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Barriers for Deconstruction and Reuse/Recycling of Construction Materials

International Council
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Barriers for Deconstruction and Reuse/Recycling of Construction Materials

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Edited by

Shiro Nakajima, Building Research Institute, Japan
Mark Russell, University of New Mexico, U.S.A.

Working Commission W115
Construction Materials Stewardship

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Foreword

Working Commission 115 Construction Materials Stewardship of the International Council for Research and Innovation in Building Construction (CIB) was formed in September 2006. Its intention is to build on the work carried out in CIB Task Group 39 which operated from May 1999 to March 2005. TG 39 produced a series of five reports which culminated in CIB Publication 300 – Deconstruction and Materials Reuse and International Overview, which is a state-of-the art report on deconstruction and materials reuse in ten countries edited by Abdol Chini.

The purpose of new working commission is to extend the work and achievements of TG39. The research to be undertaken by this working commission is more extensive in nature, scope, depth and coverage than the work undertaken covered by TG39. The status of a working commission acknowledges that research into construction materials stewardship is important in making a substantive contribution to progressing CIB's stated aims of promoting sustainable construction and development. The mission of W115 is to drastically reduce the deployment and consumption of new non-renewable construction materials and to replace them with renewable ones whenever possible.

The first meeting of the commission members took place in conjunction with SB07- International Conference on Sustainable Construction - in Lisbon, Portugal in September 2007. The commission's first publication (CIB Publication 318), "*Construction Materials Stewardship – The Status Quo in Selected Countries*," edited by John Storey, includes the reports presented at this meeting and a number of other reports received subsequent to the meeting. Nine counties were represented, Germany, Japan, New Zealand, Slovenia, Sweden, Switzerland, The Netherlands, United Kingdom, and the United States of America.

The third annual meeting of W115 was in conjunction with the Construction Materials Stewardship Conference at the University of Twente in Enschede, The Netherlands in June 2009. The commission's second publication (CIB Publication 323) titled, "*Lifecycle Design of Buildings, Systems and Materials*," edited by Elma Durmisevic, is the Proceedings of this conference and includes twenty two fully reviewed papers presented at the conference.

The third publication of W115 titled, "*Construction Waste Reduction around the World*," (CIB Publication 364) edited by Gilli Hobbs was published in 2011. This report provides an overview of construction waste reduction activities across the world through a series of country reports from Canada, Germany, Israel, Japan, Norway, Singapore, Slovenia, Switzerland, Turkey, UK, and USA.

The sixth annual meeting of W115 was in conjunction with the Green Design Conference in Sarajevo, Bosnia Herzegovina in September 2012. The commission's fourth publication (CIB Publication 366) is the proceedings of this conference edited by Elma Durmisevic and Adnan Pasic and includes thirty six fully reviewed papers presented at the conference.

This report is the fifth product of W115 and provides an overview of barriers for deconstruction and reuse/recycling of construction materials across the world through a series of country reports from Canada, Germany, Japan, Netherlands, New Zealand, Norway, Singapore and United State of America. The W115 coordinators would like to acknowledge the major contributions made by Shiro Nakajima and Mark Russell in developing the initial

template for data collection, and formatting and editing all country reports. Special thanks to the authors of the country reports for their time and efforts in collecting the needed data and writing the report.

Abdol Chini, Frank Schultmann, and John Storey
W115 Coordinators

OVERVIEW: GLOBAL BARRIERS FOR DECONSTRUCTION AND REUSE/RECYCLING OF CONSTRUCTION MATERIALS

Shiro Nakajima, Building Research Institute, Japan

Mark Russell, University of New Mexico, U.S.A.

Introduction

This report has been produced by the CIB Working Commission 115 "Construction Materials Stewardship". The mission of the Working Commission W115 is to drastically reduce the deployment and consumption of new non-renewable construction materials, to replace non-renewable materials with renewable ones whenever possible, to achieve equilibrium in the demand and supply of renewable materials and ultimately to restore the renewable resource base, and carry out these tasks in ways to maximize positive financial, social and environmental and ecological sustainability effects, impacts and outcomes.

To achieve this mission the Working Commission set its objectives to:

1. determine ways to utilize new and existing construction materials in the most effective and ecologically, environmentally, socially and economic manner possible
2. develop life cycle costing and management mechanisms for materials
3. develop systems to mitigate and ultimately avoid construction material waste
4. develop ways of using material wastes as raw material for making construction materials
5. develop methodologies for designing transformable and adaptable buildings and spaces to extend service life and so reduce overall construction material resource use
6. establish strategies to promote whole buildings, components and materials re-use
7. establish ways to regenerate the renewable material resource base and improve the performance, availability and use of renewable construction materials
8. establish methods and strategies to enhance utilization of used construction materials
9. establish what the barriers are to the sustainable use of building materials and devise methodologies to overcome those barriers
10. develop information and research outcomes that will contribute to and facilitate the establishment of policy and regulatory standards, initiatives and options aimed at reducing new materials deployment and consumption
11. develop the necessary techniques and tools to support the foregoing objectives

This report is mainly prepared for the objective No.4. The report is intended to provide an overview of the "Barriers for deconstruction" and "Barriers for reuse and recycle" across the world through a series of country reports. In 2005 the CIB Task Group 39 "Deconstruction" produced a report entitled: "Deconstruction and Materials Reuse, an International Overview" (CIB Publication 300). That report summarized the activities that were being conducted by ten countries regarding deconstruction processes and the design for disassembly. W115 members decided to provide an update on the effectiveness of their deconstruction and material reuse programs with a particular emphasis on the barriers encountered and the means that have been employed to overcome these barriers.

A template was produced and sent to W115 members for completion. This template was intended to correct the following information.

1. Commonly used method to remove buildings (deconstruction / dismantle)
2. Barriers for deconstruction.
3. Technical strategies to overcome the barriers for deconstruction.
4. Political strategies to overcome the barriers for deconstruction.
5. Other strategy to overcome the barriers for deconstruction (ex. Ecological Incentive).
6. Type of C&D waste and its recycle ratio.
7. Products produced from C&D waste.
8. Barriers for reuse and recycle.
9. Technical strategies to overcome the barriers for reuse and recycle.
10. Political strategies to overcome the barriers for reuse and recycle.
11. Other strategy to overcome the barriers for reuse and recycle (ex. Ecological Incentive).

Country reports have been submitted from Canada, Germany, Japan, Netherlands, Norway, Singapore and United State of America. One paper from New Zealand and one survey from United State of America are also included in the Annex. Following is a summary of the country reports as well as common themes and issues that arise across the globe.

Common Themes

Technical Strategies

A common theme from the national reports was that education could play a significant role in persuading owners, architects, and contractors to design for deconstruction and likewise encourage the reuse of materials from demolished buildings. In most regions the specifications for structural components limit the use of recycled or reclaimed material without extensive testing to verify their integrity. Further research is encouraged to find more uses for the recycled material or methods to process the recycled products and develop a cost effective means to obtain similar structural qualities as the raw materials. Another advantage to this research is that by developing a larger market for recycled products it would provide the economic incentive that would encourage more deconstruction activities. Finally, many countries have recommended developing an EPR program in which the original product manufacturer would be responsible for providing recycling resources for the product at the end-of-life, thus reducing the landfilling potential of the material.

Political Strategies

A predominant concept from all of the countries is that without legislative action to create an artificial economic driver, the current market for deconstructed material is difficult to remain economically feasible. Only in remote situations in which the scarcity of raw materials promotes the reuse of demolished buildings, has it been seen where a taxation or penalty fee was not needed to encourage a higher percentage of material reuse. The common barrier in most regions is that still the demand for the reused material is relatively low. When coupled with the added cost for sorting the materials from a deconstruction site, it precludes most contractors from participating in the practise. Therefore, the common recommendation among the nations for improved design for deconstruction and reuse of demolition materials was to encourage financial burdens on the landfill process through tipping fees or taxes and provide financial incentives for efficient designs that facilitated end of life deconstruction or that demonstrated higher than normal recycling rates. Local or national legislation would be necessary to make these programs effective and establish the need within the industry for greater participation in the deconstruction design and demolition recovery efforts.

Summary of report from Canada:
Barriers for Deconstruction and Reuse/Recycling of Construction Materials in Canada
Author: Joe Earle, Deniz Ergun, and Mark Gorgolewski of Ryerson University

Canada has reportedly one of the highest levels of solid waste per capita. The construction industry accounts for 25% of the total waste generated. The average cost for handling waste is $79 per person, although there is extensive variation in the methods or processing waste from region to region.

The deconstruction process in Canada looked at the major structural elements of steel, wood, and concrete. Although the majority of steel from demolition is considered as scrap and sent to recycling facilities, the study focused on the reuse of steel “as is”. The major barriers for steel reuse are associated with structural liability, a lack of awareness of the demolition crews, an inconsistent market for reused material, the damage during deconstruction, and competition with a well-established scrap steel recycling industry. Since the majority of wood from deconstruction is landfilled, it was evaluated that the barriers for reuse include the difficulty in dismantling due to time required to disassemble, new products require more adhesives and the wood is destroyed in the process, the wood waste is mixed with other contaminants, new products are often cheaper than reused materials, and the lack of regulations dealing with wood reuse procedures. Concrete is difficult to reuse in the “as is” condition and is thus normally crushed for aggregate. The barriers for concrete reuse include the challenges with concrete design normally being cast in place and thus unable to directly reuse the products and the cost associated with transporting large sections of cast concrete normally exceed the cost for cast in place construction.

The strategies to overcome the barriers for deconstruction of structural materials include for steel: improving the deconstruction process to reduce damage to the material and streamline the process for recertifying the structural capability of the steel. To overcome the barriers of wood deconstruction, the design of the new buildings should be improved to reduce the adhesives that damage the wood during removal and encourage more adaptive use of older buildings instead of demolishing the entire structure. The barriers for deconstruction of concrete and masonry can be overcome through better design of the building to account for salvage of materials.

For material reuse and recycling, the products that were evaluated were wood, drywall, and concrete. A common barrier for reuse/recycling of these products is the challenge of on-site sorting to ensure that the product stream is relatively pure. Additional barriers for wood reuse/recycling include the lack of knowledge on how to reuse/recycle treated wood, and the ease of landfilling. For drywall, the major barriers for reuse/recycling are the lack of gypsum recycling facilities. A major barrier for reuse/recycling of concrete is the contamination of the crushed product reduces the strength of the aggregate and increases the cost as compared to virgin material.

To overcome the barriers for reuse/recycling, education is necessary to promote the programs that are available to provide information and resources for reducing the landfilling of products. For wood products, the reuse of products could be increased by promoting the use of old wood products in new construction for its architecturally aesthetic value. The barrier for reuse/recycling of drywall could be encouraged through the implementation of more bans on the landfilling of gypsum.

The common barriers to deconstruction and reuse/recycling that apply to all of the materials in Canada are: lack of knowledge about the value of the reused material, the impression that industry professionals have that deconstruction costs more, the short turn-around time for deconstruction, poor planning of waste management, the lack of cooperation between subcontractors, and the lack of a market for the reused material. To overcome these barriers the following activities are recommended: develop the market for reused materials, increase the use of the Canadian guides for buildings demolition, encourage the development of plans for demolition/dismantling that all subcontractors will be required to follow, expand the Extended Producer Responsibility (EPR) program that requires material manufacturers to take back waste materials, improve the zero waste initiatives to diminish the amount of waste that is landfilled, use an integrated design process to communicate the techniques that can reduce waste, and require building rating systems certification to increase the awareness of waste conservation practices.

Summary of report from Germany:
Barriers for Deconstruction and Reuse/Recycling of Construction Materials in Germany
Author: Anna Kuehlen, Neil Thompson, Frank Schultmann of Karlsruhe Institute of Technology

The three major construction materials used for structural support in Germany are masonry with reinforced concrete, masonry with timber ceilings, and precast concrete with reinforced concrete. During deconstruction, the most common techniques include removal with hand tools, ebbing, pressing, and blasting. Although, often a combination of these methods is used depending on the location, space constraints, material separation requirements, and legal conditions regarding noise, dust, and health protection.

The major barriers for deconstruction in Germany include: the existing buildings are not designed to be dismantled, major building components are not designed for dismantling, suitable deconstruction equipment is not available, disposal to landfills is often more economical, separation of materials can be time consuming, building codes may limit the reuse of some structural components, uncertain costs factors for dismantling, there is a lack of "best practices", the presence of hazardous materials such as lead and asbestos, and a lack of quantitative case studies to demonstrate the benefits.

To overcome the barriers for deconstruction political, technical, and research activities are proposed. The political strategies to encourage reuse of construction waste involve ordinances to permit more reuse of materials and a Federal regulation "Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible

Waste Disposal". The technical strategies to overcome the barriers for deconstruction involve standards such as ATV DIN 18459 regarding the contracting issues for deconstruction materials, advancement of building certifications, and work instructions for the recycling of deconstruction material. Research projects to overcome barriers to deconstruction include the development of "best management practices" by the French-German Institut of Technology regarding the cost, time and selective dismantling processes. Other research and development strategies include the development of software tools to minimize the environmental and human impacts through the deconstruction planning process.

The common construction wastes for recycling in Germany include excavated earth, demolition debris, road construction waste, construction waste, and cement construction material. The waste recovery rate for Germany is one of the highest in the world. Approximately 88% of these waste products are reused or recycled with the remainder going to landfills and only a small percent being incinerated.

Barriers for reuse/recycling include lack of specific laws regarding reduction of landfilling construction waste and lack of regulations on manufacturer's responsibility to minimize waste. The political strategies to overcome these barriers involve the establishment of legislations to enforce the reduction of landfilling construction waste and the development of regulations to encourage material manufacturers to develop higher standards for products that reduce waste. Technical strategies to address waste reuse and recycling would include research on packaging materials and government sponsored research & development for waste minimization of material producers. Additionally, financial incentives to encourage construction waste reuse/recycling would include government sponsored programs to reward project teams that achieve high waste recovery ratios and incentives to waste management companies for developing new technologies that improve waste recycling processes.

Summary of report from Japan:
Barriers for Deconstruction and Reuse/Recycling of Construction Materials in Japan
Author: Shiro Nakajima of Building Research Institute

In Japan, the major types of construction in which dismantling is used for demolition are: post and beam timber houses, wood frame houses, and light steel framed houses. The primary barriers for deconstruction of these style of homes is that it can take three times longer to dismantle the building in such a manner to preserve the components and to segregate the waste products. An additional barrier for deconstruction is due to the increased use of composite materials due to safety, durability, and energy conservation requirements. The composite materials make it difficult to deconstruct and difficult to selectively dismantle the waste products.

To overcome the barriers of deconstruction the recommended strategies involve technical, political, and ecological initiatives. The technical strategies include: design buildings for end of life easy deconstruction and design materials for ease of reuse/recycling. The political strategies are associated with providing financial advantages such as tax reductions for: environmentally friendly building removal, designing buildings for deconstruction, designing materials for reuse/recycle. Additionally, financial disadvantages such as increased taxes could be associated with deconstruction methods, building design, and material use that is not considered environmentally friendly. Other strategies to overcome deconstruction barriers could include providing rating systems to evaluate the environmental impacts of the building removal process and creating deposit systems to give incentives for deconstruction and reuse/recycle.

In Japan, 68% of the wood waste is recycled for raw materials, with 70% of it going to particle board manufacturing. A recent demand in using wood waste for renewable energy has created a shortage of wood for the particle board industry. However the recycling policy of Japan establishes that the first priority is to use the waste as raw materials and energy source is only secondary. Unfortunately, this is currently not being followed in Japan. To overcome the barriers for recycling wood waste the following methods are recommended: conduct research on .increasing the durability and stability of particle boards, follow the recycling policy of using wood waste as raw materials, and provide financial advantage such as tax reductions for using recycled wooden materials.

Of the other recycled construction wastes in Japan, concrete has a recycled rate of 97% and steel has a recycled rate of 100%. Most of the concrete waste material is recycled as road foundation and some is reused as raw material for other concrete. To overcome the barriers for recycling concrete it is recommended that more low energy methods are developed that will recycle the concrete to equivalent standards as raw materials. Although there are no significant barriers for recycling steel, it is recommend to find new methods to facilitate sorting of the steel and conducting research on reusing steel as structural elements. Additional strategies for both concrete and steel involve establishing more financial advantages such as tax reduction to encourage the design of new buildings to use the recycled products.

Summary of report from Netherlands:
Barriers for Deconstruction and Reuse/Recycling of Construction Materials in Netherlands
Author: Elma Durmisevic and Stefan Binnemars of University of Twente

The major forms of construction in the Netherlands are concrete panel systems, brick façade, and timber frame paneling. Depending on whether the building is a permanent or temporary structure determines how it is dismantled. The two step process for permanent buildings involves striping the building of useable material and then concluding with the processing of the structural elements and brick in crushing plants. As temporary buildings are designed for short term, they are often standardized in their elements and thus lead to quick removal and reuse of elements. However, for temporary structures, the quality of the material may be inadequate and thus the material is often downgraded in the recycling process.

The barriers for deconstruction involve the absence of designs for disassembly of the elements and a lack of government regulations to stimulate material reuse. The strategies to overcome these barriers include transforming the construction industry such that the future value of the building will be focused on the actual value of the materials. This transformation will help to change the design process to accommodate for the dismantling of the building and incorporating reused material into new construction. The Industrial Sustainable Flexible buildings subgroup has developed several demonstration projects of this technology. Continued research through a building innovation platform may provide more models for innovation in the near future.

The reuse and recycling of construction and demolition (C&D) waste in the Netherlands usually results in the burning of combustible waste, the granulating of concrete mortar, and the recycling of bituminous waste. Investments are being made in quality improvements, reduction of dust emissions, and research into dry separation techniques.

C&D waste that is sent to a crusher plant for granulating poses usually originates concrete, tarry asphalt and non-tarry asphalt. The majority of the reused granulated product is supplied to the foundation and heighten market with other industries being: road construction, asphalt industry, thermal purification, concrete industry, sieve sand, sorting company, dump, and export. Sorted C&D waste that is not granulated normally goes to energy recovery with the following exceptions: wood is shredded for particle board, plastic is transferred to specialty plastic recyclers, and metals are recycled to new products.

The economic crisis in the Netherlands has resulted in uncertainty in the construction industry with many building remaining vacant. A transition of building evaluation is necessary in which the building value is directly related to the intrinsic materials in the construction. The Green Transformable Building Laboratory at the University of Twente is working to implement these changes and establish a methodology that will eliminate construction waste and create a framework for sustainable design.

Summary of report from Norway:
Barriers for Deconstruction and Reuse/Recycling of Construction Materials in Norway
Author: Rolf Andre' Bohne of Norwegian University of Science and Technology and Eirik Rudi Wærner, Hjellnes Consult AS

Policies and national action plans in Norway have resulted in increasing the amount of construction and demolition waste being recycled to 75%. Generally, Norwegian buildings are either wood or concrete and brick with only a small number of steel structures. Legislation requires that larger buildings have a waste handling plan for construction, renovation, or demolition. Additionally source separation for 60% of the waste is normally conducted on site.

The predominant barriers for deconstruction often deal with the scale of the project, economy, knowledge, and space for source separation. To increase the amount of deconstruction, four strategies have been implemented: general ban on landfilling organic materials, waste handling plans with inspections and sanctions, knowledge transfer and the voluntary involvement of industry, and the establishment of recycling stations for sorting. Besides the efforts to encourage recycling, there is an effort to reduce waste production of building elements by prefab and precut materials and designing buildings for flexible uses of the spaces.

The five construction product groups evaluated for recycling in Norway are: brick and concrete, wood, asphalt, metals, and gypsum. Each of these groups have their own barriers for reuse and specific strategies to overcome these barriers.

Concrete has three major categories for recycling: pure concrete, low polluted concrete, and toxic waste. The barriers for recycling the concrete include the following: For contaminated concrete, it can be costly to remove the pollutants and is often easier to landfill the material. Equipment availability can also play a significant role in recovering the concrete in a form that is recyclable. The cost of virgin gravel can be cheaper than recycled aggregate when the transportation and storage costs are added. Additionally, recycled product may have unknown strength and quality properties. To overcome the barriers of recycling concrete the following actions are recommended: Crushed concrete can be used as road base aggregate and would replace 0.5% of the required virgin product. Bricks can be removed by skilled equipment operators or sorted by hand for future reuse. Another option is to research how and where to use low polluted concrete. In conjunction with this need, the criteria for labeling concrete as low polluted is also being reviewed.

Wood is also divided into three categories: Clean studs from construction, treated woods, and impregnated woods. Most of the waste wood in Norway is currently used as biofuel. The major barriers for recycling wood are related to form, strength, and contaminations. The direct reuse of wood is rarely encountered due to the demand for altered dimensions and better thermal properties for new construction. The main strategies for overcoming the barrier for recycling are to improve the sorting techniques and to focus on research to reduce waste production.

Metal and asphalt are considered valuable products and thus 90% of the construction waste is being recycled. As these products are near their technical limit of reuse, there is no work in progress to increase the recycling.

Despite 4 - 16% of the construction waste being gypsum, there are limited resources available for recycling gypsum in Norway. The primary barrier for recycling is due to the transportation costs. To overcome this barrier, there is work in progress to ensure better compression of the gypsum and provide green return trips or trains. Political strategies to increase gypsum recycling include increased gate fees and waste compensation fees on new gypsum products.

Mixed waste contribute to 18% of the total waste stream in Norway. Strategies to reduce the overall mixed waste production include source separating the waste and split the waste into combustible/non-combustible categories. For recent glass waste, the producers are responsible by regulations to handle the recycling of double glazed windows. The main barriers for glass recycling include cost and contaminants. Although there are facilities available to recycle most of the glass, they do not receive much of the market share. To overcome these barriers, there are regulations being developed that would treat all windows as toxic waste and thus allow the same facilities that handle the double glazed windows to also handle all other windows. The other predominant mixed waste is plastics. Since different types of plastic have different potentials for recycling there is a wide variety of success in plastic reuse. The three barriers for plastic recycling are: many plastics are considered toxic, it can be difficult to get the pureness needed for recycling, and it is cheaper to incinerate. The strategies to overcome these barriers are to train personnel in source separation and to require producers to be responsible for recycling their plastic products.

