materials. For example, Dan Phillips of Phoenix Commotion talks about using patterns and repetition to make imperfections desirable.

Architecture that uses technological parameters as a source of inspiration for design is described as tectonic in nature. Frampton describes tectonic architecture as a '*poetic manifestation of structure…as an act of making and revealing*.'[18] The tectonics of reuse acknowledges different stages of the life of buildings, components and materials, and their changing nature over time. Hinte talks of a '*building as a living thing/ organism, constantly changing, growing, and degenerating, absorbing the superfluous*.'[19] The architecture of reuse recognizes that used materials and components have distinctive characteristics and does not hide the changing nature of these materials but expresses and celebrates it as a positive driver for architectural design. Reuse can become the generative idea to create an exciting and unique built environment that celebrates the imperfections and individuality of used materials (Figure 6.6). Thus, both matter and the means of making are made visible. This allows the user to take more pleasure in discovering a work of architecture and how it evolves.

Figure 6.6 This wall system was created by tres birds workshop for the TAXI project with a layer of sandblasted Plexiglass, 5-inch reclaimed PET bottle cylinders and a clear layer of Plexiglass.

6.3 UNDERSTANDING SOURCES AND OPPORTUNITIES

To work in a circular economy, architects need to become familiar and comfortable with a new set of sources for the materials and components they design with. Innovative design based on availability can increase the chance for a high percentage of reuse being incorporated into projects. Some of the sources for second use materials that have commonly been used are discussed here. At the end of this section Figure 6.10 provides a matrix of sources used in the case studies discussed in Chapter 3.

Materials Present on the Site

Perhaps the easiest approach is to base a new design on the resources that are present on site. These can be whole buildings that are adapted, partial reuse of a structure (sometimes including foundations) or use of reclaimed components from deconstructing a previous building on the site. The design team needs to have the appropriate expertise to appraise the components that are available for suitability. The starting point is usually a survey of the building and an assessment of the available components.

The Mountain Equipment Coop has taken this approach for some of their recent stores in Canada, including in Ottawa (Figure 6.7) and Winnipeg. The site for its Ottawa store was previously occupied by a 40-year-old former grocery store. This building was not suitable for adaptive reuse but all the components were carefully dismantled and catalogued.

Figure 6.7 Mountain Equipment Coop store in Ottawa built with components from the previous building on the site.

The new building was designed around the available components from the old building, including using the old structural grid, footings and steel frame components. About 75% of the existing building was incorporated into the new building and the layout, aesthetics and performance of the new building were all influenced by the characteristics of the old components.

Occasionally, other materials from the site can be used, including old industrial materials such as steel components, the earth available at the site, trees growing on or near the site or other agricultural waste such as straw from nearby. This is what was used at the Tysons Living Learning Centre (see Chapter 3.2.3).

Buildings Being Demolished Nearby

Looking further than the actual site, some designers find buildings that are at the end of their life and scheduled for demolition and come to an agreement with the demolition company and the owner for items that are of use to them to be extracted prior to destructive demolition. Lists of recent demolition permits and contacts with the demolition industry can facilitate this. In some cases it may be possible to deconstruct and relocate the entire structure for reassembly at the new site. This sometimes occurs with light industrial and warehouse buildings, but can also happen for other buildings. For example, the Roy Stibbs school (see Chapter 3.1.5) reused the steel structure from a dismantled school in a new location near Vancouver, BC. In other cases individual components can be extracted. Organizations such as tres birds workshop in Denver, CO, and Rotor in Belgium act as deconstructors–designers–builders and have the in-house expertise and resources to quickly strip a building of useful components when it becomes available.

Busby and Associates (now Perkins and Will Canada) used components from locally demolished warehouse buildings to provide many components for the new City of Vancouver Materials Testing Laboratory. Approximately three-quarters of the building's structure and fabric consists of salvaged and recycled materials, including heavy timber structural members, roof trusses, existing laboratory and mechanical equipment, light fixtures and furniture from buildings nearby (Figure 6.8).

Before committing to particular components it is important to survey the building, examine the drawings (if possible) and inspect their condition to consider if an existing building is suitable for deconstruction and the components are suited for reuse.

Demolition Contractors

Some demolition contractors have marketing departments to gain additional value out of components that they deal with, and

Figure 6.8 The City of Vancouver Materials Testing Laboratory uses materials from local demolitions.

may even send out e-mail newsletters announcing what they will have available soon. The organizations described in Chapter 5 have all developed links with these contractors to help them connect with the construction salvage market.