Summary of report from Singapore:
Barriers for Deconstruction and Reuse/Recycling of Construction Materials in Singapore
Author: Edward Anggadjaja of Centre for Sustainable Buildings and Construction, Building & Construction Authority

In Singapore there are two predominant methods for deconstruction of buildings: top-down demolition and controlled demolition. Top-down deconstruction is the most predominant method and involves starting from the top of the building and working down in a sequence of demolition that is in reverse of the construction process. The controlled demolition process involves using diamond cutters to remove parts of the structure. The main barriers to top-down deconstruction are: the design and construction methods do not focus on the reusability of materials and thus building components are damaged during disassembly, there is a lack of technical knowledge and experience in performing deconstruction, the dismantling process will take significantly longer, and there is skepticism from building owners to install used building products in their new construction projects. In addition to the barriers for top-down construction, the controlled demolition process has a barrier associated with the cost of diamond cutters.

To overcome the deconstruction barriers the following technical strategies are recommended: education and promotion of the techniques is needed for industry professionals on the Design for Disassembly process, the existing building codes should be updated to allow for demolition methodologies or innovations, and in depth pilot studies should be conducted to demonstrate the concepts of deconstruction. The political strategies to overcome the deconstruction barriers would include: promotion of the Green Mark Scheme building rating system which includes points for deconstruction, create a public awareness program on the benefits of Design for Disassembly, and organize study trips of industry stakeholders to visit other countries that have successfully implemented deconstruction techniques. Other strategies to overcome the barriers would be to provide governmental monetary incentives for contractors conducting research or demonstration project through the Sustainable Construction Capability Development Fund.

The majority of the construction waste in Singapore is concrete and brick, with the remainder being metals, timber, glass, plastic, and gypsum. Of the concrete waste, 98% is currently being reused as recycled aggregate. To overcome barriers for recycling, the same technical strategies as overcoming the barriers for deconstruction can be applied: education and promotion, revise codes, and conduct pilot studies. Additionally, the Sustainable Construction Capability Fund could be used to provide incentives to support the strategic shift in industry to adopt reuse/recycling properties. Since the metal waste from demolishing is being recycled at 100%, there are no barriers to be overcome.

Summary of report from United States:
Barriers for Deconstruction and Reuse/Recycling of Construction Materials in U.S.A
Author: Abdol Chini and Ryan Buck of University of Florida

In the United States wood frame construction is very common for residential construction. The normal method of demolition is to use heavy equipment to break apart the facility. This method of demolishing the building normally destroys most of the materials and make recovery of products nearly impossible. The major barriers to deconstruction are the time required to disassemble the facility and the costs associated with the extra time and labor. Strategies that can be used to overcome the deconstruction barriers may primarily focus on the economic incentives. By using more labor and less equipment, it is possible to preserve more of the construction material and save the costs of heavy machinery. Encouraging the contractors to resell the deconstruction material can also provide a financial incentive. Assigning permitting fees that are cheaper for deconstruction projects may also be economically desirable for contractors. Pursuing more productive methods of deconstruction such as power tools for nail removal, may also save time and money on demolition projects. Another strategy would be to mandate a percent of the material to be recovered and also to reward contractors with financial incentives for higher than normal levels of material recovery.

Steel structured construction is most common in large commercial facilities in the United States. In the demolition process, it is common to crush everything other than the steel and then to disassemble the steel frame. The barriers to deconstruction normally involve the problems associated with demolishing all the associated materials. Due to the size of the building, it can be very time consuming to attempt to preserve the materials in a ready to use quality. The strategies to overcome this barrier would involve providing incentives to owner or contractors to reward them for preserving more of the material and forcing government projects to set an example by performing deconstruction instead of demolition. In addition, since deconstruction is a slower process and thus may involve less safety hazards, it may provide a financial incentive if insurance companies could offer discounts to contractors that use a deconstruction process.

Concrete/masonry structures normally use a variety of techniques such as cast-in-place or pre-cast concrete members. Although it is common to demolish the concrete and reuse the material as aggregate, it is economically not worth the effort to attempt to deconstruct the concrete or masonry. The primary barrier is the added time it takes for the contractor to selectively deconstruct the building. Unfortunately due to the added costs of extra time for deconstruction and since the material can still be reused or recycled, there are no strategies recommended to overcome these barriers.

US estimates for concrete recycling indicate that 50% of the material is recycled for raw materials. Of the recycled product, 68% is used as road aggregate and the remainder is used for new concrete, asphalt hot mixes and low value products like general fill. The main barrier for recycling concrete is associated with the transportation of the waste. Since recycling centers are often further away than landfill sites, recycling would incur added time and costs compared to normal dumping. Technical strategies to overcome these barriers would include increasing the landfill dumping fees and creating more recycling facilities to reduce the driving distances. The US or state government could also assist with overcoming barriers by establishing mandates that require a percent of concrete to be recycled or a certain percent of recycled product be included in particular new projects. Other strategies to overcome these barriers include crushing and screening the concrete on site, adjusting the fees for recycling centers to compensate for a lower market price, and developing specifications and guidelines for their use.

It is estimated that 48.5% of the wood C&D waste is recycled in the United States. Some of the products derived from recycled wood include furniture, mulch, particle board, and feedstock. The main barrier for recycling wood is the effort that is required by owners and contractors to sort the waste instead of throwing it into a landfill dumpster. To overcome the barriers for recycling wood, it is recommended that the owners and contractors are educated on the value of the recycling process. Government programs to require a percentage of the waste to be recycled or provide incentives for recycling large percentages of waste would encourage contractors to participate. Other strategies to overcome the barriers would involve encouraging contractors to deconstruct the building instead of performing demolition and then stockpiling the wood products for future resell or use on a later project.

The amount of drywall that is recycled in the US annually is 28%. The recycled drywall primarily uses the gypsum in new drywall manufacturing or as an additive to Portland cement. Other applications of the gypsum include fertilizers and soil enhancements for drainage or nutrients. The primary barrier for recycling drywall is the difficulty in separating the material from a mixed waste stream, which would result in extra time and expenses. To overcome this barrier it is recommended that the drywall be removed through deconstruction so that the material is not mixed with other waste. Political strategies to encourage drywall recycling would include laws or ordinances to control C&D wastes and percentage of recycling from construction sites. Another strategy to promote drywall recycling would be to ban the disposal of drywall in landfills. As there has been evidence of hydrogen sulfide production associated with the gypsum in landfills, many communities have initiated the ban on landfilling drywall.

Asphalt shingles in the US are typically landfilled; but can be recycled for use in asphalt concrete. One of the main barriers for recycling the asphalt shingles is that there is a very limited market available for them. Additionally, it is often cheaper to landfill the material as opposed to recycling. A technical strategy to overcome these barriers would involve finding a different use of the recycled product. The government can also play a role in developing laws and regulations that would require an increased percentage of asphalt shingle recycling. Other legislation could be encouraged that would facilitate using the asphalt shingles and create a larger market for their reuse. Other strategies to overcome the barriers would involve the recycling facility providing financial incentives for the contractors that recycle the product instead of landfilling.

In the US, 85% of the steel from building demolition is recycled. Although direct reuse of steel is possible, the greater percentage of waste steel is melted down and recycled for other steel products. The primary barrier for steel is in direct reuse instead of recycling. To overcome this barrier it is recommended that new construction projects are designed with the waste steel shapes in mind. Additionally, ecological incentives can be provided to contractors for directly reusing steel by reducing the material transporting and reducing the costs for new steel purchases.

Annex 1
Overcoming the Barriers to Deconstruction and Materials Reuse in New Zealand

Authors: John B. Storey and Maibritt Pederson of Victoria University of Wellington, Wellington, New Zealand

New Zealand has four million people in an area of 268,021 square kilometers. Over three fourths of the population live in central business districts with a full range of building materials and construction systems. The remainder of the population live in one or two storey light timber frame construction. The current construction waste for New Zealand is estimated to be 17% of the municipal waste.

The *New Zealand Waste Strategy – Towards Zero Waste and a Sustainable New Zealand 2002* provides the NZ government policy to reduce by 50% the weight of construction waste that goes to a landfill. It is the responsibility of local Territorial Authorities in New Zealand to implement waste minimization policies. Over 50% of the territories have established a goal of zero waste by 2015. Enforceable waste strategies need to be established and reinforced by mandatory requirements with support and funding.

There are a variety of acts, policies, and targets in New Zealand regarding construction and demolition waste minimization. It is recommended that a comprehensive document be provided that would consolidate the policies for the public. In addition, the lack of specifications and testing for the approval of reused construction material provides a barrier for deconstruction. National standards should be developed that would provide acceptable standards and reduce the confusion.

There are two markets for resource recovery: unique or antique architectural components and the market for reused material such as concrete. The architectural market is well established with numerous small businesses. The material reuse business is only in large cities and rarely collects material from smaller population areas due to transportation and economic feasibility. To overcome this barrier in geography it is recommended that local authorities cooperate on a regional basis to manage the construction waste. Another option would be to encourage innovation in finding new uses for C&D waste in the local communities.

The New Zealand building demolition industry is largely unregulated; although there is guidance entitled "Approved Code of Practice for Demolition" on safety practices. As there is a lack of networking among demolition contractors, increased cooperation and networking may enhance the knowledge of environmental responsibility. Demolition contractors stated that if there were more building designs that included disassembly techniques it would facilitate the deconstruction for the demolition contractors and a higher percentage of material could be recovered. Education on life-cycle resource conservation and deconstruction could demonstrate recycling techniques and inform the design professionals.

Despite a recent interest in salvage material, the primary barrier is the economics of the projects which varies from locations. In larger industrial area, contractors have indicated that an avoidance of landfill tipping fees has provided an economic benefit. Establishing recycling quotas may provide the impetus to encourage recycling in the smaller communities in which raw materials are less expensive than recycled and there are minimal landfill costs. Other financial incentives could involve reduction in taxes for projects or industries that promote recycling strategies. Another option would be to advertise demolition projects in advance to permit material salvagers to take as much material in advance as feasible.

A lack of construction material details prior to a demolition leads to uncertainty in the deconstruction process. Not knowing the strength, integrity, and quality of the structural elements can make it difficult to determine future uses of the waste. Although the buildings require a pre-demolition survey, the material properties of the components are normally not included. A strategy to resolve this issue may involve including a condition survey to determine the actual properties of the building. Another option may involve an Extended Producer Responsibility (EPR) program in which the original manufacturer is held responsible for recycling their products at demolition. Additionally, a challenge to recycling occurs with the introduction of composite materials that require adhesives that form chemical bonds and become difficult to source separate. It has been proposed that legislation be developed that would preclude the use of these composites until effective safe methods are developed for disassembly.

Annex 2
Survey of Deconstruction Operations by Building Materials Reuse Organizations in the US

Author: Brad Guy of The Catholic University of America

A survey of deconstruction operations was sent to building materials reuse stores in the US. Of the 21 respondents, 60% were non-profit organizations and 40% were for profit. The number of employees for the companies ranged from 1 to 25 with the average being 6.8.

The amount of time that the companies had been conducting deconstruction operations ranged from 1 to 14 years with an average of 4.9 years. The average number of deconstruction projects per year was 37 with the highest being 200 and the median was 16.

Half of the deconstruction companies work in an urban environment with 78.9% being private middle-income homeowners. The private residences are attractive for deconstruction for tax deduction purposes.

As deconstruction and material recovery becomes attractive as a means for avoiding landfill fees, none of the responding companies operated where disposal costs were less than $40 per ton for construction waste.

The survey indicated numerous common practices associated with the deconstruction contractors. The following is a summary of the some of the more relevant findings: the deconstruction process is primarily hand-labor, telescopic forklift was the most common piece of equipment, material loading is often done with a trailer or truck at the site and removed as the vehicle fills, de-nailing is common on site, and volunteer labor is far less often than paid employees.

Barriers for Deconstruction and Reuse/Recycling of Construction Materials in Canada

Joe Earle, Deniz Ergun and Mark Gorgolewski

Ryerson University
CANADA

INTRODUCTION / BACKGROUND

Canada is located on the northern portion of the North American continent. It is the second largest country in the world by land mass covering 8,965,121.42 square km (Statistics Canada, 2012), and spanning from the Atlantic ocean in the east, the Pacific ocean in the west to the Arctic ocean to the north. The county shares the world longest land border with the United States of America along its south and parts of the western border. Statistics Canada 2011 census data lists a population of 33,476,688 people meaning a population density of 3.7 per square km (Statistics Canada, 2012). Although vast in size and sparsely populated, 90% of Canadians reside within 160 km of the southern border (Central Intelligence Agency, 2012). There are ten provinces and three territories all with their own governments and legislatures. These are further divided into municipalities which have their own by-laws and regulations depending on local circumstances. This complex multi-tiered political environment leads to great variation in policies and regulations from region to region.

Canada has one of the highest levels of solid waste per capita in the world. As of 2007 Canada produced 894 kg of municipal solid waste per capita, last out of 17 OECD nations (Conference Board of Canada, 2012). Waste management expenditures for all local governments was $2.6 billion for 2008 (Statistics Canada, 2010). Collection and transportation comprise $1.1 billion of the cost, followed by operation of disposal facilities, and tipping fees (Statistics Canada, 2010). According to the 2008 Waste management industry survey waste management expenditures accounted for $79 per capita on average for Canada with great variation in the expenditures and methods of processing this waste from province to province (Statistics Canada, 2010).

Canada's construction industry employs 6% of the workforce making it the third largest employment sector behind services, and manufacturing (Statistics Canada, 2006). The construction, renovation, and demolition wastes contribute an estimated 25% of all solid waste by volume (Recycling Council of Ontario, 2006). Buildings are a major contributor to waste, greenhouse gas emissions, and resource consumption in Canada. The Commission for Environmental Cooperation 2008 report *Green Building in North America* provides statistics on the various impacts of the built environment in Canada some of which are listed below:

- 33 percent of all energy used;
- 50 percent of natural resources consumed;
- 12 percent of non-industrial water used;
- 25 percent of landfill waste generated;
- 10 percent of airborne particulates produced; and
- 35 percent of greenhouse gases emitted.

1. BARRIERS TO DECONSTRUCTION IN CANADA

This section discussed the barriers to deconstruction for 3 major structural materials used in Canada: steel frame used in commercial and industrial buildings, wood frame which predominates in low rise residential buildings and concrete which is used in office and high rise residential buildings amongst others.

1.1. Steel Framed Construction

1.1.1. Commonly Used Methods To Remove Steel Framed Buildings

Structural steel buildings are most often removed by mechanical demolition. In order to have the demolition project proceed quickly and efficiently, heavy machinery does all the major work and building components are often damaged in the process of their destruction. Valuable components may be source separated if a known revenue stream exists for the waste products. Structural steel is one such product and Gorgolewski, Straka, Edmonds, & Sergio (2006) indicate that:

> "… approximately 90% of steel arising from demolition goes back to the steel mills for recycling, about 10% goes to some form of component reuse, and only a minimal amount, perhaps less than 1% goes to landfill as it is difficult to extract from the waste stream." (p. 4)

The level of steel recycling should be commended, however the deconstruction process and structural steel re-used in 'as is' condition will save energy, money and resources. Steel only forms the structural core of the building and as with all building types the finish materials, cladding, glazing, or doors may be demolished in the same manner or by selective deconstruction, where the most valuable and easily accessible components are removed before the structure comes down. If the waste from demolition of this building type becomes mixed the steel can be easily separated by magnets (Falk, 2002) and so steel is not generally contaminated by being mixed with other wastes.

1.1.2. Barriers for Deconstruction of Steel Frame Construction

Complications of reusing building components in 'as is' condition.

Engineers will not always approve the reuse of structural steel components as they have not been tested in accordance with current standards and the specifications are not immediately known, unlike with new structural steel components. Liability becomes the main concern (Gorgolewski et al. 2006). The costs to test reclaimed steel components for structural integrity are relatively high and may result in prices that are similar to new structural steel components for reused components to be viewed as cost effective

Lack of awareness of reused structural steel components within construction industry

A general lack of awareness of potential for reuse of materials 'as is' makes demolition crews more likely to work recklessly and simply remove components as quickly as possible (Gorgolewski et al. 2006).

Reliability of supply of building components/lack of markets for deconstructed building materials

Building components are often not available when needed for a new construction project and so more planning has to be undertaken and components acquired when they are available. This may result in building components needing to be stored and results in higher than normal storage costs for new construction projects. There may also not be enough of a single component type to meet the demands of a new construction project. Designs would then need to be adaptable in order for major steel building components to be accepted and integrated into a project.

Unnecessary damage being done to building components as they are removed.

The use of welded joints instead of mechanical joints on structural steel components can make the deconstruction of building components more difficult. In these cases care needs to be taken to remove the components undamaged through grinding and cutting of welded joints (Canadian Standards Association, 2012).

High price of scrap steel makes reusing steel components less worthwhile.

The steel recycling industry is very well established in Canada and much of the reclaimed steel is already sent to steel recycling facilities instead of reused in as is condition. This is quicker and easier solution for contractors because they already have established networks for this process. The immediate recycling of steel building components decreases any storage costs and results in immediate income for the projects (Gorgolewski et al. 2006).

1.1.3. Strategies to Overcome Barriers to Deconstruction of Steel Framed Buildings

Improve the deconstruction process by taking more care in dismantling of components

Building components can often be damaged in the process of their removal which decreases their value as reusable building components. By improving the removal practices of building components, for example through careful cutting and grinding of welds, more material could be reclaimed (Canadian Standards Association, 2012).

Improve and streamline the process of re-grading structural steel components

In the search of literature there was no specific Canadian research regarding the improvement of the steel re-grading process. If steel products could be proven to be structurally sound for future construction projects it would be more likely that used building components would be adopted.

1.2. Wood Framed Construction

1.2.1. Commonly Used Methods To Remove Wood Frame Buildings

The most common method of removing wood framed buildings in Canada is through demolition with the majority of wastes sent to landfill. Demolition is completed as quickly as possible with mixed wastes being disposed of in common waste bins. This results in very little care be paid to the valuable components that could be source separated. In some cases there is selective deconstruction of easily accessible and easily sold building materials. There are scattered companies across Canada that specialize in building deconstruction with most demolition companies performing mainly mechanical demolitions with heavy equipment.

1.2.2. Barriers Specific To Wood Framed Buildings Deconstruction

Deconstruction of wood building is difficult

Wood frame buildings can be difficult and time consuming to dismantle. The wood components need to have a large number of fasteners removed from them to be reused. This can add a great deal of labour costs to a deconstruction project. Framing members such as stick framing or trusses for roofs can be awkward and dangerous to remove and may require special equipment or bracing during the deconstruction process (Canada Wood Council, No date).

Use of new generation of products can make deconstruction more difficult.

Falk (2002) indicates that the use of new products such as oriented strand board, plywood and construction adhesives make deconstruction process more difficult. Products are less likely to come out intact as compared with older buildings which may have used simple mechanical fasteners and solid boards.

Wood waste is often mixed with other materials and contaminated by other substances

Standard demolition techniques create mixing of building products to make recovery of materials cost effective. Deconstruction by selective dismantling is a cost effective solution to increase the rate of material recovery (Canada Wood Council, No date).

Low cost and abundant availability of new building materials

Scrap wood is difficult to separate from all of the other building components and is extremely cheap to buy new and clean so there is very little value in recycling or reclaiming the material from disposal bins. Canada is a world leader is sustainable and well managed forests (Canada Wood Council, no date), and considered a renewable resource under such circumstances.

Lack of regulations demanding waste management plans for this building type.

Typical wood framed construction in Canada consists of individual residential houses and therefore is not big enough to fall under the regulations that do exist. Therefore no waste management plan is necessary and any waste that is removed from demolition sites is most often sent to landfill. Unless selective deconstruction is demanded or the value of building components is understood by the building owner/contractor then the building will most likely be removed as quickly as possible which is most often by mechanical demolition.

1.2.3. Strategies To Overcome Barriers In Wood Framed Buildings Deconstruction

Design for deconstruction

This process considers the entire lifecycle of the building and helps builders and designers to make decisions regarding design, materials choices, all in an effort to mitigate waste created at the end of life of individual building components, and the entire structure. Falk (2002) states that highly engineered materials might not be the best choices for wood framed buildings given the difficulty in removing and reusing these components in an ‘as is’ condition.

Encourage greater adaptive reuse

This is a common strategy amongst older buildings within Canada. They are often well suited for making major changes to layout and which can result in extending the life of a building instead of its demolition. Adaptive reuse is when there are specific components of the building that are removed, redesigned and/or adapted in order to change the functionality of an existing building. Wood framed buildings are particularly well suited to this type of renovation given the ease with which wood framing can be adapted and moved.

1.3. Concrete/Masonry Construction

1.3.1. Commonly Used Methods to Remove Concrete/Masonry Construction

This building type is most often demolished with traditional mechanical demolition. Concrete structure is brought to the ground in pieces and crushed to remove any reinforcing steel. As with other building types interior finishes may be removed by other means but they too are removed as mixed wastes and sent indiscriminately to landfill. Demolition of this building type can be dangerous and time consuming if manual removal of concrete components is undertaken.

1.3.2. Barriers to Deconstruction of Concrete/Masonry Buildings

Source Separation of materials is difficult

Concrete is particularly difficult to deal with because it is generally not reusable in the 'as is'state on new construction projects. It is often mixed with other wastes such as reinforcing steel and gets easily damaged in the demolition/dismantling process. It cannot often be reused as is and instead can be crushed and down cycled as aggregates for future projects. (Canadian Standards Association, 2012; Hurley, Goodier, Garrod, Grantham, Lennon, & Waterman, 2002)

It is not cost effective deconstruct and reuse concrete

Most concrete construction is cast in place and this means it is specific to the building in which it was constructed. This leads to problems of dimensions, and the high costs of transporting concrete components makes it unfeasible to reuse compared to new concrete (Hurley et al., 2002).

1.3.3. Strategies to Overcome Barriers in Concrete/Masonry Construction

Better planning of projects from the design stage through to end of service life

If planning for end of service life was done from the earliest stages of a concrete construction project then when that time arrives for the building the likelihood of major portions of the building being salvaged is greatly improved (Canadian Standards Association, 2006). This could include designing with precast concrete that can be used in other applications instead of purely cast in place concrete.

2. BARRIERS FOR REUSE AND RECYCLE

In this section the barriers to reuse and recycling in Canada are discussed for 3 construction materials: wood, drywall and concrete.

2.1. Wood

Wood constitutes 30-34% of the waste stream from construction, renovation, and demolition activities (NRCan, 2006).

2.1.1. Diverted rate (reuse and recycle): 5.4%

This figure only accounts for waste diverted by the waste management industry. Any waste reclaimed directly from the waste generator is unaccounted for (CCA, 2001).

2.1.2. Products produced from wood waste

Reuse: In Canada, high quality architectural pieces such as beams, posts, trusses, and millwork are the most often salvaged and reused wood products (Cooper, 1999). Another common activity is salvaging wood from barns to be repurposed as flooring.

Recycle: Wood is most often recycled in Canada as feedstock for landfill or as mulch used in the landscape cover (Cooper, 1999). Although other recycled wood products include composite wood materials, paper pulp, animal bedding, soil amendment, and compost (Cooper, 1999). Wood can be recycled into building materials such as singles or roof felt (Cooper, 1999).

2.1.3. Barrier to wood reuse and recycle

On-site sorting

One of the main challenges with diverting wood is sorting wood on-site for proper management. This problem is particularly true for the case of preserved wood products. (Cooper, 1999)

Research in treatment options

In Canada, not enough is understood of the treatment options to facilitate recycling or reuse of preserved wood. Some research indicates that building composite products such as wood and plastic or wood and cement may be viable in the future, but more research needs to be done. Currently, the market for treated wood composite materials is not strong in Canada. (Cooper, 1999)

Easy access to landfill

Infrastructure needed to collect, transport, store, and prepare preserved or untreated wood is widely unavailable. Infrastructure would be expensive to design, implement, and enforce. At the same time, there is no deterrent to landfilling. For example, preserved wood is still accepted as nonhazardous waste in most provinces and can be disposed of in unlined landfills. (Cooper, 1999)

2.1.4. Strategies to overcome barriers for wood reuse and recycle

Industry promotion through education

The Forest Products Association of Canada (FPAC) has set a carbon neutrality goal for 2015. As part of their initiatives to promote carbon neutrality, they have developed the 'Don't Waste Wood' campaign. The program highlights the role of the construction and demolition industry to make significant reductions in wood waste disposal. The campaign stresses the importance of diverting wood from landfill and uses the globally accepted waste hierarchy (reduce-reuse-recycle-then, landfill) to discuss the appropriate options for wood waste treatment. Reuse is particularly promoted through case studies and additional resources that offer further information and links to deconstruction and reuse professionals. However, most of the links provided by campaign are to businesses and groups in the United States. (Forest Products Association of Canada, 2012)

Increased aesthetic value

Architectural salvage is a small but growing industry in Canada. Older, rare, and weathered wood in particular is sought after for its aesthetic value. Interest is growing as the inventories of old grow woods and certain species of wood are becoming increasingly more difficult to acquire. As mentioned about high quality architectural items such as posts, beams, and trusses are popular reuse items.

2.2. Drywall

Drywall constitutes 11-13% of the waste stream from construction, renovation, and demolition activities (NRCan, 2006)

2.2.1. Diverted rate (recycle): 33%.

This figure only accounts for waste diverted by the waste management industry. Any waste reclaimed directly from the waste generator is unaccounted for.

2.2.2. Products produced from gypsum waste:

Drywall is rarely reused. Most often in Canada, gypsum is recovered from drywall and recycled as a soil amendment or incorporated again into the gypsum component of drywall. In Canada, manufacturers of recycled drywall products typically include 25% secondary gypsum. (Saotome, 2007)

2.2.3. Barrier to drywall reuse and recycle

Inaccessibility to gypsum recycling facilities

There are very few facilities that recycle gypsum in Canada and the majority are located on the west coast. With minimal options, most gypsum waste is produced at far distances from recycling facilities. With no financial incentive to spend additional resources coordinating transportation to long distance facilities, it is often deemed as more practical to dispose of drywall at near-by landfill sites. (Saotome, 2007)

On-site separation

Drywall is difficult to separate on-site because demolition contractors are typically unaware that gypsum can be recycled. Furthermore, demolition sites are often too small to include a separate bin for drywall. (Saotome, 2007)

2.2.4. Strategies to overcome barriers for drywall reuse and recycle

Municipal bans of gypsum from landfills across Canada

When disposed of in landfill, gypsum biological and chemical reacts with organic waste to produce hydrogen sulphide gas (Saotome, 2007). The hydrogen sulphide gas is harmful to human health and creates an unpleasant odour (Gratton, n.d.).

In some major municipalities across Canada, such as Vancouver and Ottawa, gypsum is banned from landfill. In the case of Vancouver, the ban of gypsum facilitated a market for recycling gypsum and, as such, facilities sprung up in the area. (Canada Green Building Council, 2009; Saotome, 2007)

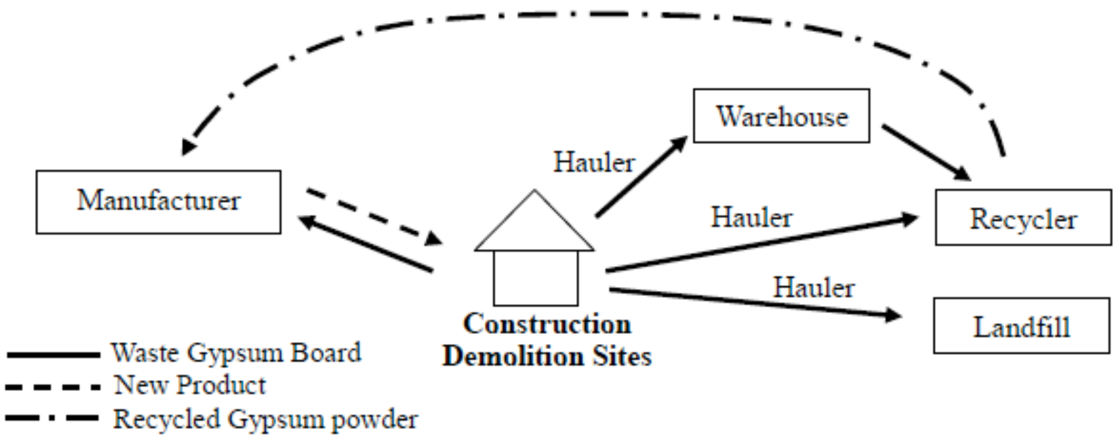

Figure 1: Typical recycling flow of gypsum (Saotome, 2007).

2.3. Concrete

Concrete constitutes 10-16% of the waste stream from construction, renovation, and demolition activities (NRCan, 2006).

2.3.1. Diverted rate (recycle): 72.4%.

This figure only accounts for waste diverted by the waste management industry. Any waste reclaimed directly from the waste generator is unaccounted for (CCA, 2001). As well, this figure includes concrete associated with civil engineering projects such as roads and bridges (NRCan, 2006).

2.3.2. Products produced from concrete waste:

In Canada, concrete is mainly recycled into aggregate. Recycled aggregate can be used to produce more concrete, but is most often used as a road base. In 2007, 13 million tonnes of recycled concrete aggregate was used in the construction of buildings, roads, sewers, and water mains. In Ontario, Canada recycled aggregate accounts for 7.2% of the aggregate market (Canadian Urban Institute, 2011).

2.3.3. Barrier to concrete reuse and recycle

Cost of recycled aggregate does not reflect product quality

Recycled aggregate often contains contaminant residuals from the previous life of the concrete. The contaminants reduce the compressive strength of the aggregate by about 25%. Because the quality of recycled aggregate is lower than the virgin aggregate materials, many Canadian industry members believe that the price should also be lower. However, the cleaning, processing, inspection, storage, and sale of recycled aggregate can result in costs comparable or higher than virgin aggregate. (Nisbet et al, n.d.)

Production costs vary depending on the use of the recycled aggregate. On-site production is the least expensive option, generating the least quality aggregate, which is used primarily as fill in road construction (Nisbet et al, n.d.).

2.3.4. Strategies to overcome barriers for concrete reuse and recycle

Recognition of recycled concrete in federal and provincial construction standards

Recycled aggregate has been incorporated into the Canadian Standard Association's (CSA) Standard A23.1-00. The standard acknowledges:

> "Concrete is a 100% reusable resource. Common practice is to recycle returned product and all materials both on and off site. Concrete can be crushed and aggregates reused in new concrete or reclaimed and used as road base, reducing the requirement for new aggregate." (Construction Standards Association, 2009)

At the same time, the CSA standard considers recycled aggregate a synthetic material and suggests that more attention to its durability characteristics, deleterious materials, potential alkali-aggregate reactivity, chloride contamination, and workability characteristics should be observed than with its virgin counterparts. (Construction Standards Association, 2009)

In 1993, recycled concrete was incorporated into the Ontario Provincial Standard Specification (OPSS) 1010, material specification for aggregates - base, subbase, select subgrade, and backfill material (Cement Association of Canada, 2003). The OPSS 1010 standard accepts up to 100% recycled aggregate for dense graded aggregates and one type of well-graded aggregates. The code mandates that recycled aggregates (either blended or homogenous) require additional testing by a contractor to ensure that quality standards are met before use. (Ontario Provincial Standard Specification, 2003)

The incorporation of recycled aggregate into the OPSS 1010 standard has pushed Ontario's industry to provide education and resources of the manufacturing and handling processes for recycled aggregate. For example, The Ontario Stone, Sand, and Gravel Association is the only provincial aggregate industry association in Canada to provide resources about recycled aggregate and these resources directly apply with the OPSS 1010 standard (Ontario Stone, Sand, and Gravel Association, 2006).

3. GENERAL ISSUES OF DECONSTRUCTION, REUSE AND RECYCLE IN CANADA

3.1. Barriers To Deconstruction, Reuse, and Recycle Common To All Major Construction Types and Material

Lack of knowledge about the value of material reuse or about materials being reused

There is very little specific private or academic research done on the deconstruction process in Canada. Although there are various resources available and scattered retailers and deconstruction practitioners around the country regular citizens seem unaware of the possibilities of reuse and the value of the existing materials. Surveys of industry professionals indicate a general lack of awareness of materials being reused in an as is condition (Gorgolewski et al., 2006), and so with no knowledge of a market and value of products little attention will be paid to maintaining quality of products as a building is demolished.

Many of the strategies discussed in Canada draw on examples from other parts of the world. For example, in establishing a waste diversion strategy for Alberta in 2001 Portland, Oregon's waste management framework was used as a model (Sonnevera International Corporation, 2006). Since Canada and the United States are very close geographically, in architecture style, and some could argue, in policy, many statistics used in Canadian literature is derived from research in the United States. Although these statistics may be perceived as accurate 'enough', research on the subject of deconstruction, reuse, and recycling must be further investigated in the scope of Canada.

Assumption of higher costs of deconstruction

It is assumed by many industry professionals that deconstruction process would result in higher overall costs for a project than traditional demolition and landfilling. (Falk, 2002; Gorgolewski et al., 2006)

Short timeframes for projects

If demolition contractors are busy they will often not carefully deconstruct building components and instead will choose the quickest method to remove the building (Gorgolewski et al., 2006). Falk (2002) points out the irony that a building may have sat derelict for years but as soon as a new project is determined for the site there is very little time to carefully deconstruct the building. Time is an easy and common excuse for fast irresponsible demolition of buildings.

Poor planning of waste management on jobsite

This can include limited space for extra waste bins required for source separation (RCO, 2006), and a lack of record keeping regarding waste removed from the site (Canadian Standards Association, 2012)

Lack of cooperation of all parties

This can include owners, contractors, subcontractors, waste haulers, architects and designers. If any of the interested parties do not fully grasp the project of deconstruction it can hinder the entire process. A thorough understanding of projects goals and a developed plan is often not shared with all parties nor monitored. (RCO, 2006)

General lack of developed market for reclaimed building materials

While a thriving market exists for architectural salvaged materials in Canada the main structural building components are often not salvaged at all. Only quick sale items are collected by selective deconstruction and sold on a large scale. This problem is one of both supply and demand, retailers will not carry products that are not in demand and consumers will not buy products they do not know are available. This issue is closely related issue to awareness of the value of reclaimed building components

3.2. Strategies To Overcome Barriers For Deconstruction Of All Major Construction Types

Market development for reused building components

The primary barrier to recycling and reuse in Canada is the balance between landfilling fees and costs to divert waste (Nisbet et al, n.d.; Saotome, 2007). For example, it is estimated that the cost of landfilling materials is about 40% lower than recycling them (Nisbet et al, n.d.). Low landfilling costs create disincentives for diverting waste.

Existing Regulations within Canada

Certain major cities and municipalities have taken steps to lead the country in producing green buildings within their jurisdictions. Metro Vancouver has a Zero waste initiative (Metro Vancouver, 2011) which includes the construction and demolition wastes, and the City of Toronto has their own green building standard which demands more stringent environmental compliance for new buildings (City of Toronto, 2012).

Another example is the City of Calgary. The city has implemented a goal to reduce all construction and demolition waste going to landfill to 20% of the amount sent in 2007. To achieve the goal, the city is utilizing an approach that includes economic, regulatory policy, and voluntary measures. (The City of Calgary, 2011)

Regulations vary vastly throughout the country, changing from province-to-province. In 1994, Ontario developed the 3R's Regulation under the Environmental Protection Act, consisting for four regulations that intended to reduce waste going to landfill by 50% in 2000. In particular two of these regulations applied to the construction industry: Waste Audits and Waste Reduction Work Plans (Regulation 102/94) and Industrial and Commercial and Institutional (IC&I) Source Separation Programs (Regulation 103/94). (Environment Canada, 2003)

However regulation 102/94 does not require waste audit plans to be submitted to the Ontario Ministry of the Environment (Environment Canada, 2003). A survey of in 2006 revealed that 90% of waste generators from the institutional, commercial, and industrial (IC&I) group were out of compliance with the regulations as a result minimal enforcement/authorization. The regulation put responsibility of waste management to the project owner, who is often removed from the contractors actually doing the construction/renovation/demolition (Nisbet et al, n.d.; Saotome, 2007). As well, the regulation only pertains to projects greater than 2000 square feet, excluding waste management to the majority of residential buildings in Ontario (Saotome, 2007). The waste management goal for 2000 was never reached and overall, the regulation continues to be viewed as not successful (Saotome, 2007).

Canadian Standards Associations (CSA) guides

There are currently two guides produced by the Canadian Standards Association that deal with buildings demolition, deconstruction and adaptive reuse. These standards are written with guidance from steering committees comprised of various construction industry professionals, academics, and parties representing various materials associations within Canada. *The Guideline For Design For Disassembly And Adaptability Of Buildings* is a 2006 publication and was written with the intention of providing a framework for reducing the amount of construction waste produced, thus improving a buildings economic, societal, and environmental impacts by designing buildings that are adaptable and easily disassembled at the end of their service life (Canadian Standards Association, 2006). The guideline provides strategies for designers, materials manufacturers, and contractors on how to make buildings that meet these requirements.

Deconstruction of Buildings and There Related Parts was published in 2012 and is intended to provide standard methodologies for building deconstruction for all interested parties (Canadian Standards Association, 2012). The guide provides general information about the business of deconstruction, procedures for deconstructing buildings, and how to appropriately keep track of materials removed from a project (Canadian Standards Association, 2012). These are excellent resources for understanding the process, products and outcomes of the deconstruction process within Canada, and demonstrate a growing interest in the appropriate manner of conducting such work.

Proper planning of the demolition/dismantling project

The CSA guide *Deconstruction of Buildings and There Related Parts* (2012) discusses the necessity of planning for how a deconstruction project will be undertaken. This includes a site plan for where on the jobsite products will be processed, keeping records of building components removed from the project, the development of material recovery targets, and a work plan for how certain materials will be dealt with once removed.

Extended producer responsibility

The Canadian council of ministers of the environment approved in principle a Canada wide plan in October 2009 recommending Extended producer responsibility(EPR) as the main avenue to decrease waste created and set for disposal (Moyes, 2010). Responsibility for the disposal and management of waste becomes that of the producer of the product and no longer simply the final user. Theoretically this takes the pressure off of consumers of products, local governments who manage the waste and landfills through the use of take-back programs and better design for end of life by product manufacturers (Canadian Home Builders Association, 2010).

Zero waste initiatives

There are various initiatives underway in Canada that strive to achieve zero waste in the construction industry. This includes not for profit organizations, associations of municipalities, and specific regions that are seeking to diminish the amount of waste that they have to deal with on a regular basis.

Specifically the Construction Resource Initiative (CRI) Council was established in coincidence of the City of Ottawa's ban on landfilling gypsum. The CRI council intention is to utilize education, advocacy, and industry support to eliminate construction, renovation, and demolition waste to landfill by 2030. Reuse, recycle, and deconstruction are all highlighted by the CRI Council as tools essential to reaching zero waste. (Construction Resource Initiative Council, 2012)

Along with zero waste, initiatives supported by industry associations include:

Recycling exchange programs (http://www.recyclexchange.com/),

Recycling Council of Alberta (http://www.recycle.ab.ca/drywall-processing),

Recycling Council of Ontario (https://www.rco.on.ca/),

Recycling Council of British Columbia (http://rcbc.bc.ca/),

The Saskatchewan Waste Reduction Council http://www.saskwastereduction.ca/.

Integrated design process

The integrated design process (IDP) involves greater communication and increased roles in the construction of a building by all interested parties, including owners, architects, engineers, and contractors. An IDP project would have an independent party in charge of managing the process and keeping all invested parties engaged throughout (Zimmerman, no date). IDP projects allow all members of the construction team to be in on the decision making processes from the very beginning of a project which leads to greater understanding of project goals and ‘green’ objectives (Zimmerman). This process would help improve deconstructability, recycling and reuse of building materials because of its inclusive approach and the awareness of the important issues throughout the project.

Building Rating systems

There are a wide number of building rating systems that are currently used within Canada. Many of them demand that certain amounts of materials be reused or reclaimed or have recycled content in order to achieve specified numbers of points within the rating system. Generally they encourage greater awareness of sustainable building policies and practices and specifically they demand better waste management practices in order to achieve certifications.

For example, one of the most widely used building rating systems for new construction is the Canadian Green Building Council’s Leadership in Energy and Environmental Design (LEED). The Government of Canada has included LEED standards in their federal sustainable development strategy for Canada. The standard requires that all new federal government buildings meet LEED gold standards (Environment Canada, 2010). Although it should be noted that using LEED does not guarantee that buildings will incorporate reused or recycled material and does not directly promote deconstruction practices, the standard does bring awareness these waste diversion tools to the construction industry (Cement Association of Canada, 2003; Sonnevera International Corporation, 2006).

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Barriers for Deconstruction and Reuse/Recycling of Construction Materials in Germany

Anna Kuehlen, Neil Thompson, Frank Schultmann

Karlsruhe Institute of Technology
GERMANY

1. BARRIERS FOR DECONSTRUCTION

1.1 Three major construction types in Germany

The three major building construction types presently found in Germany are listed in Table1 (Klauß et al., 2009):

Table 1: The three major construction types in Germany

Type	Vertical support structures	Horizontal support structures
1. Masonry (partly with reinforced concrete frames) and reinforced concrete (framed) ceilings	Masonry	Reinforced concrete
2. Masonry with timber framed ceiling	Masonry	Timber
3. Precast concrete slabs with reinforced concrete ceilings (especially in the eastern Parts of Germany)	Precast concrete	Reinforced concrete

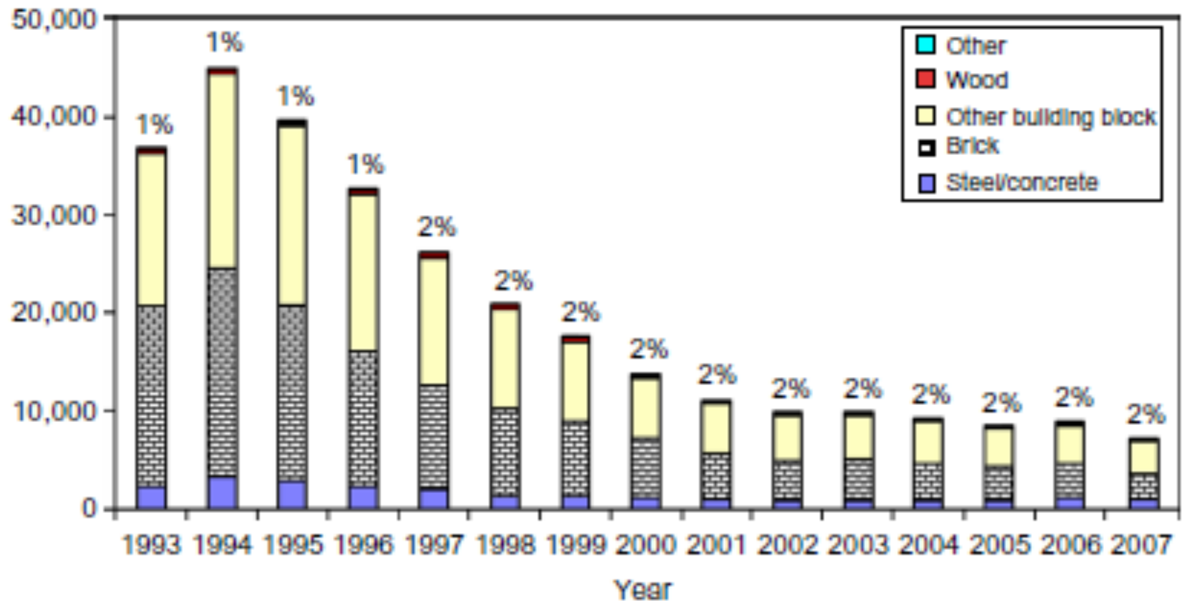

Figure 1: Major building construction types in Germany and the percentage of wood types thereof (Mahapatra et al, 2009)

Other common building construction types in Germany include timber frame, steel skeleton frame and precast reinforced concrete frame, noting that timber frame type construction represents only around 2% of all building permits issued in Germany up to 2007 (Figure 1).