Salvage Yards

Most local salvage yards will sell whatever they can find a market for. In the building sector this has mainly consisted of heritage components but if demand for other types of materials grows they may be able to provide a supply. Some specialist salvage yards collect heavy timber and steel components, interior components and others. Organizations such as Rotor DC are trying to build a market for a wider range of salvaged components. Habitat for Humanity ReStores can be a source for a variety of smaller components, such as windows, doors, kitchen units and ironmongery, mainly for small-scale projects.

Exchange and Sales Websites

Websites such as Craig's List and Kjiji often have construction materials and components, but in small amounts. For small projects these can be a suitable source. The digital age also makes this type of exchange easier to facilitate and a more general acceptance of purchasing from networks and Internet sources is making this form of exchange more common.

Databases of local and available reclaimed construction materials, with criteria that materials have to meet to get on the list, are springing up in various locations,and can help inform, educate and inspire developers, architects and clients alike. Such databases help break down some of the barriers to material reuse. Examples include opalis.be, seconduse.com and planetreuse.com.

Specialist Brokers
This is a new type of networking organization that works to find value in discarded materials. These '*matchmakers*' have the skills necessary to recognize the potential of available waste and surplus materials, and understand the logistics of transport and refabrication to make such materials useful. They connect potential users of these resources with their current owners, saving them from landfill. This has helped to grow the market for reclaimed construction materials and components. Examples include Rotor in Belgium, the Scottish Materials Brokerage Service, Boston Building Resources Reuse Center and Planet Reuse in the USA. Their popularity is growing and they can also be hired to search out particular types of materials and components.

Architects need to understand these networks, which generally start as local enterprises but are now beginning to work at national level, sharing information about materials that are available. Their experience can reduce the risks of disruption or delay. Sometimes such organizations are hired as a consultant as part of the design team or as client advisors. They offer advice to the client and design team on the potential for reclaimed materials and disposal of materials on construction projects, and some can help source materials and provide quantified assessments of the potential reduction in environmental impact from using reclaimed materials.

Industrial Waste Streams
Some industrial waste streams provide useful materials that can be remanufactured or upcycled into construction products. Construction uses for industrial waste are demonstrated in several of the case studies in this book (see Chapter 3.4). This usually requires research into waste streams and creative thinking from the design team. For example, Superuse Studios demonstrated that timber from the centre of large waste cable reels, which are used to distribute large amounts of communication wires, are suited for use as cladding in a building. It developed a fixing system and an aesthetic, which it used in the Villa Welpeloo, based on these short timber lengths (see Chapter 5.4). Another example is the use of waste tyres by MooRoof in the PEEC (see Chapter 3.4.1).

Figure 6.9 Shipping containers used in the Upcycle House.

Infrastructure Waste

Some large infrastructure projects use durable materials for short periods, for example as temporary structures, and often with little consideration for what they could be used for after the initial use ends. There is often considerable potential for these materials. The Big Dig project in Boston (see Chapter 3.4.2) is an example of this approach, using components from temporary highway bridges. Research into these projects and establishing contacts with the contractors involved is needed to make this happen. Another example is shipping containers, which have been used in a variety of building projects, including the Upcycle House in Denmark (see Chapter 5.3 and Figure 6.9).

The Client's Other Building Resources

Clients with a large portfolio of buildings (for example universities, school boards, local municipalities, pension funds) may have several construction projects planned or in progress. One project may generate a stock of discarded elements that could be fed into other projects. In particular, interior elements of fit out projects can be reused in this way. For such clients it can be

Table 6.1 Matrix of sources for the case study buildings.