1.2 Methods commonly used to remove buildings in Germany for each construction type

The methods commonly used to remove each of the three major construction types presently found in Germany vary depending on key variables including the *location*, the *building type and surrounding conditions* together with the *time* and *budget* allocated for demolition. Subject to assessment of these variables, the following four demolition methods can be used selectively as shown in Table 2 for each of the three major construction types as detailed in section 1 (cf. Rentz et al, 1994; DIN 18007, 2000):

Table 2: Suitability of various demolition methods for each of the three major construction types in Germany

Construction type with respect to table 1	Types of demolition methods			
	Removal **(with hand tools)**	***Ebbing*** **(top down removal with grabber or gripper)**	***Pressing*** **(horizontal pressure from outside with excavator or bulldozer)**	***Blasting*** **(tumbling building down through use of explosives)**
Type 1	√	√	√	√
Type 2	√	√	X	X
Type 3	√	X	X	X

Often a mixture of these methods is employed. The selection and combination of demolition methods depend on local conditions, such as space constrains, specifications on material separation and reusability of demolition waste as well as legal conditions in terms of national and local limited values for noise, dust and vibrations with respect to environmental and health protection.

For instance the combination, manual removal combined with machine ebbing, is used for projects, where high quality materials that attract premium EUR/t rates for recycling can be economically recovered using more expensive manual labour methods. The lower value C&D materials are demolished as a heterogeneous mass via lower cost automated methods for subsequent sorting and designations, as reuse, recycle or landfill items.

1.3 Barriers for deconstruction to make better use of the C&D waste in Germany

The major barriers for deconstruction in the German market that prevent the property development industry from making better use of the C&D waste include:

- Existing buildings are not designed for dismantling;
- Major components within these buildings have not been designed for disassembly;
- Suitable machines for deconstructing existing buildings often do not yet exist;
- Disposal costs for demolition waste are often very low offering no financial penalty;
- Deconstruction of existing buildings by focussing on a high level of material separation often takes additional time;

- Building codes and/or materials standards often make the reuse of C&D waste difficult;
- Uncertain cost factors for the deconstruction process of existing buildings;
- Lack of standardised “best practice” for deconstruction in the demolition industry;
- Hazardous materials such as lead, asbestos and PCBs in pre-1980’s buildings;
- Lack of quantitative case studies to show economic, environmental and social benefits.

Whilst architects and engineers in Germany are now starting to design new buildings for future deconstruction (BMVBS, 2011), the problem remains with deconstruction of existing building stock particularly with regards to the contamination and heterogeneity of C&D waste. Accordingly, government, academic institutions and industry associations in Germany are currently focusing their efforts on development of technical, policy and other solutions to support the advancement of “sustainable” deconstruction, which includes the reuse of recycled material as well as design for deconstruction in the future (BMVBS, 2011; DIN 15643, 2011, DGNB, 2012).

1.4 Strategies to overcome these barriers in Germany – technical, political and other

The main **political** strategy that has been developed to overcome some of the barriers in Germany with respect to making better use of C&D waste is the Federal “Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal” (KrW-/AbfG). It aims to ensure, as far as possible, avoidance and recovery of C&D waste through waste producers and the property developers in case of deconstruction, and contains basic principles for waste management and closed loop recycling strategies. It provides a waste management hierarchy and states, that the first goal of waste management must be waste prevention and avoidance. If prevention is not possible, the composition of waste must be improved in order to permit reuse or recycling (KrW-/AbfG, 2012). With respect to this issue, the ordinance about waste treatment (NachwV, 2006) reinforces the KrW-/AbfG. Tariffs for disposal of C&D waste vary locally across Germany.

There are several **technical** strategies in Germany that have also been developed to overcome some of these barriers. Technical standards are set, such as the ATV DIN 18459, which covers, amongst other general and contracting issues regarding all kinds of construction work, the extraction, storage and transportation of deconstruction materials and components based on the European Waste Catalogue (EWC) (Sunke and Schultmann, 2008). As mentioned above, government, academic institutions and industry associations in Germany are currently developing technical solutions, such as building certification systems to support the advancement of “sustainable” deconstruction, which includes the reuse of recycled material as well as design for deconstruction in the future (BMVBS, 2011; 2011, DGNB, 2012). There is also a work instruction for the recycling of C&D wastes as well as the use of recycled materials in federal buildings (BMVBS, 2008).

Furthermore, research projects, such as the study of “best practice” methods for deconstruction and recycling of C&D waste by the French-German Institut of Technology (DFIU) in conjunction with various industry association partners, support political efforts to overcome barriers with respect to making better use of C&D waste. Here studies have been undertaken to compare the cost, time and percentage to landfill impacts of various deconstruction methods such as selective dismantling versus manual sorting of C&D waste after conventional demolition as shown in Figure 2 (Schultmann and Rentz, 2002):

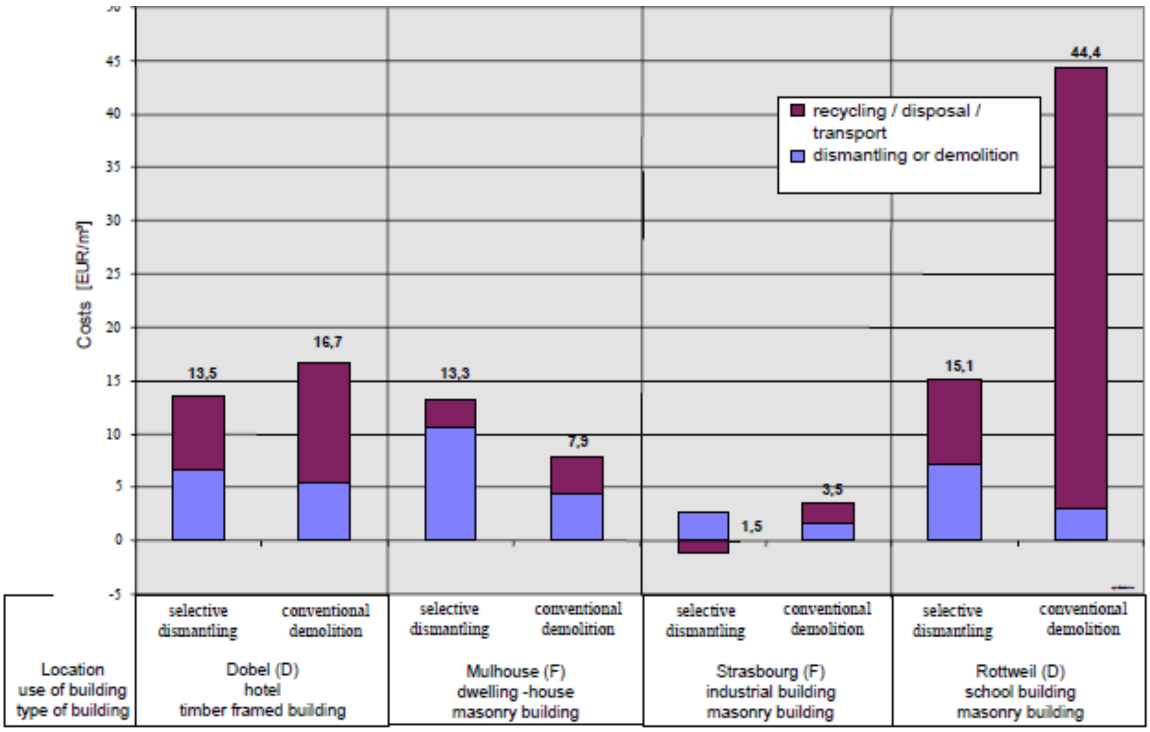

Figure 2: Sample study of various deconstruction methods (Schultmann and Rentz, 2002)

Depending on the disposal costs and recycling income opportunities in the region where the building is situated, the additional personnel costs for selective dismantling may outweigh the landfill disposal and raw material cost offsets plus the income received from local recycling of C&D materials thus favouring post demolition sorting of C&D materials (Schultmann, 1998). Studies of recycling methods for C&D waste have also been undertaken, which show that whilst the air flow separation methods as used in the majority of German recycling facilities have lower operating costs, the more expensive water based separation systems result in higher recovery rates from mixed C&D waste, as shown in Figure 3 (Hanisch, 1998).

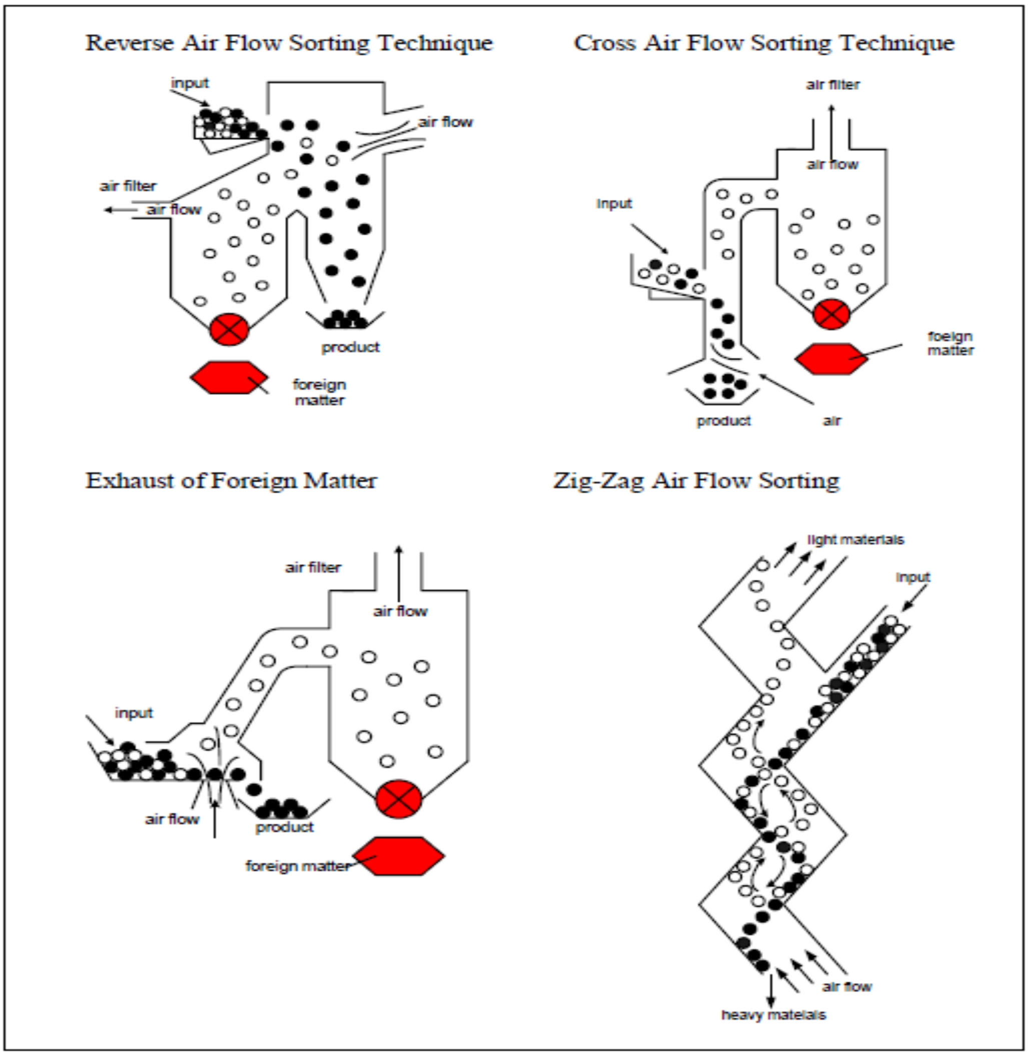

Figure 3: Sample study of air flow based C&D waste separation systems (Hanisch, 1998)

Other strategies in Germany that are being developed to overcome remaining barriers to making better use of C&D waste include the research and development of **systems supporting sustainable deconstruction already in the deconstruction planning phase.** For instance, the French-German Institute for Environmental Research (DFIU) at the Karlsruhe Institute of Technology (KIT) does research together with the Institute for Technology and Management in Construction (TMB) at the KIT, the "Fachgruppe Bauliches Recycling" at the Bandenburg University of Technology Cottbus (BTU) and two industrial partners with respect to a sustainable deconstruction approach built on common technical strategies by adding environmental metric measurements, such as noise, dust, vibration and hazardous materials, at new case study sites for integration with computer based decision support and an optimisation tool (DFIU, 2012). The objective of this research project, which is funded by the "Deutsche Bundesstiftung Umwelt" (DBU), is to develop an enhanced software tool and a sustainable deconstruction protocol that supports the engineer as well as the deconstruction company in the first instance in minimising any potential negative environmental and human impacts through the deconstruction process during the deconstruction planning phase.

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2. Barrier for Reuse and Recycle

2.1 The top five C&D wastes in Germany

The top five C&D wastes in Germany consist of excavated earth, demolition debris, road construction waste, construction waste and cement construction material.

Table 3 shows the relative composition of C&D waste and the status of recycling in 2004. As shown, most recycled C&D waste is demolition waste and road scarification (Sunke and Schultmann, 2008).

Table 3: C&D Waste Composition and Recycling in Germany, 2004 (Sunke and Schultmann, 2008, cf. Li et al. 2012)

Waste type	Total C&D waste production		Amount of waste recycled
	million tons	%	million tons
Demolition waste	50.5	25.2%	31.1
Road scarification	19.7	9.8%	18.4
Construction waste	1.9	0.9%	0.1
Cement	0.3	0.2%	-
Total (without excavation)	72.4	36.1%	49.6
Waste from excavation	128.3	63.9%	9.1
Total	200.7	100%	58.7

With regards to the overall treatment of C&D waste in Germany, most of the recovered waste was dealt with by "treatment for recovery" and "energy recovery" is largely avoided, as shown in Table 4 for 2008. For disposal, most waste went to landfill, followed by "treatment for disposal". Only a small part of the waste was incinerated, which resulted in an overall recovery rate of 88% (Federal Statistical Office, 2010).

Table 4: C&D waste balance in Germany in 2008 (units '000 tonnes) (Federal Statistical Office, 2010, cf. Li et al. 2012)

		C&D waste	Hazardous waste	Non-hazardous waste
Total		200 517	8 489	192 028
Disposal		24 024	3 713	20 311
Of which	Landfill	22 577	2 671	19 906
	Incineration	154	50	104
	Treatment for disposal	1 293	992	301
Recovery		176 494	4 777	171 717
Of which	Energy recovery	824	201	623
	Treatment for recovery	175 670	4 576	171 094
Recovery rate %		88	56	89

2.2 Other C&D wastes in Germany for universal concern

A total of approximately 8.5 million tonnes of "hazardous" C&D waste was generated in Germany in 2008, which included materials of universal concern, such as asbestos and plastic sealants containing PCB's. These materials are classified under codes 17 06 05 and 17 09 02 respectively in the integrated European Waste Catalogue (EWC) (Figure 4), which came into force in 1999 via the national ordinance EAKV.

[17 BUILDING AND DEMOLITION WASTES (INCLUDING EXCAVATION OF CONTAMINATED LOCATIONS)
17 01 concrete, brick, tiles and ceramic(s)
17 01 01 Concrete
17 01 02 Bricks
17 01 03 Tiles, bricks and ceramic(s)
17 01 06 * Mixtures of, or fractions of concrete, bricks, tiles and ceramic(s), containing dangerous material
17 01 07 Mixtures of concrete, bricks, tiles and ceramic(s) with exception of those that fall under 17 01 06
17 02 Wood, Glass and Plastic
17 02 01 Wood
17 02 02 Glass
17 02 03 Plastic
17 02 04 * Glass, plastic and wood contaminated by dangerous materials
17 03 Bitumen mixtures, Coaltar and Tar containing products
17 03 01 * Coal tar contaminated bitumen mixtures
17 03 02 Bitumen mixtures with exception of those under 17 03 01
17 03 03 * Coal tar and tar containing products
17 04 **Metals (including alloys)**
17 04 01 Copper, bronze, brass
17 04 02 Aluminum
17 04 03 Lead
17 04 04 Zinc
17 04 05 Iron and steel
17 04 06 Tin
17 04 07 Mixed metals
17 04 09 * Metal waste contaminated by dangerous materials
17 04 10 * Cables contaminated by oil, coal tar or other dangerous materials
17 04 11 Cables with exception of those, under 17 04 10
17 05 **Soil (including excavation of contaminated locations), stones and waste**
17 05 03 * Soil and stones containing dangerous materials
17 05 04 Soil and stones with exception that covered by 17 05 03
17 05 05 * Waste containing dangerous materials
17 05 06 Waste with exception of that under 17 05 05
17 05 07 * Track ballasts containing dangerous materials
17 05 08 Track ballasts with exception of that under 17 05 07
17 06 **Damming material and asbestos contaminated building materials**
17 06 01 *Damming material containing asbestos
17 06 03 *Other damming material, which consists
17 06 04 Damming material with exception of those under 17 06 01 and 17 06 03
17 06 05 *Asbestos contaminated building materials
17 08 Gypsum based building materials
17 08 01 * Gypsum based material contaminated by dangerous materials
17 08 02 Gypsum based building materials with exception of those under 17 08 01
17 09 Other building and demolition wastes
17 09 01 * Building and demolition wastes containing mercury
17 09 02 * Building and demolition wastes containing PCB (e.g. PCB contaminated sealants, PCB contaminated floor mats on resin base, PCB contaminated insulating glazings, PCB contaminated condensers)
17 09 03 *Other building and demolition wastes (including mixed wastes), the dangerous materials contained
17 09 04 Mixed building and demolition wastes with exception of those falling under 17 09 01, 17 09 02 and 17 09 03

(* denotes waste requiring special examination or monitoring)

Figure 4: European Waste Catalogue showing asbestos and PCB codes (EAKV, 1999)

Whilst it is difficult to obtain data on the amount of asbestos containing C&D waste in Germany, the amount of C&D waste containing PCB's was estimated at 0.02 million tonnes based on 2006 data contained in the report "Waste Accounting in Germany – Possibilities and Limits" (Federal Statistical Office, 2011).

2.3 Recycle ratio of C&D waste in Germany

The C&D waste recovery rate in Germany is one of the highest in the world. In 2006, the recovery rate of C&D waste was 70% or 51 million tons (Federal Ministry for the Environment, 2006), which well exceeded the targets set for EU member states (Commission, 2010a). The individual recycle rates for the top five C&D wastes in Germany range from 0% to a maximum of 93% as shown in Table 5 (Sunke and Schultmann, 2008):

Table 5: Recovery rates by C&D waste type in Germany (Sunke and Schultmann, 2008)

Waste type	Recovery rate (%)
Excavation waste (i.e. earth)	7
Demolition waste (i.e. bricks, concrete, steel etc)	62
Road scarification (i.e. bitumen)	93
Construction materials (i.e. packaging, off-cuts etc.)	5
Cement (i.e. leftovers from batch mixes)	0

The recovery rate for hazardous materials such as PCB's has been estimated at 49% with other materials of universal concern such as asbestos having a 0% recovery rate as it is normally disposed of in clearly marked landfill areas (Federal Statistical Office, 2011).

2.4 Products produced in Germany from C&D waste

A detailed study of potential products that can be produced from C&D waste has been undertaken for the demolition waste category, as shown in Table 6 (Leal et al, 2006).

Table 6: Demolition waste reuse and recycling options in Germany (Leal et al, 2006)

Demolition waste type	Reuse options	Recycling options
Concrete	Prefabricated items & concrete blocks can be reused directly with little processing	Can be crushed and ground to aggregate or sorted and used as fill
Brick	Can be reused directly after considerable time is taken to sort and clean suitable bricks	Can be crushed and ground to aggregate or sorted and used as fill
Wood	Solid elements can be reused directly in structural applications	Shredding for use as mulch or in engineered wood products and pelletisation for use as fuel
Steel	Some elements such as roofing sheets can be reused directly subject to condition	Shredding for use in place of gravel fill or smelting to replace use of new ore
Aluminum	Rarely reused directly as aluminum is often designed for one time use only	Commonly melted in rotary furnaces under a layer of liquid melting salt, refined and cast
Plastics	Rarely reused directly as plastic is often designed for one time use only	Plastic tubes, PVC floor mats and windows are melted to form new PVC roofing sheets
Tiles	Can be directly reused when free of dangerous materials and damage	Crushed with brick and concrete to be used as fill in place of gravel
Mixed excavation waste	Soil mixed with foundations can generally be reused on site as backfill for sand and gravel pits	Treated for contamination and sorted for use as backfill or as road base

2.5 Barriers for reuse and recycling of C&D waste in Germany – technical, political and other strategies to overcome these barriers

Most C&D waste recycled in Germany is from demolition work without much recovery from new construction waste, as shown in Table 5. One of the barriers to achieving this is the lack of specific laws relating to the reduction of the use of landfill sites for non-recycled C&D waste. As these landfill sites take up more land resources and impose risks on the environment, it is therefore necessary for the German government to employ **political** strategies to overcome this barrier, such as the establishment of relevant legislations enforcing the reduction of new construction waste being sent to landfill (Li et al., 2012).

Another barrier is the lack of specific regulations on manufacturers' responsibility for waste minimisation in the German construction industry. The products produced by manufacturers, transported to construction sites and used in buildings contribute to waste problems and environmental impact, if the products cannot be recovered or degraded. It is therefore necessary for the German government to adopt additional **political** strategies to overcome this barrier such as regulations and policies on C&D waste minimisation from the perspective of the construction material manufacturer. Higher standards for material design and product stewardship need to be established for construction material manufacturers so as to encourage them to take up their responsibilities for waste minimisation in construction projects.

Technical strategies to help overcome these barriers could include research regarding innovation in packaging production for construction materials in order to minimise waste and facilitate ease of recovery. The government needs to establish R&D incentive measures for technological innovation in construction material packaging so as to minimise waste and increase reuse and recycling, similar to what has been done in the German automotive component industry since 1995 when suppliers were made responsible for recovery of their packaging materials from the auto manufacturer. This leads for instance to the development of the reusable, collapsible auto component package, as shown in Figure 5 (Bylinsky and Moore, 1995).

Figure 5: Example of reusable, collapsible auto industry component packaging (Bylinsky and Moore, 1995)

Other possible strategies to overcome these barriers to greater reuse and recycling of C&D waste in Germany include **financial incentives** from the government for the recovery of waste generated from construction processes. The construction industry client needs to be financially motivated to incorporate waste management as part of the project delivery process. Project teams who successfully achieve high waste recovery rates also need to be rewarded financially and the lessons learned need to be shared via case studies. Waste management companies also need to be provided with financial incentives to encourage the adoption of new technologies to improve the effectiveness of waste recycling processes. (Li et al., 2012).

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Barriers for Deconstruction and Reuse/Recycling of Construction Materials in Japan

Shiro Nakajima

Building Research Institute
JAPAN

1. BARRIERS FOR DECONSTRUCTION

1.1 Post and Beam Timber Houses

1.1.1. Commonly used method to remove buildings

The post and beam timber houses are mainly removed by selectively dismantling operation. In the selectively dismantling operation the joineries, the dry walls, the insulation materials, the roofing materials and the equipments such as kitchen unit and bath units are removed by hand prior to the machine dismantling process. During the machine dismantling process the waste generated are separated into several different types of materials. The types of waste that have to be separated are wooden waste, steel waste, aluminium waste, glass and ceramic waste, gypsum waste, plastic waste and concrete waste. The outline of the selectively dismantling operation of post and beam timber houses is summarized in figure 1.

Some of the post and beam timber houses are also removed by deconstruction method. In this case every composing members of the house are taken apart carefully by hand. As hand deconstruction method needs time and cost more than the selectively dismantling method it is used only in case the house is planned to be rebuilt using the deconstructed material or in case the client ask to do so for some environmental concern. But in the past time say 50 years ago most of the post and beam timber houses were deconstructed and the deconstructed materials were in market as building materials. And for this we can sometime find columns or beams that are reused lumbers when we dismantle houses whose ages are more than 50 years. The out line of the deconstruction method of post and beam timber houses is summarized in figure 2.

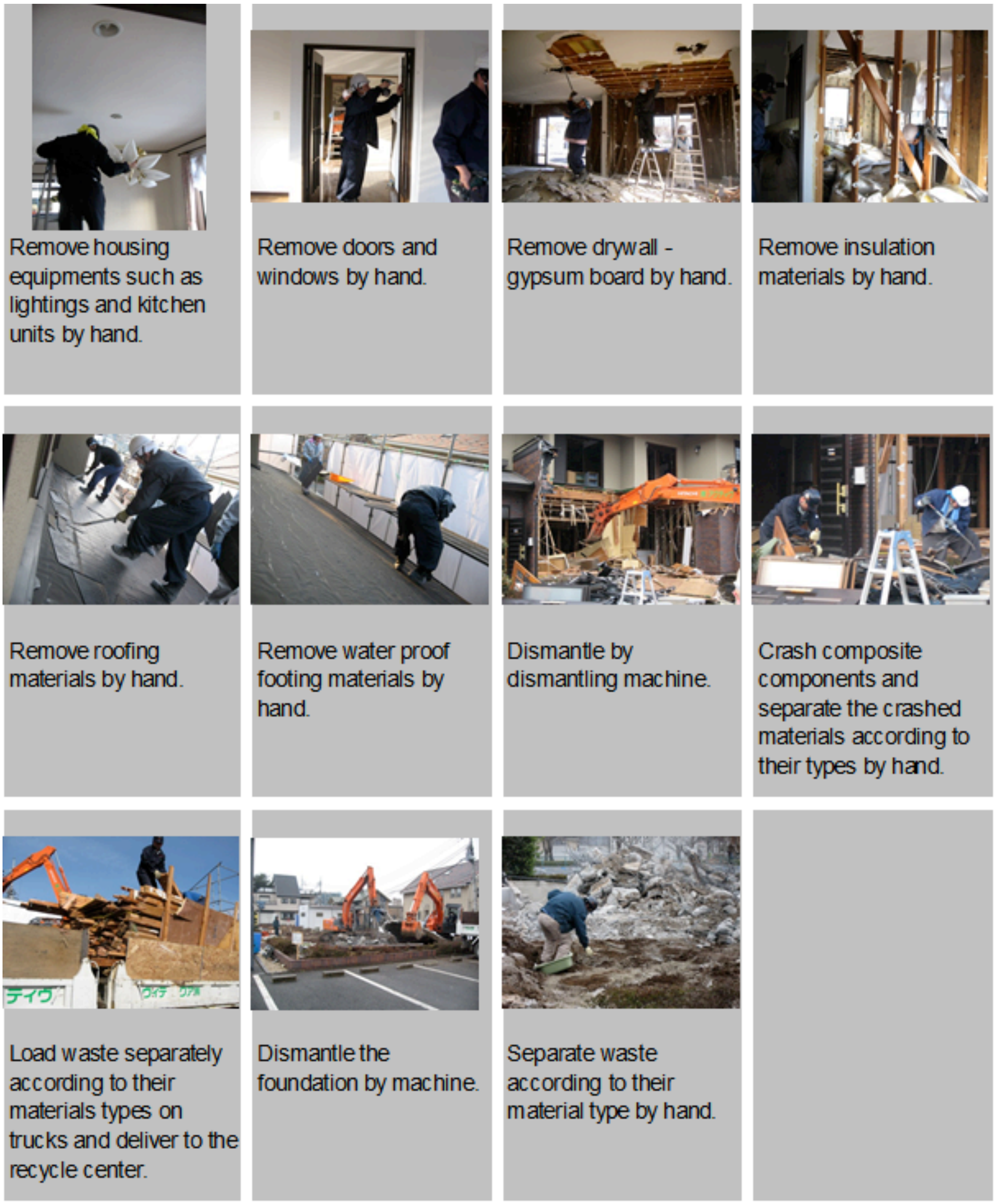

Figure 1: Outline of the selectively dismantling operation of post and beam timber houses.

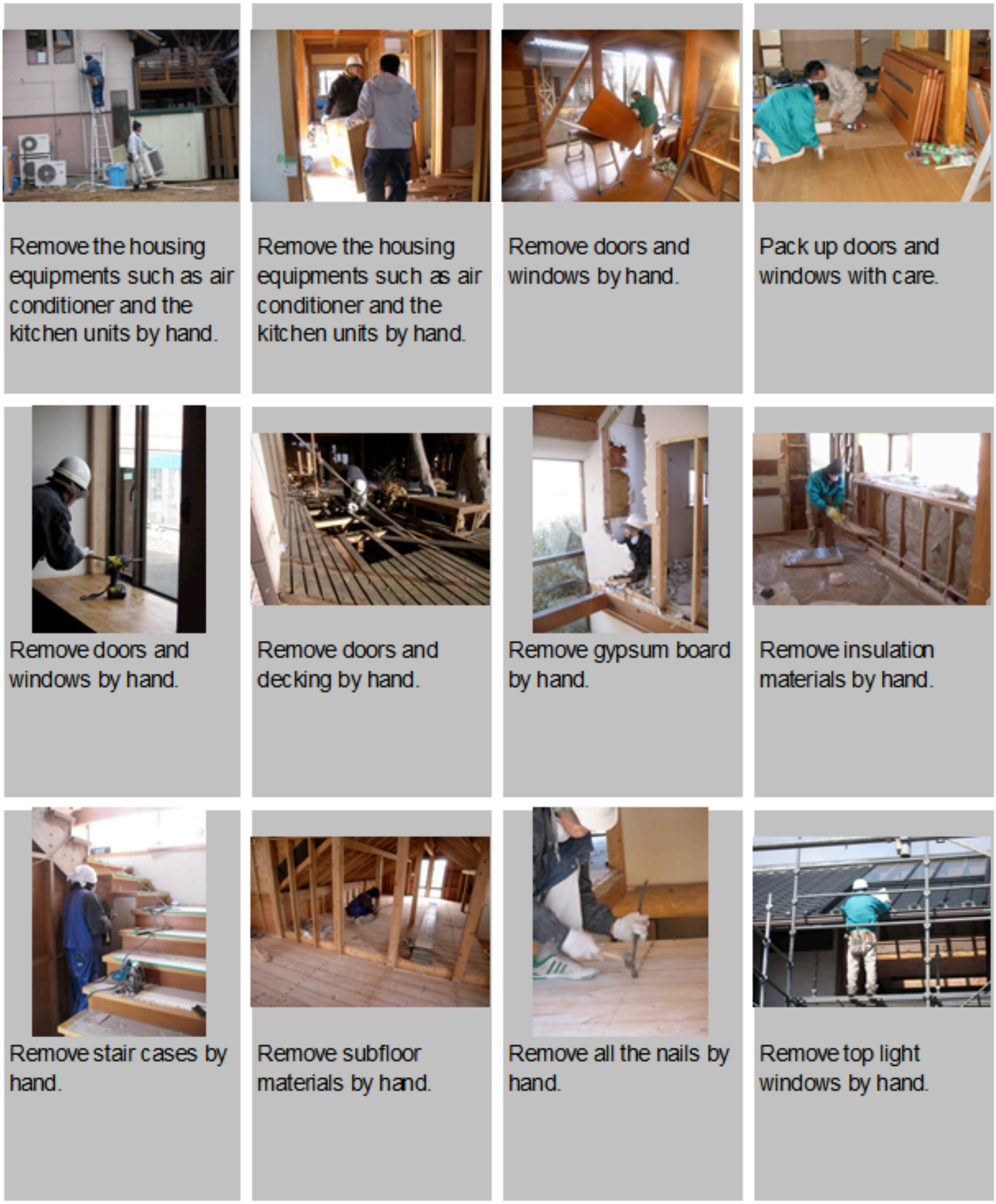

Figure 2a: Outline of the of the deconstruction method of post and beam timber houses. (Part 1)

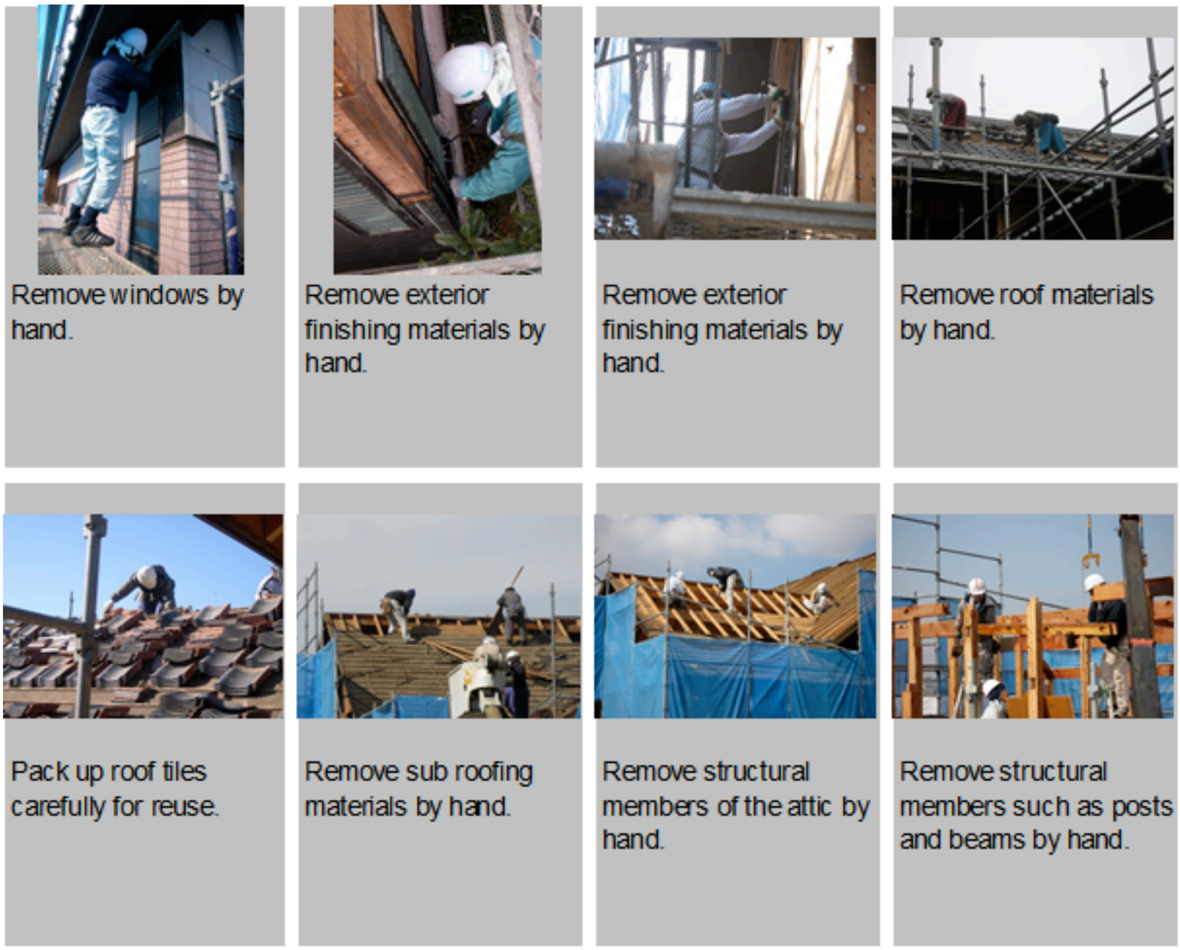

Figure 2b: Outline of the of the deconstruction method of post and beam timber houses. (Part 2)

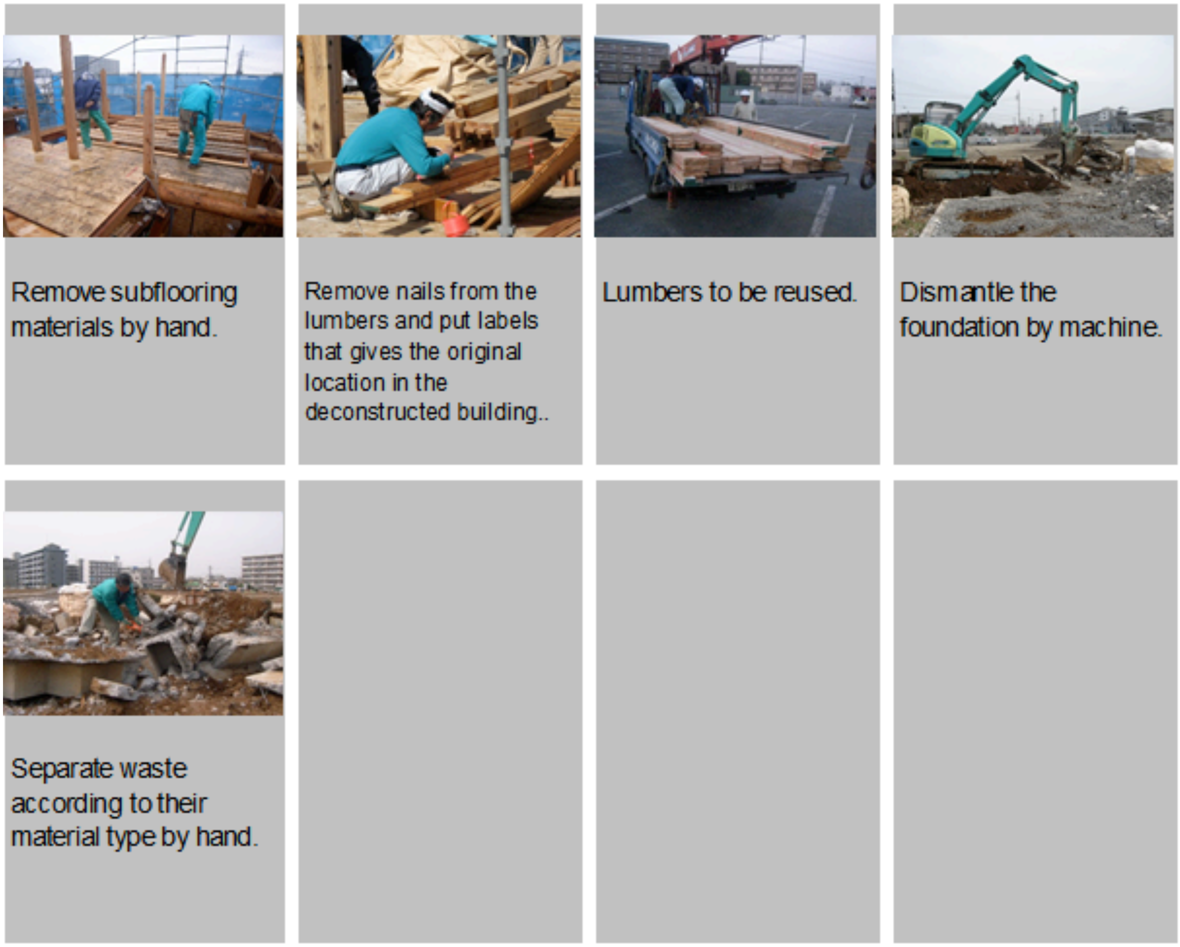

Figure 2c: Outline of the of the deconstruction method of post and beam timber houses. (Part 3)

1.1.2. Barrier for deconstruction

Deconstruction seems to be the most environmentally friendly way to remove post and beam timber houses. But deconstruction requires more than three time longer duration than selective dismantle method. For this the selective dismantle method is chosen as a common method for removing post and beam timber buildings. Recently for structural safety, durability and energy conservation issues not only timber buildings but also all types of buildings in Japan are composed of composite structure and composite materials. Composite structure and composite materials leads buildings to be difficult to deconstruct and also difficult to selectively dismantle. Some of the undesirable design for deconstruct or selective dismantle are summarized in figure 3.

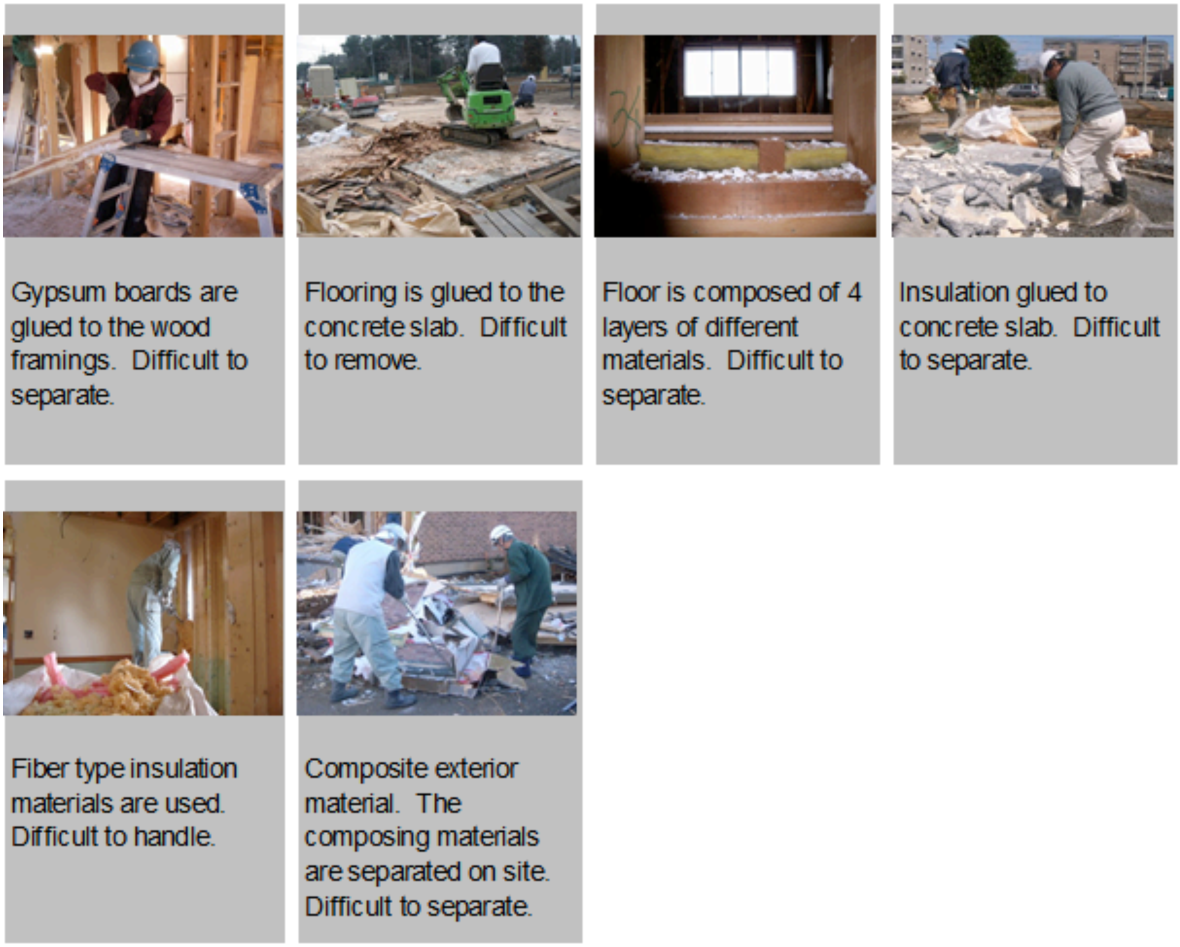

Figure 3: Examples of undesirable design for deconstruct or selective dismantle for post and beam construction.

1.1.2. Strategies

(1) Technical strategies to overcome the barriers

The technical strategies can be summarized as follows;

1. Design buildings with consideration of the requirements that will rise at the end of their service life. Design buildings easy to deconstruct and easy to selectively dismantle.
2. Design materials with consideration of the requirements that will rise at the end of their service life. Design materials easy to reuse/recycle.

(2) Political strategies to overcome the barriers

The political strategies can be summarized as follows;

1. Give financial advantages to the environmentally friendly methods for removing buildings. For example financial advantages will be reduction of tax.
2. Give financial advantages to buildings that are designed for deconstruction. For example financial advantages will be reduction of tax.
3. Give financial advantages to building materials designed for reuse or recycle. For example financial advantages will be reduction of tax.
4. Give financial advantages to buildings that are not removed by the environmentally friendly removing methods. For example financial disadvantages will be additional tax charge.
5. Give financial advantages to buildings that are not designed for deconstruction. For example financial disadvantages will be additional tax charge.
6. Give financial advantages to building materials that are not design for reuse or recycle. For example financial disadvantages will be additional tax charge.

(3) Other strategy to overcome the barriers (ex. Ecological Incentive)

Other strategies can be summarized as follows;

1. Produce rating system that can evaluate the environmentally friendliness of the removing methods.
2. Create deposit system that will give incentive to deconstruction and reuse/recycle.