Case study building	Databases of reclaimed materials	Materials on the site	Buildings being demolished nearby	Demolition contractors	Salvage yards	Exchange and sales websites	Specialist brokers	Industrial waste streams	Infrastructure waste	Client's other buildings	Reconditioned goods direct from supplier
Alliander		■			■		■			■	■
Posner Centre		■	■				■	■			
Energy Resource Center		■			■		■	■		■	
Hughes Plumbing Warehouse		■								■	
Roy Stibbs School			■								■
Hindmarsh Shire Council Offices		■									
Ford Calumet Environmental Centre	■	■			■	■		■			
Hill End Ecohouse		■		■	■						
Tysons Living Learning Centre		■				■				■	
Parkwood Residences		■									
Headquarters Council of the EU					■	■	■				
La Cuisine – Winnipeg Folk Festival			■	■			■	■	■		
Pointe Valaine Community Centre											■
Oasis Children's Venture			■								
Old Oak Dojo	■				■		■	■			
Pocono Environmental Education Centre								■			
Big Dig House									■		
Kaap Skil Museum									■		
Waste House	■		■		■	■	■	■			

beneficial to develop a strategy and mechanism for identifying components that may have a future value and facilitating a mechanism to connect them to new projects or to store them. Careful scheduling is needed.

Reconditioned Goods Direct from Supplier

Some types of components may be returned to the supplier, reconditioned and resold, sometimes with a warranty and a similar specification. These include electrical and mechanical components, carpet tiles, furniture and acoustic ceiling panels. It is an area that is likely to expand into other sectors of the industry as interest in a circular economy grows. Sourcing such components has less effect on the process, as they are usually readily available and can be identified as a requirement in the specification.

6.4 DECISION PROCESS

A review of the case study projects and practitioner experiences suggests that when choosing materials and components from the various sources, design teams need to consider the following questions:

- What materials and components are available locally?
- Is the volume sufficient for the project?
- Are there any contamination risks?
- What are the transport implications – how far is it coming?
- Does it need reprocessing – where will this happen and what does it involve?
- Does the timing work for supply when needed?
- Is there a need for storage – where can it be stored on site?
- What prototyping and testing is required?
- Are there any code issues?
- Are there any performance concerns – does it conform to the required performance standard?
- What are the environmental benefits – can they be quantified?
- What are the cost implications – relative capital cost, operating costs and whole life costs?
- Does it help with achieving a credit in an environmental rating such as LEED, BREEAM or LBC?
- What condition is it in – how long will it last, has its durability been reduced by previous use or the deconstruction process?
- Are there more valuable uses available for this material/component?

6.5 CONCLUSION

Three nutrition groups exist in ecosystems: producers (plants), consumers (animals) and decomposers (bacteria). The third group of decomposers is critical as it links the circle by making waste from the other two into a valuable resource. Manufactured systems have typically focused on producers and consumers and relied on nature to absorb and deal with the wastes that result.

Little effort has been made to consider decomposer (or end of life) processes within man made systems. This discards the value that is present in used resources and leads to a build-up of waste.

This observation can be used as a conceptual tool to reconfigure design practices and the processes that we use to create and manage our urban environment into new and different directions that confront the challenges facing us. As Jeremy Till, Jeanne Gang and others point out, the emerging conditions of scarcity are rich in possibilities for the design professions. Recognizing the challenges and opportunities facing architects Buckminster Fuller's called for a new kind of designer, a '*synthesis of artist, inventor, mechanic, objective economist and evolutionary strategist*'.[20] This is what is needed to embrace the opportunities that the circular economy and material reuse offers. But beyond this we need to build an infrastructure that embeds circular systems into its core assumptions.

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IMAGE CREDITS

Figure 6.1 Courtesy Steve Hall © Hedrich Blessing; figures 6.2, 6.4, 6.5, 6.7 & 6.10 Author; figure 6.3 Courtesy of Vandkunsten; figure 6.6 Courtesy of Brooks Freehill and Mike Moore of tres birds workshop; figure 6.8 By Martin Tessler, courtesy: Perkins+Will; figure 6.9 By Jesper Ray, courtesy of Lendager Group

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FURTHER INFORMATION

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- Association for Sustainable Building Products – Networking organization which is leading the Reusable Buildings Network (RUBN) in the United Kingdom. http://asbp.org.uk/
- Habitat for Humanity – Operates a chain of non-profit home improvement stores and donation centres (ReStores) across North America. www.habitat.org/restores
- Reuse Development Organization (ReDo) – Has an online reuse center directory. loadingdock.org/redo/Search/index.html
- National Institute of Building Sciences' Whole Building Design – A web-based portal providing information on companies that transport, collect and process recyclable debris from construction projects. www.wbdg.org/tools/cwm.php
- WRAP (Waste and Resources Action Programme) – A UK organization that works with governments, businesses and communities to deliver practical solutions to improve resource efficiency. http://www.wrap.org.uk/

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