1.2 Wood Frame Houses

1.2.1. Commonly used method to remove buildings

The wood frame houses are mainly removed by selectively dismantling operation. In the selectively dismantling operation the joineries, the dry walls, the insulation materials, the roofing materials and the equipments such as kitchen unit and bath units are removed by hand prior to the machine dismantling process. During the machine dismantling process the waste generated are separated into several different types of materials. The types of waste that have to be separated are wooden waste, steel waste, aluminium waste, glass and ceramic waste, gypsum waste, plastic waste and concrete waste. The outline of the selectively dismantling operation of wood frame houses is summarized in figure 4.

There is almost no case that the wood frame houses are being deconstructed in Japan. Exceptionally they are deconstructed for research purpose or for case study.

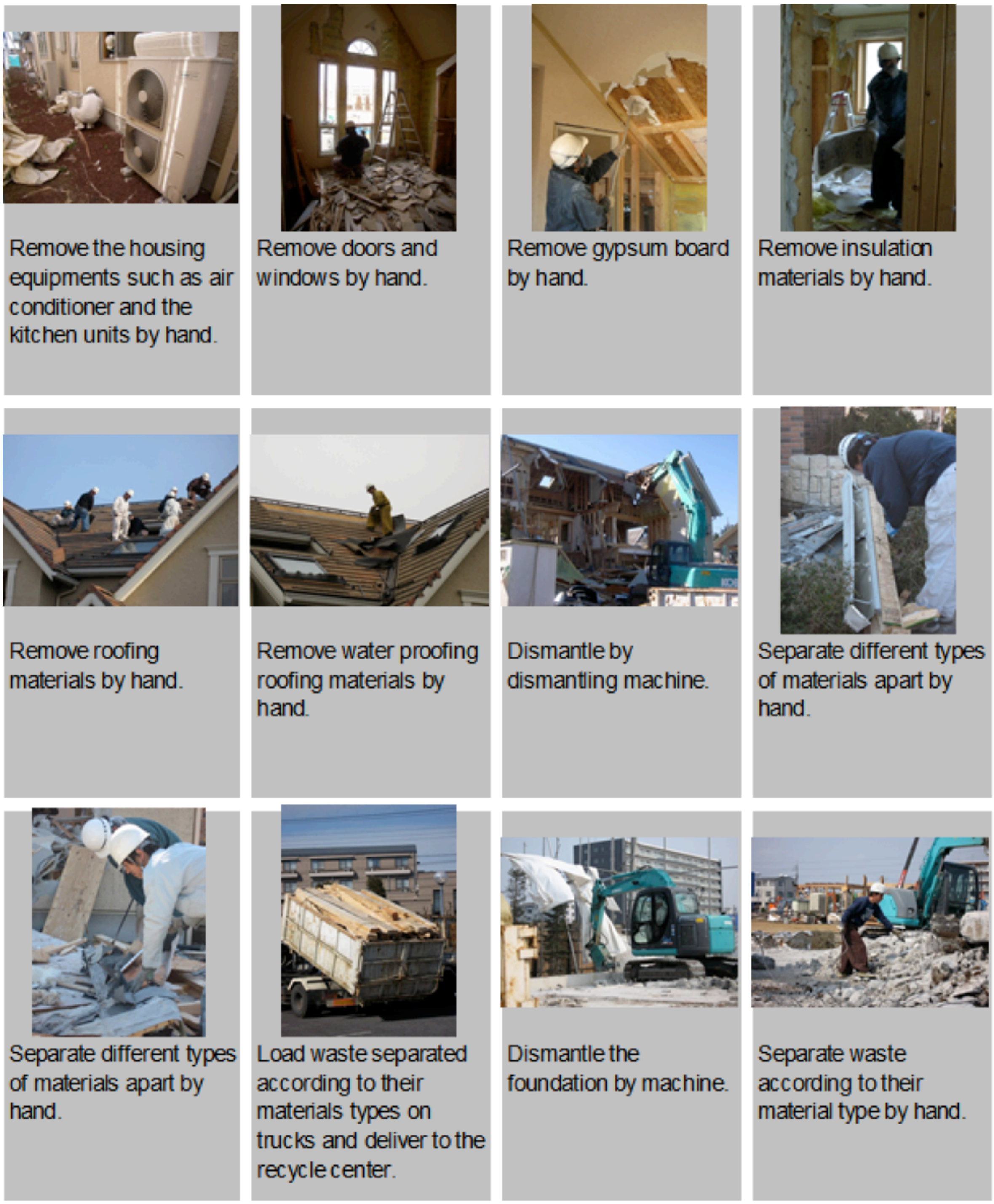

Figure 4: Outline of the selectively dismantling operation of wood frame houses.

1.2.2. Barrier for deconstruction

Barriers for deconstruction for wood frame construction are same as the barriers for post and beam timber houses. As the structural members of the wood frame construction are strongly jointed with many nails it is quite difficult to deconstruct the wood frame houses. The amount of nails used to construct one single detached house of floor area of $150m^2$ is about 50,000.

As common to all buildings in Japan for structural safety, durability and energy conservation issues buildings wood frame construction are composed of composite structure and composite materials. Composite structure and composite materials leads the buildings to be difficult to selectively dismantle.

1.2.2. Strategies

(1) Technical strategies to overcome the barriers

The technical strategies are almost same as that for post and beam timber houses.

1. Design buildings with consideration of the requirements that will rise at the end of their service life. Design buildings easy to selectively dismantle.
2. Design materials with consideration of the requirements that will rise at the end of their service life. Design materials easy to reuse/recycle.

(2) Political strategies to overcome the barriers

The political strategies are same as that for post and beam timber houses.

1. Give financial advantages to the environmentally friendly methods for removing buildings. For example financial advantages will be reduction of tax.
2. Give financial advantages to buildings that are designed for deconstruction. For example financial advantages will be reduction of tax.
3. Give financial advantages to building materials designed for reuse or recycle. For example financial advantages will be reduction of tax.
4. Give financial advantages to buildings that are not removed by the environmentally friendly removing methods. For example financial disadvantages will be additional tax charge.
5. Give financial advantages to buildings that are not designed for deconstruction. For example financial disadvantages will be additional tax charge.
6. Give financial advantages to building materials that are not design for reuse or recycle. For example financial disadvantages will be additional tax charge.

(3) Other strategy to overcome the barriers (ex. Ecological Incentive)

Other strategies are same as that for post and beam timber houses.

1. Produce rating system that can evaluate the environmentally friendliness of the removing methods.
2. Create deposit system that will give incentive to deconstruction and reuse/recycle.

1.3 Light Steel Framed Houses

1.3.1. Commonly used method to remove buildings

Light steel frame houses may be locally specific buildings in Japan. As shown in figure 5 almost 20% to 25% of the single detached houses built annually in Japan are of light steel frame construction. As common to wood frame houses the light steel frame houses are removed by the selectively dismantling operation. In the selectively dismantling operation the joineries, the dry walls, the insulation materials, the roofing materials and the equipments such as kitchen unit and bath units are removed by hand prior to the machine dismantling process. During the machine dismantling process the waste generated are separated into several different types of materials. The types of waste that have to be separated are steel waste, wooden waste, aluminium waste, glass and ceramic waste, gypsum waste, plastic waste and concrete waste. The outline of the selectively dismantling operation of light steel frame houses is summarized in figure 6.

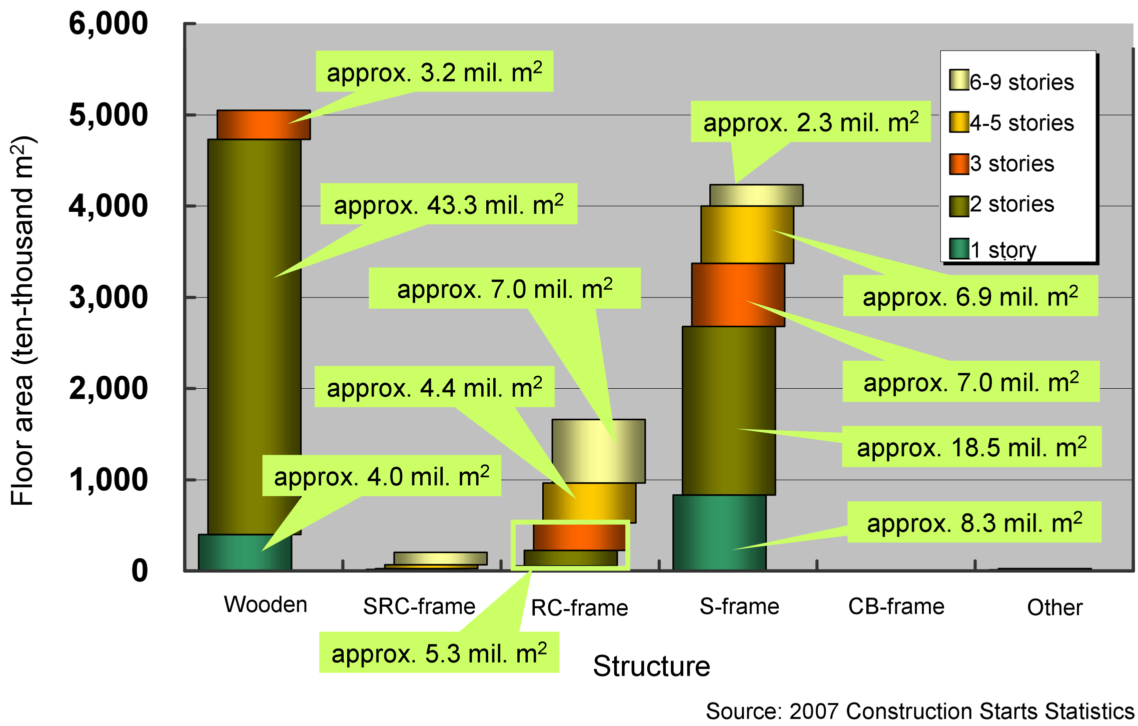

Figure 5: Total Floor Area of Housing Starts by Structure / Number of Stories.

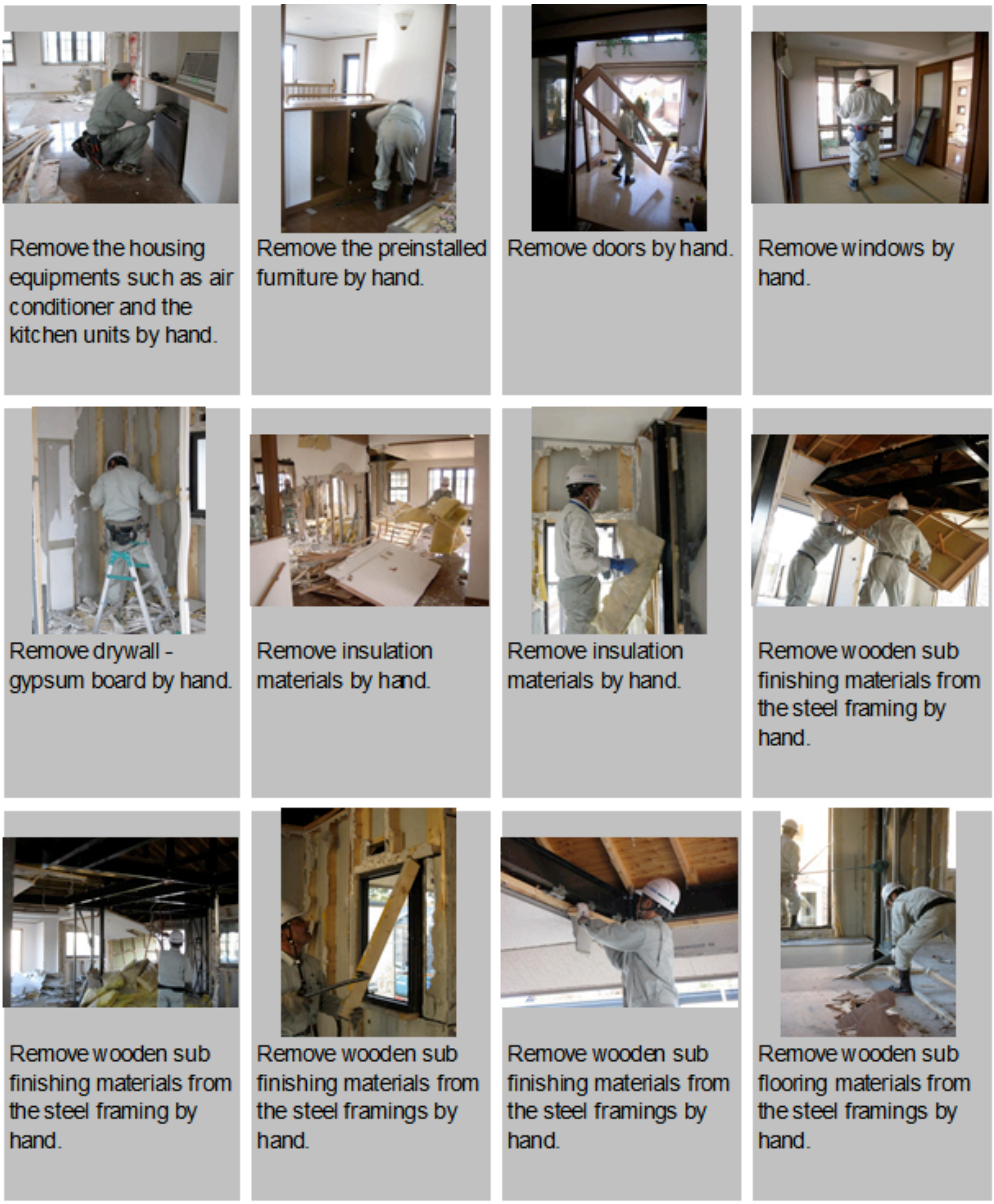

Figure 6a: Outline of the selectively dismantling operation of light steel frame houses (Part 1).

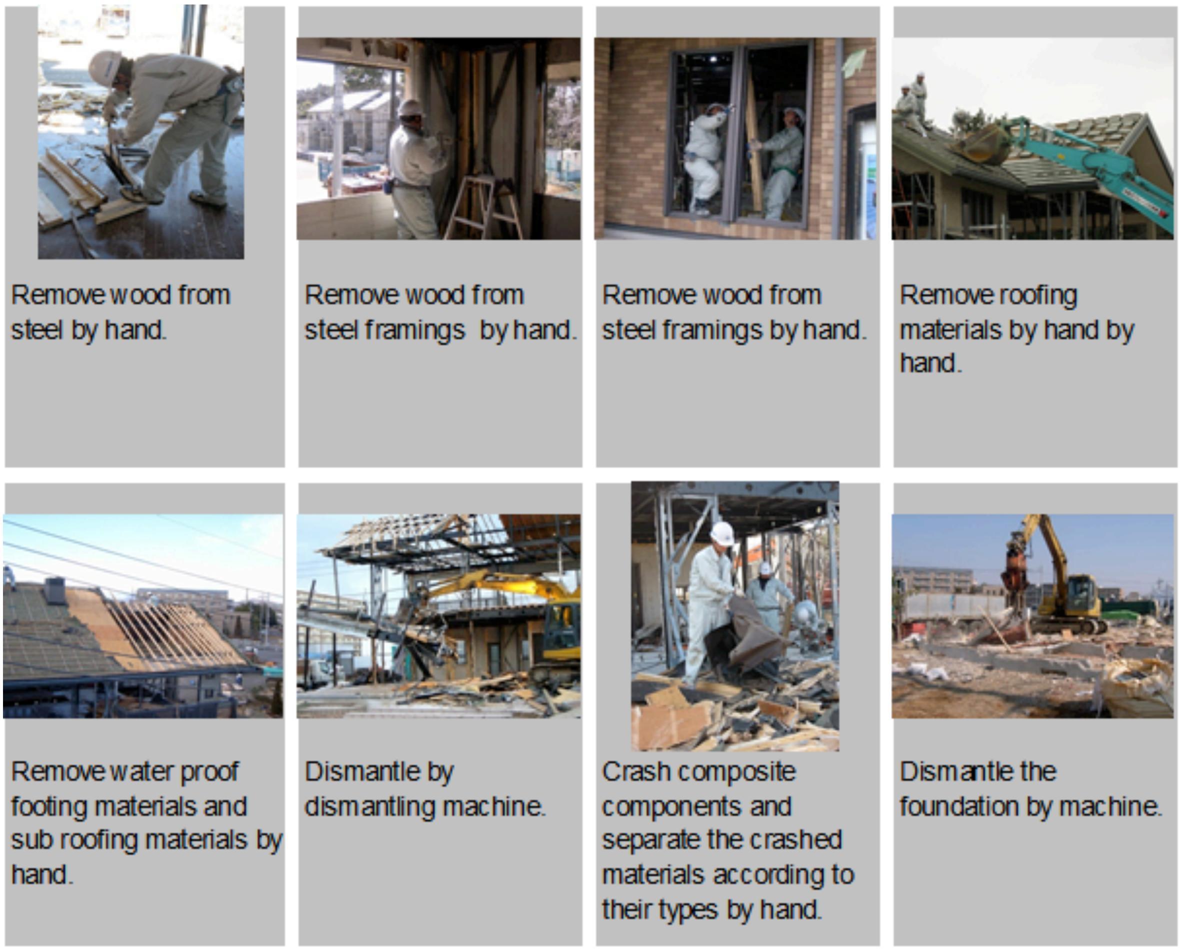

Figure 6b: Outline of the selectively dismantling operation of light steel frame houses (Part 2).

1.3.2. Barrier for deconstruction

Barriers for deconstruction for light steel frame houses are similar to that for the wood frame houses. As common to all buildings in Japan for durability, energy conservation and onsite works reduction issues the light steel frame houses are composed of composite materials and composite units. Composite materials and composite units lead the buildings to be difficult to selectively dismantle. Some of the undesirable design for deconstruct or selective dismantle are summarized in figure 7.

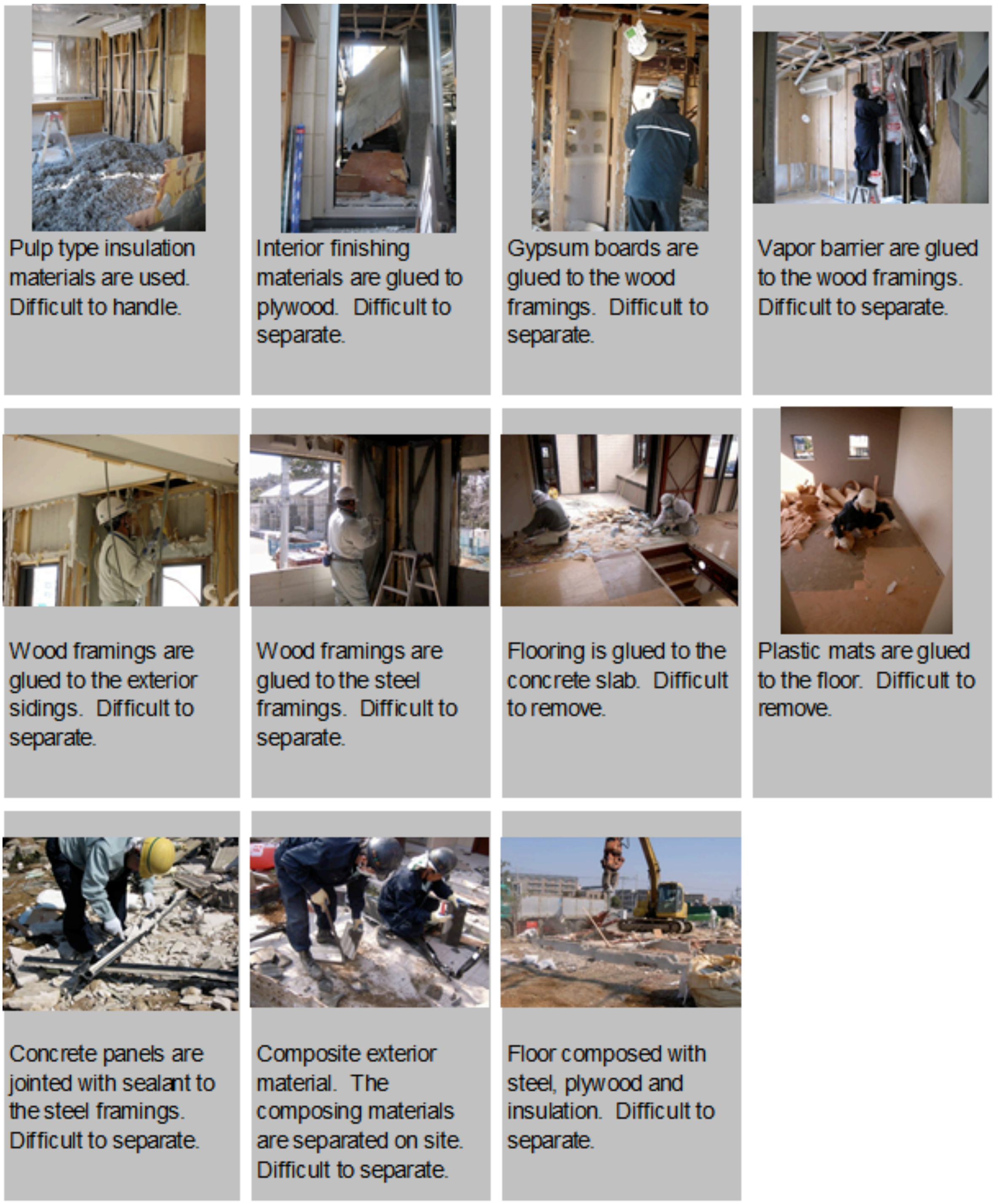

Figure 7: Examples of undesirable design for deconstruct or selective dismantle for light steel frame construction.

1.3.2. Strategies

(1) Technical strategies to overcome the barriers

The technical strategies are almost same as that for the wood frame houses.

1. Design buildings with consideration of the requirements that will rise at the end of their service life. Design buildings easy to selectively dismantle.
2. Design materials with consideration of the requirements that will rise at the end of their service life. Design materials easy to reuse/recycle.

(2) Political strategies to overcome the barriers

The political strategies are same as that for the wood frame houses.

1. Give financial advantages to the environmentally friendly methods for removing buildings. For example financial advantages will be reduction of tax.
2. Give financial advantages to buildings that are designed for deconstruction. For example financial advantages will be reduction of tax.
3. Give financial advantages to building materials designed for reuse or recycle. For example financial advantages will be reduction of tax.
4. Give financial advantages to buildings that are not removed by the environmentally friendly removing methods. For example financial disadvantages will be additional tax charge.
5. Give financial advantages to buildings that are not designed for deconstruction. For example financial disadvantages will be additional tax charge.
6. Give financial advantages to building materials that are not design for reuse or recycle. For example financial disadvantages will be additional tax charge.

(3) Other strategy to overcome the barriers (ex. Ecological Incentive)

Other strategies are same as that for the wood frame houses.

1. Produce rating system that can evaluate the environmentally friendliness of the removing methods.
2. Create deposit system that will give incentive to deconstruction and reuse/recycle.

2. BARRIERS FOR REUSE AND RECYCLE

2.1 Wood Waste

2.1.1 Recycle ratio

Reused	No data
Recycled for raw materials of products	68 %
Recycled for energy source	No data
Land filled or burned	32 %
Other	0 %
Total	100 %

2.1.2 Products produced from No.1 C&D waste

Particle Board

Fiber Board

2.1.3.1 Barrier

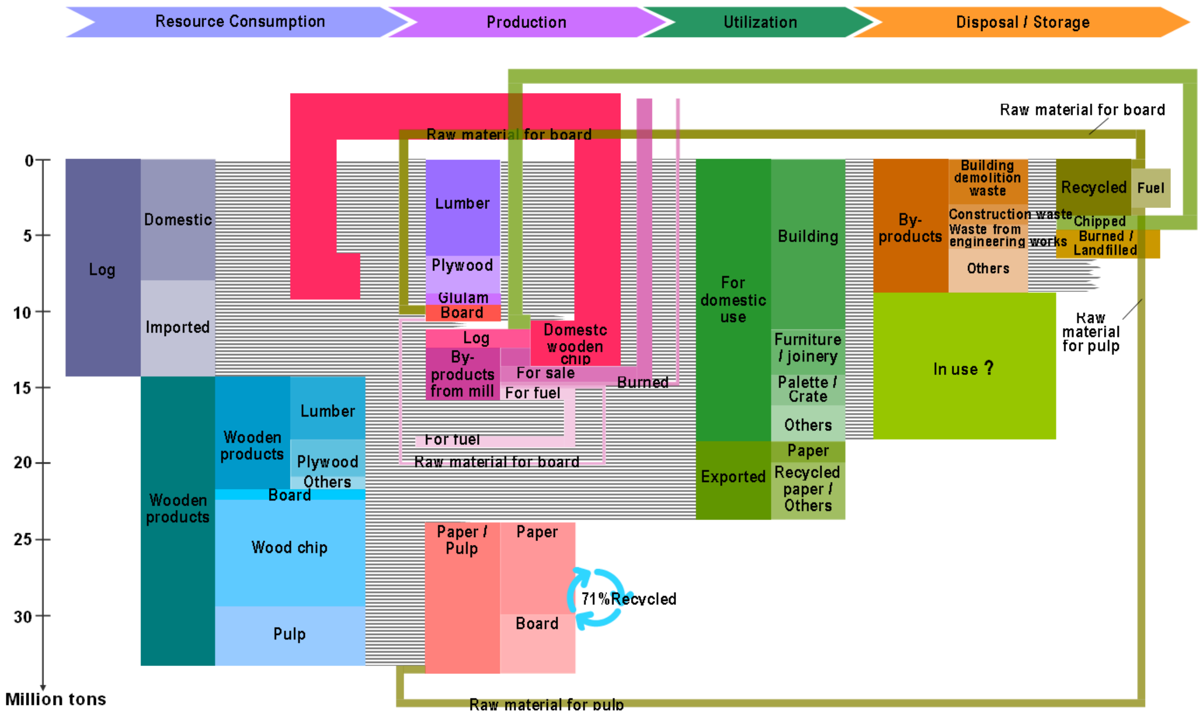

Figure 8 shows the material use and circulation of wooden materials in Japan in 2005. Wooden C&D waste has the possibility to be recycled as raw materials for wood based panels such as particle board. Almost 70% of the raw material of particle board is wooden C&D waste. Recently there is a strong demand for renewable energy source. And as a result there is a demand for wooden C&D waste as energy source. And for the wooden panel producing industry it is becoming difficult to keep having enough wooden C&D waste for their raw materials. The recycling policy in Japan recommends to recycle waste as raw materials first and if not possible to do so recycling as energy sources. The situation now is no following the recycling policy.

2.1.3.2 Strategy

(1) Technical strategies to overcome the barriers

Particle boards and fiber boards are used for structural materials for timber buildings and also used for non-structural purpose. The Japanese Building Code allows using both materials as structural elements for timber buildings. Particle boards can be used for sheathing materials for wall and floor for timber buildings. But some technical issues such as durability and stability should be resolved. The research body in the related industrial association has been working on this issue and has provided some technical reports.

(2) Political strategies to overcome the barriers

The recycling policy that recommends recycling waste as raw materials first should be reviewed and carefully followed.

(3) Other strategy to overcome the barriers (ex. Ecological Incentive)

Give financial advantages to buildings that are using recycled wooden materials. For example financial advantages will be tax reduction.

2.2 Concrete

2.2.1 Recycle ratio

Reused	0 %
Recycled for raw materials of products	97 %
Land filled	3 %
Other	0 %
Total	100 %

2.2.2 Products produced from No.2 C&D waste

Recycled concrete aggregates

Road bedding materials

2.2.3.1 Barrier

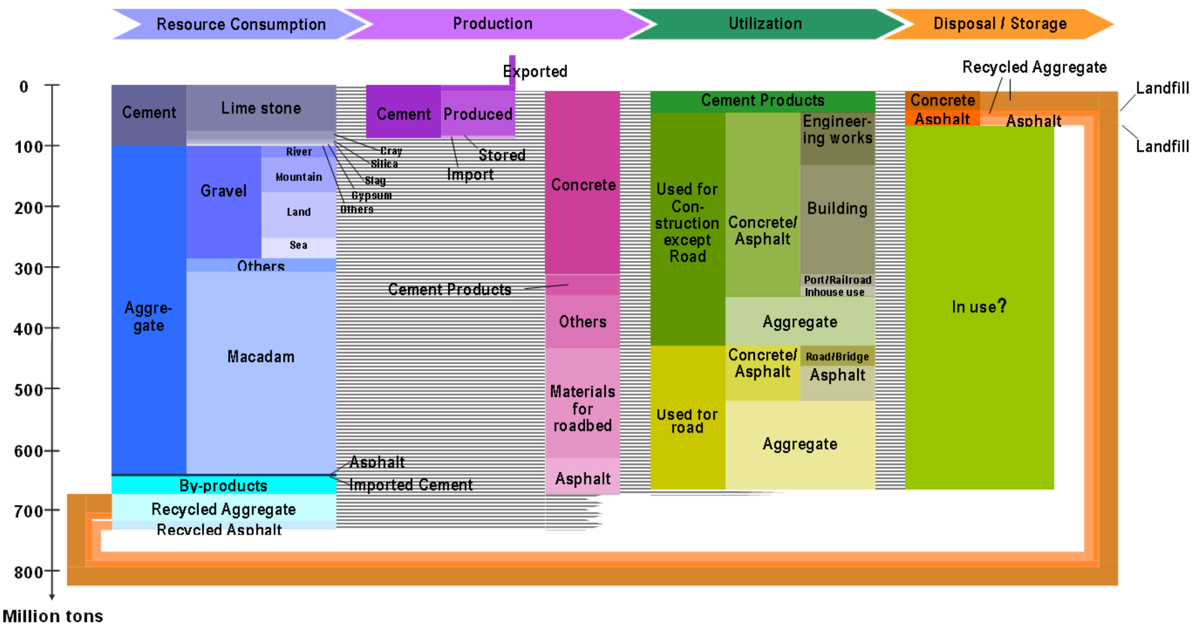

Figure 9 shows the material use and circulation of concrete materials in Japan in 2005. Most of the concrete aggregates are recycled as road foundation materials and only few are recycled as raw materials for concrete. The reason for this is that more energy and cost are required to produce recycled concrete aggregates than virgin concrete aggregates. On the other hand the road construction in Japan is decreasing so the demand for the road foundation materials is reducing.

2.2.3.2 Strategy

(1) Technical strategies to overcome the barriers

New technologies that can produce recycled concrete aggregates with low energy and low cost should be developed. Technical standard for recycled concrete aggregates should be also produced so that the materials can have the opportunity to be equivalently used as virgin concrete aggregates.

(2) Political strategies to overcome the barriers

Financial advantages should be given to recycled concrete aggregates such as tax reduction.

(3) Other strategy to overcome the barriers (ex. Ecological Incentive)

None

2.3 Steel

2.3.1 Recycle ratio

Reused	No Data
Recycled for raw materials of products	100 %
Land filled	0 %
Other	0 %
Total	100 %

2.3.2 Products produced from No.2 C&D waste

Steel

2.3.3.1 Barrier

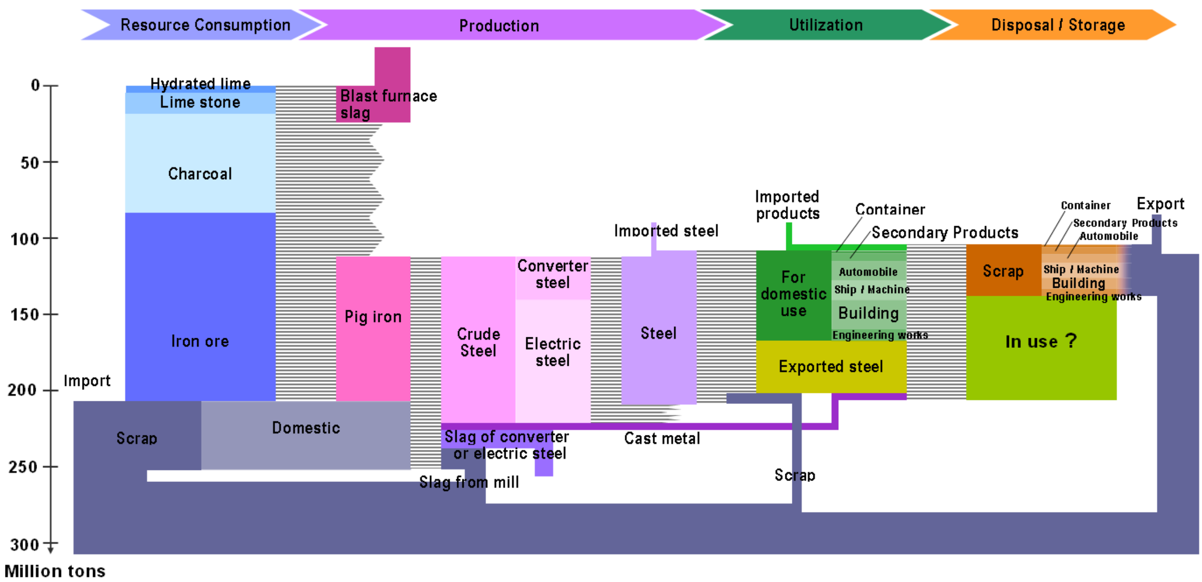

Figure 10 shows the material use and circulation of steel materials in Japan in 2005. Steel are 100% recycled. There seems to be no big barriers for recycling steel. The only issue is to how easily the steel materials can be separated from other materials so get the best recovery ratio. There are also some research and case study done for reusing steel structural elements. To reuse steel structural elements as structural elements for newly constructed buildings standards and regulations are needed for reclaimed steel elements.

2.3.3.2 Strategy

(1) Technical strategies to overcome the barriers

To make recycle more easy building should be designed in a manner that steel materials can be easily separated for the other materials. To reuse steel structural elements as structural elements for newly constructed buildings standards and regulations should be prepared for reclaimed steel elements.

(2) Political strategies to overcome the barriers

Buildings standards and regulations should be prepared for reclaimed steel elements. Well designed steel buildings should have financial advantages such as reduced tax.

(3) Other strategy to overcome the barriers (ex. Ecological Incentive)

None

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Barriers for Deconstruction and Reuse/Recycling of Construction Materials in Netherlands

Elma Durmisevic and Stefan Binnemars

University of Twente
NETHERLAND

1. BARRIERS FOR DECONSTRUCTION

1.1 Major Construction Types

Major construction type in the Netherlands consists of concrete panel system and brick façade. Just recently, timber frame paneling started to be used more often in housing projects and building system for schools.

1.2 Methods Used to Remove Buildings State of the Art

1.1.1. Commonly used method to remove buildings

There are two major methods commonly used to remove buildings: one related to permanent structures and other related to temporally structures and schools, shops etc.

In general, more permanent building structures are not designed to be demountable. Their components are not designed to be reused and reconfigured, and the applied materials are often composed of composites, which are not designed to be recycled. Buildings are not designed with the goal to recover their materials for a future use. The lack of potential for material recovery in the building industry can best be seen during the demolition phase of building, which is a typical end of life of building structures.

Most demolition processes in the Netherlands have two stages:

Stage one in the demolition of buildings is the stripping of building finishes in two steps:

1. Step one involves the stripping of reusable components. Those are mainly glass elements removed from the window frames, sanitary fixtures, wooden floor finishes, and radiators. Phase two includes the stripping of plasterwork, service installations, pipes, and roof coverings. In the case of flat roofs, the roofing is removed and taken to a landfill. The roofing gravel, in case of a flat roof, is usually contaminated with PAH (polycyclic aromatic hydrocarbons) and should be treated as a chemical waste. This phase of stripping a building produces a number of waste streams. The waste is transported to a sorting plant where they are separated in recyclable, burnable, and non-burnable materials. The burnable portions are incinerated in a waste incineration plant and the non-burnable portions are land filled.

2. After stripping of the building, the demolition of the rest of the building begins. When only the brickwork and concrete is left, the building is demolished floor by floor. Beams and wooden floors are removed with cranes and equalizer beams. The nails in joints are removed by punching. Brickwork is cut into sections and taken to a crusher plant. Most of the brickwork is not reusable because of the use of strong mortar that breaks only after the brick itself. The concrete structure is cut up using breaker shears and taken to a crusher. In the past, concrete rubble was cut into smaller parts and iron was removed on site. Today, crushing plants have developed methods to handle large sections of concrete and to extract reinforcing steel using magnets

The demolition sequence of buildings with steel frames depends on the connections between structural elements. If columns and beams can be reused, then the structure is disassembled. Otherwise, the steel structure is cut up and sent to a steelwork. Besides the use of cranes, equalizer beams, and breaker shears, demolition of buildings using explosives is also a common technique. It is often used for demolition of high-rise buildings. This process involves high risks for the surrounding community and for demolition workers.

As a result of demolition processes that reflect conventional methods of construction, the demolition of building structures produces enormous amounts of waste and down-cycling of materials.

Temporally structures on the other hand have been designed to be used for 5 or 6 years and then replaced and reused somewhere ales. Therefore, these structures have been optimized and standardized their design for fast assembly and disassembly. However, they have limited applications. The systems are optimized to replace the whole building very fast. This results in a construction method of big size panels that can be reused more or less in similar application and configuration. Modular panels themselves are not designed for disassembly or reconfiguration. As long as they can be used for the same school type for example they will be reused. Disadvantage of these systems for deconstruction is that usually no deconstruction or reuse takes place on the system and component level. Furthermore, since systems are designed for temporally structures the quality and durably of materials is not that high. Therefore, the end of life scenarios for most of the materials in temporally buildings is down-cycling.

1. 3 Barriers and Strategies for Deconstruction

1.3.1. Barriers

Most modern buildings today are made of prefabricated components designed to be mountable, but not demountable. This is one of the major barriers for deconstruction. Besides the disposal taxes which are not very high, the government is not willing to impose more regulations to stimulate material reuse in construction and believes that at this stage the market should see advantages of this approach and develop new economic models.

1.3.2 Strategies

Considering the economic crises, a significant part of construction sector in the Netherlands is on a hold. In 2008, 3 billion euro has been spend in construction only in the Dutch Eastern Province Overijssel. 36% of this investment was spent on material resources.(Jaarverslag Pioneering 2009 of 2010)

On the other hand, one can see that material costs have risen recently by 10% and this trend will be continuing in the coming years. There is also a huge percentage of uncertainty in the duration and sort of exploitation of a building once it is built. There are more and more empty buildings in the Netherlands which are useless because they cannot be adapted to a new use, and therefore materials are wasted as well. There are fewer investments made for new constructions nowadays since the risk is too high. All this is creating a growing awareness in the Netherlands that the construction industry needs to reinvent itself and that market conditions demand a new construction and new business model for the construction. This is where design for reuse and deconstruction starts to play an important role in transforming the construction industry. The major consideration is that the future value of the building will be greatly focused around the actual value of materials and that the key challenge is in shaping a business model around the ownership and reuse of the materials as a resource for the new construction.(Real Capital - Towards Green Economy, Gielingh SGDF2012)

A building innovation platform has been formed in the Netherlands that aims at investigating the new way of construction which is based on design for disassembly principles and how to reach a broader implementation(www.pioneering.nl). A subgroup of this platform (IDF- Industrial Sustainable Flexible buildings) developed several systems in the past three years in order to illustrate what the advantages of the new sustainable construction methods would be, and is in preparation of a couple of pilot projects.

A flexible and demountable system for construction and renovation of bathrooms and toilets has been developed, a demountable 3D modular façade element for transformation of the existing buildings has been developed whose materials can be dismantled and reused. At the University of Twente a new Master program has been developed that will educate new designer for buildings into looking primarily from industrial design, design for disassembly and transformation point of view at the built environment. At the same time, the University of Twente initiated the Center for Green Transformable buildings located at the University of Twente with its demonstration project Green Transformable Building Laboratory. In this lab the potentials for deconstruction, reuse and transformation of buildings and its parts are being further investigated and tested.

Recent economic crisis has brought great challenges in front of the designers and construction industry and only significant transformation of the sector's businesses approach and mentality will help to regain its market position. These new business models will certainly be looking at the real value of a construction and will become more critical regarding the value of material capital in the building and the adaptability to functional changes of buildings. Considering the activities within innovation platform group Pioneering and new educational and research program at the University of Twente, we may see in the next few years more concrete examples of such an approach in the Netherlands in terms of new business models and their implementation in the construction projects.

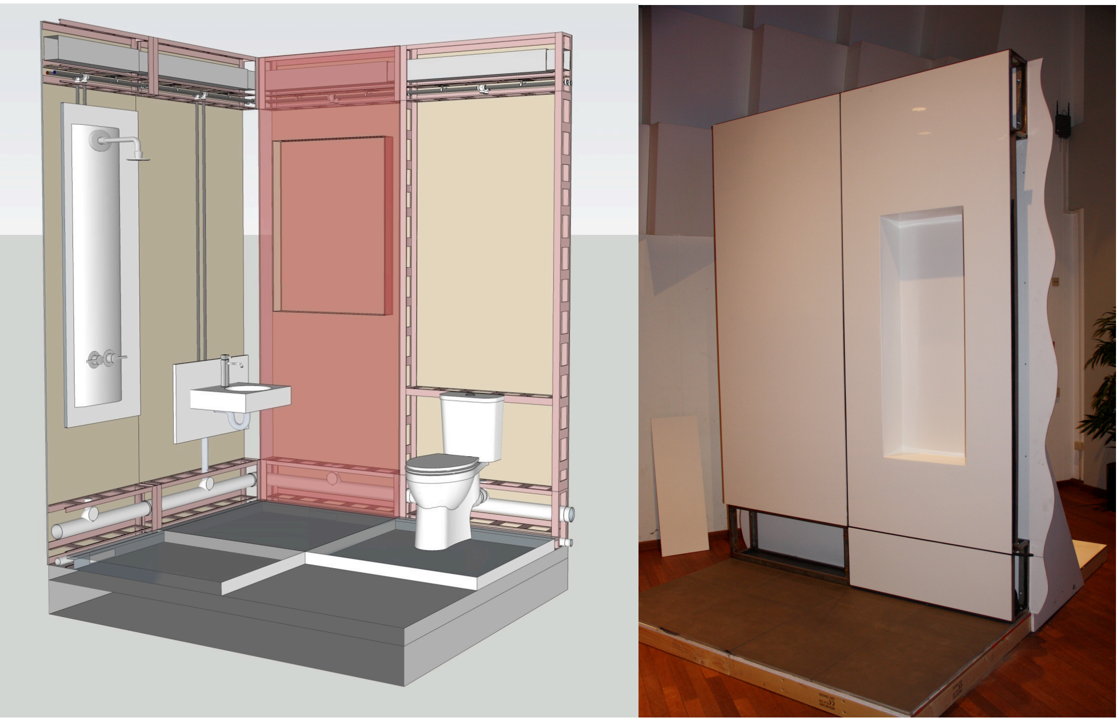


Figure 1: Sustainable Construction methods, demountable bathroom system (IDF consortia)

2. BARRIERS FOR REUSE AND RECYCLE

Agentschap NL appointed Van Ruiten Adviesbureau B.V. in combination with Rense Milieu Advies for the following assignment: *conduct a research into the amount of construction and demolition waste over the years 2008 and 2009*. This is the most recent research into the C&D

waste in the Netherlands. More than 80% of the data is directly from the source, the rest is estimated based on averages. The previous research of 2006-2007 was conducted by INTRON. All data and figures in this chapter are directly translated from their report.[1]

The report states that several trends are visible in the C&D waste market. Firstly, there is a strong increase in the burning of sorting residue caused by low prices for burning through market competition. Secondly, the export of combustible C&D waste is almost completely stopped also because of low burn charges and additionally the ban on landfill in Germany. Thirdly, concrete mortar companies obliged in a covenant to buy 300.000.000 kg of granulated material. Fourthly, research is conducted into new dry separation techniques.

Despite the low burn charges there is increasing interest to separate smaller partitions from C&D waste. In recent years, several companies applied to collect bituminous waste from roofs and PVC-frames, and recycle these materials. Recycling however remains in strong competition with burn installations.

There is clarity about the status of C&D waste granules within the framework of Reach. Registration for Reach is not necessary because granules are considered "articles" and it is a "recovered substance". With this many costs are prevented and sales are not hindered.

The professionalizing of the sector continues with investments in: quality improvement, GPS-systems (for tracking where the crashing takes place), reduction of dust emission, concrete mortar companies and research into dry separation techniques.

2.1 C&D crusher waste

This section is about the total construction and demolition waste offered to crusher companies. These are companies, which process stone like materials to granules. The section follows a chronological structure by subject, firstly the origin of the C&D waste offered to the crushers, secondly the type of materials offered to the crushers, thirdly the products produced from the waste by the crushers and finally the market for those products.

2.1.1 Origin of C&D crusher waste

The origin of construction and demolition waste consists of six specific groups and a rest group. The groups are: firstly, the construction industry, secondly the road construction industry, thirdly, the building material industry, fourthly, municipalities, fifthly, private persons and finally import from foreign countries. The major contributors are the construction industry and the road construction industry. The table gives a clear overview.

[1] Rense R., van Ruiten L., *Monitoringrapportage bouw- en sloopafval - Resultaten 2008-2009*, March 28th 2011

Table 1: Origin Stone like material from debris crushers (Mton)

Origin	2002	2003	2004	2005	2006	2007	2008	2009
Construction Industry (Construction, demolition, renovation)	14,1	12,8	13	14,2	12,7	12,5	12	12,6
Road Construction Industry (reconstructions)	3,1	4,9	3,6	3,9	5,1	5,6	7,6	7,6
Building material industry	0,45	0,45	0,51	0,55	0,7	0,7	0,3	0,2
Municipalities (e.g. Reconstruction waste)	0,45	0,45	0,37	0,42	0,4	0,4	0,7	0,9
Private persons (direct)	0,2	0,2	0,24	0,28	0,1	0,1	0,2	0,2
Import from foreign countries	-	-	-	-	0,0	0,0	0,0	0,0
Other origin	-	-	0,0	0,14	0,1	0,2	0,5	0,6
Total	**18,3**	**18,8**	**17,7**	**19,5**	**19,3**	**19,5**	**21,3**	**22,1**

The graph below shows the development of the total amount of C&D waste (blue) and contribution of the construction industry (pink) and road construction industry (yellow).

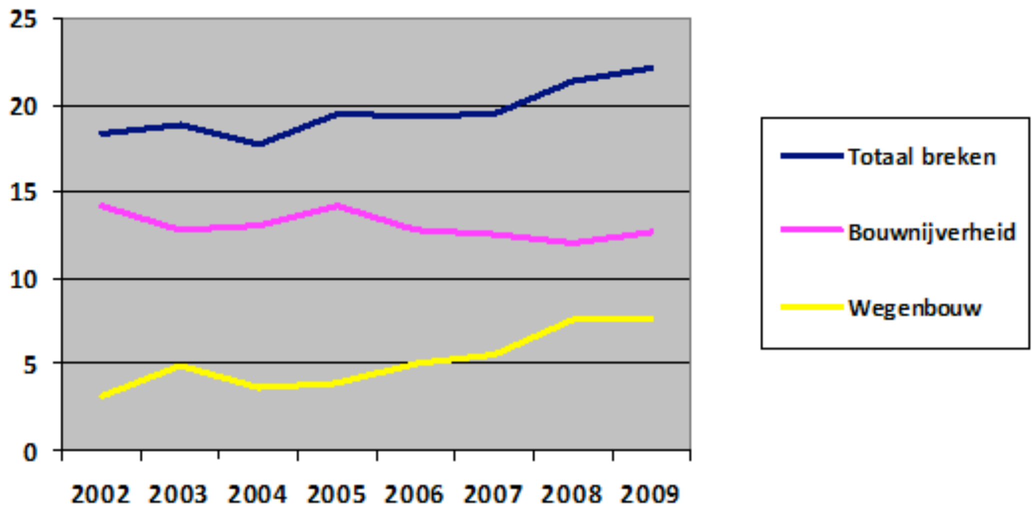


Figure 2: Development and origin from the C&D waste offered to the crushers (in Mton) (Blue - total crushed, pink – construction industry, yellow – road construction)

2.1.2 Types of input materials

Although the C&D crusher waste has several different sources, they are processed from one total material pool. The gathered information by Rense and Ruiten provides a table with ten types of materials. This information is shown in the next table. As can be observed in this table there is one large share for mixed waste. Because the way the C&D waste is collected a lot of waste is received by the crusher companies as mixed waste. Besides this mixed waste the main materials are: Concrete, Tarry Asphalt and Non-tarry Asphalt.

Table 2: Type stone like material offered to be crushed (Mton)

Type of Material	2003	2005	2006	2007	2008	2009
Concrete waste	3,0	3,1	1,7	2,0	3,9	3,7
Masonry waste	1,0	0,8	0,4	0,3	0,3	0,3
Mixed waste	11,6	12,2	15,2	15,5	12,6	12,4
Unsorted waste	0,2	0,4	<0,1	0,0	0,3	0,3
Mixed debris from sorting companies	0,4	0,3	0,2	0,2	0,4	0,4
Non-tarry asphalt	1,0	1,4	0,5	0,4	1,5	1,5
Tarry asphalt	0,9	0,9	1,0	1,0	1,5	2,7
Old foundations of roads	0,3	0,2	<0,1	0,0	0,2	0,4
Debris from (illegal) dumpsites	-	-	<0,1	-	0	0
Rest of stone like materials (slag)	0,4	0,2	0,1	0,1	0,6	0,4
Total	**18,8**	**19,5**	**19,2**	**19,7**	**21,3**	**22,1**

2.1.3 Products produced from C&D crusher waste

The materials described in the previous section are processed by the crusher industry into granulates. The amount of output granulates and other output products is shown in the next table.

Table 3: Final Products (Mton)

Created products	2005	2006	2007	2008	2009
Mixed granulate unwashed	13,8	16,1	16,4	13,6	13
Mixed granulate washed	??	??	??	0,4	0,4
Concrete granulate unwashed	2,1	0,9	0,9	1,4	1,4
Concrete granulate washed	??	??	??	0,3	0,3
Masonry granulate	0,03	0,1	0,0	0	0
Fine granulate / recycling crusher sand	??	0,0	0,0	0	0
Hydraulic mixed granulate	1,3	0,8	0,8	2,6	2,0
Asphalt granulate	1,3	0,7	0,7	2,1	2,1
Agrac	0,2	0,0	0,0	0	0
Crusher sieve sand	0,2	0,0	0,0	0	0
Other products	0,4	0,5	0,7	<1	<3
Non useful applicable materials	0,03	0,1	0,1	0,0	0,1
Total	**19,4**	**19,2**	**19,7**	**21,3**	**22,1**

2.1.4 Product Market for products produced from C&D crusher waste

The products, described in the previous section, which are produced by the crusher industry, are applied into different markets. The next table shows the percentage of products which is applied to which market.

Table 4: Market for crushed stone like material (percentages)

Market	2003	2005	2006	2007	2008	2009
Foundation and heighten market (excl. asphalt/brac/agrac)	85%	89,2%	85,5%	84,6%	91,7%	90,6%
Crush asphalt (cement)/brac/agrac road construction	1,4%	1,4%	0,9%	1,0%	2,8%	2,7%
Asphalt industry (warm application)	4,0%	1,9%	3,1%	2,6%	2,4%	2,8%
Tarry asphalt carries away for (storage) thermal purification	2,4%	2,4%	5,9%	7,5%	0,8%	0,7%
Concrete industry	3%	3,3%	2,1%	1,8%	1,7%	1,9%
Crusher sieve sand for applications	0,8%	0,6%	0,9%	0,6%	0,1%	0,15%
Sorting company	0,7%	0,4%	0,2%	0,2%	0,2%	0,2%
Dump	1,0%	0,1%	0,0%	0,0%	0,05%	0,05%
Special dump (asbestos containing)	0,2%	0,0%	0,7%	0,0%	0,0%	0,0%
Export	-	0,4%	1,0%	1,2%	0,1%	0,9%
Sales metals (from reinforced concrete)	1,5%	0,3%	0,3%	0,2%	0,1%	0,1%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

2.2 Sorted C&D waste

This section is about sorted C&D waste. The sorting process itself is not reprocessing materials for reuse or recycling, in the end of this section however several remarks are made by an C&D expert.

2.2.1 Origin of sorted C&D waste

The next table shows the origin of construction and demolition waste in the Netherlands. The major contributor is the Construction industry followed by Municipalities and Private persons.

Table 5. Origin of the sorted material 2002-2009 (in Mton)

Origin	2002	2003	2004	2005	2006	2007	2008	2009
Construction Industry (Construction, demolition, rennovation)	2,14	2,36	1,88	2,02	1,68	2,10	1,53	1,61
Road construction (reconstruction)	0,03	0,02	0,07	0,08	0,02	0,03	0,14	0,10
Building material industry	0,04	0,04	0,03	0,04	0,03	0,04	0,00	0,00
Other sorting organistion	-	-	-	-	0,09	0,10	0,10	0,07
Municipalities (eg. Reconstruction waste)	0,13	0,11	0,11	0,11	0,09	0,10	0,21	0,22
Private persons (direct)	0,05	0,06	0,10	0,13	0,06	0,08	0,25	0,21
Import from foreign countries	-	-	-	-	0,12	0,11	0,00	0,00
Other Origin	0,00	0,00	0,02	0,02	0,00	0,00	0,08	0,06
Total	**2,4**	**2,6**	**2,2**	**2,4**	**2,1**	**2,7**	**2,3**	**2,2**

2.2.2 Amount of Sorted C&D waste

The sort and amount of materials is shown in the next table. The major share will go to energy recovery installations or to the crusher industry. Besides those there is a significant share for unwashed sorting sieve sand and wood. The next table shows a more detailed overview of the amount of sorted C&D waste.

Table 6. Amount final products from sorting process 2002 – 2009 in Mton

End product	2002	2003	2004	2005	2006	2007	2008	2009
Wood (A+B quality)	0,37	0,42	0,42	0,52	0,35	0,39	0,31	0,29
Wood (C quality)	0,02	0,03	0,01	0,02	0,02	0,02	0,01	0,01
Metals	0,13	0,12	0,07	0,09	0,06	0,07	0,09	0,08
Paper en Cardboard	0,02	0,02	0,00	0,00	0,01	0,02	0,01	0,01
Plastics	0,01	0,00	0,00	0,00	0,01	0,01	0,01	0,01
Secondary fuels	0,03	0,04	0,11	0,08	0,03	0,03	0,05	0,07
Debris (to crushers)	0,46	0,48	0,42	0,47	0,67	0,95	0,51	0,49
Unwashed sorting sieve sand	0,34	0,40	0,34	0,42	0,31	0,32	0,45	0,42
Washed sorting sieve sand	0,18	0,20	0,00	0,00	0,00	0,00	0,00	0,00
Plaster, gas-/cell concrete	-	-	-	-	0,02	0,02	0,03	0,03
Plaster, gas-/cell concrete (export)	-	-	-	-	0,01	0,01	0,02	0,02
Monoflows	0,00	0,01	0,02	0,02	0,01	0,02	0,00	0,00
Roof covering material	0,01	0,01	0,00	0,00	0,01	0,02	0,01	0,01
Sorting NL	0,04	0,03	0,05	0,06	0,12	0,09	0,00	0,01
Export for removal	0,02	0,02	0,13	0,07	0,00	0,00	0,00	0,00
Export for sorting	0,61	0,70	0,47	0,32	0,08	0,23	0,00	0,00
Residue to dump	0,10	0,06	0,10	0,25	0,24	0,23	0,11	0,08
Residue to energy recovery	0,06	0,05	0,05	0,06	0,14	0,23	0,71	0,65
Total	**2,4**	**2,6**	**2,2**	**2,4**	**2,1**	**2,7**	**2,3**	**2,2**

As for the table above, there is some additional information about Metals, Plastics and Roof coffering. The distribution of those materials for 2008-2009 is further specified in the next table.

Table 7: Shares of subgroups of metals, plastics and roof coffering for 2008-2009

Metals	Ferro	82%
	non ferro	18%
Plastics	PVC	14%
	hard (others)	48%
	Soft	39%
Roof coffering	Tarry	97%
	non tarry	3%

2.2.3 Products produced from sorted C&D waste

There is no explicit data about the products which are produced from sorted C&D waste, an expert on C&D waste however made some remarks about the general practice. This is summarized below.

Wood is sorted according to quality, shreddered and used in the particle board industry.

The complete group of plastics is transferred to specialized companies which sorts the plastics further on kind and type of plastic. Several plastic industries use those plastics for new products.

Metals are sorted in two groups: ferro and non-ferro. Then they are transferred to more specialized companies to further sort and process them before they are used in new products.

The rest fraction is processed in several ways to create high end fuels for energy recovery.

For bitumen, textiles, artificial turf, gypsum, mineral wool, etc there are specialized processes for recovery, reprocessing and reuse.

2.2 Total C&D waste

An overview of the total of C&D waste (including crushed waste, stock mutations, direct applied material and sorted waste) and its origin is shown in the next table.

Table 8: Origin Construction and Demolition Waste and comparable materials (in Mton)

	2008				2009			
	Crushing	Direct applied stone like materials	Sorting	**Total**	Crushing	Direct applied stone like materials	Sorting	**Total**
Construction Industry	12		1,53	**13,5**	12,6		1,61	**14,2**
Road Construction	7,6	4	0,14	**11,8**	7,6	4	0,1	**11,7**
Building materials incl.	0,3		0,0	**0,3**	0,2		0,0	**0,2**
Other sorting organisation	-		0,10	**0,1**	-		0,07	**0,07**
Municipalities	0,7		0,21	**0,91**	0,9		0,22	**1,12**
Private persons	0,2		0,25	**0,45**	0,2		0,21	**0,41**
Import from foreign countries	0,0		0,0	**0,0**	0,0		0,0	**0,0**
Other	0,5		0,18	**0,68**	0,6		0,6	**1,2**
Total	**21,3**	**4**	**2,41**	**27,7**	**22,1**	**4**	**2,81**	**28,9**

* including stock mutations

The totals for each year from 2002 to 2009 are summarized in the next table. A slow growth in the total amount of waste can be seen.

Table 9: Total waste (in Mton)

Kind of Waste	2002	2003	2004	2005	2006	2007	2008	2009
Crushed waste	17,0	16,7	18,3	19,4	19,2	19,7	21,3	22,1
Stock mutations of waste which still needs to be crushed	+1,3	+2,1	-0,6	+0,1	-0,2	-0,3	-1,4	-2,3
Direct applied stone like material	3,5	3,5	3,5	3,5	3,8	4,0	>4	>4
Amount of sorted waste (netto)*	3,04	3,2	3,2	2,8	2,4	2,6	2,6	2,6
Total	**24,8**	**25,5**	**24,4**	**25,8**	**25,2**	**26**	**26,5**	**26,4**

*Taken into account the mutations between the sorting and crushing companies to prevent double counting

The next graph shows an overview of the total amount of C&D waste over the period 2002-2009. As can be observed the relative proportions roughly stay the same.

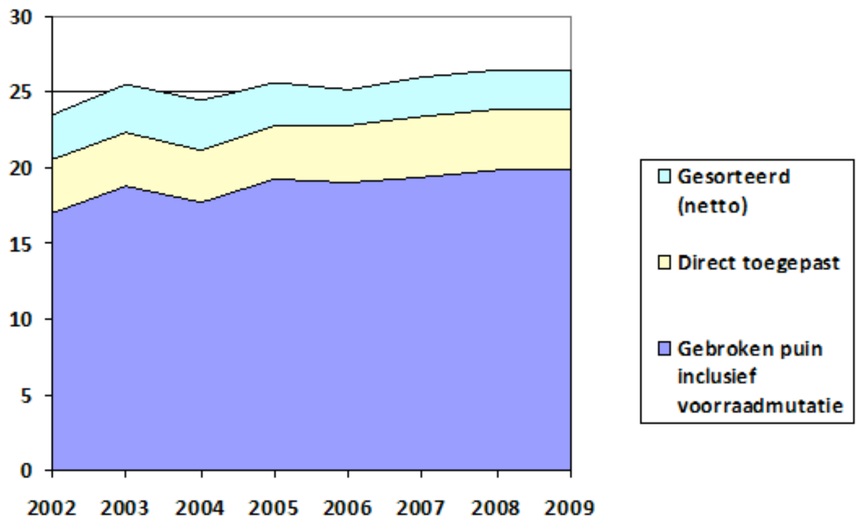
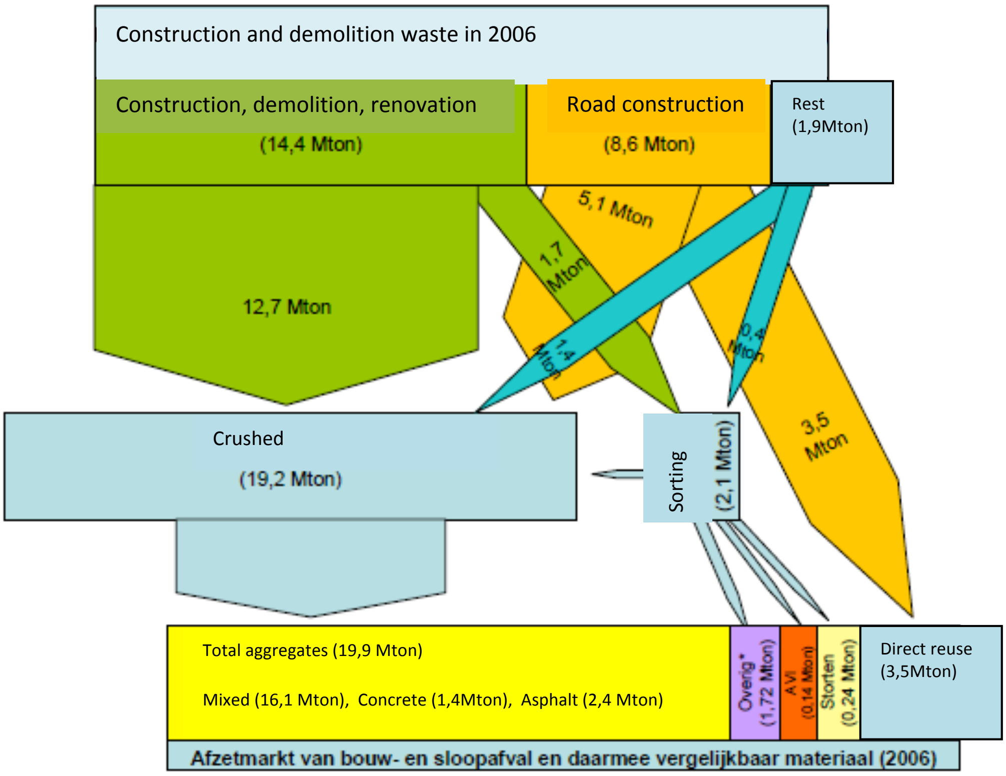


Figure 3: Total offered Construction and Demolition waste in Mton (Green – Sorted, Yellow – Direct applied, Blue – Crushed)

The next Figure represents the waste flows for 2006.This picture shows first the origin of the materials, then the processing step and finally the reuse market.



The category "Rest" consist of wood, metal, composites

Figure 4: Majority of the building waste in the Netherlands, 93% is down cycled to the aggregate.

SUMMERY

Nowadays economic crises in the Netherlands which have stopped mayor building activities, combined with millions of m2 of unused office spaces and housing that is not up to the standard, brought in lot of uncertainty into a construction world. Existing construction and demolition methodology cannot give an answer to this uncertainty of investors who are questioning the future value of a building that is built for one prepuce knowing that the use requirements and standards will change. Investors witness in the Netherlands that if change cannot be accommodated building will loos its market value and stay empty as the case with 9milion m2 of office space in the Netherlands today. Under these circumstances a value of materials is getting greater attention since the only certainty in a building with uncertain use scenarios is material. Thus future value of a building can be defined through a material value, which tends to grow. This brings attention to a method of construction that will consider disassembly and material recovery of all materials in the building so that the existing building can be seen as a recourse pool for a new building.

In order to bring the implementation of such approach closer to realisation, the University of Twente under leadership of Elma Durmisevic has initiated a construction of Green Transformable Building Laboratory. Lab is a dynamic structure that can accommodate different functions and the transformations from one function to another will be simulated in real-time with real systems, once a year. The key challenge of the initiative is to developed a construction methodology together with construction industry that will eliminate concept of waste in construction. A method that will take into account that also building installations and climate and energy concepts need to be adaptable, upgradeable and replaceable without creating waste. The first factory production of components of the Building Lab will start in March 2013. Transformations, monitoring and upgrading of methodology will take place once a year during four years. This being set up as a time limit to define a solid framework for sustainable way of design and construction in 21^{st} century. [2]

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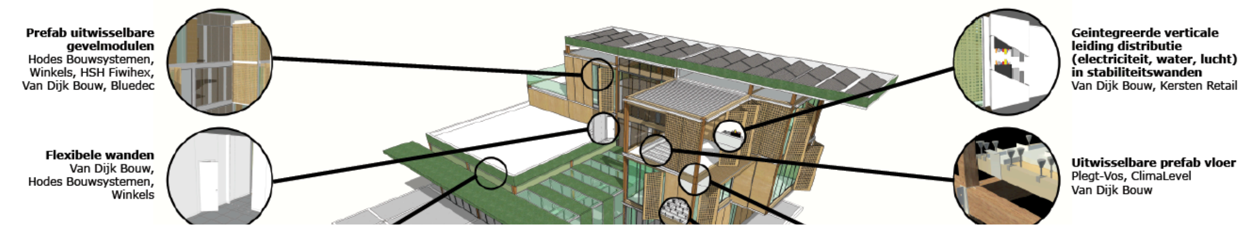

Figure": Green Transformable Building Lab at the University of Twente[3]

[2] E.Durmisevic, Green Transformable Building Centre 2010, International Design Studio, University of Twente, ISBN: 978-90-365-3060-6, 2010

[3] E.Durmisevic, International Design Studio, Green Transformable Building Centre 2011, University of Twente, ISBN 978-90-365-3231-0, 2011

Barriers for Deconstruction and Reuse/Recycling of Construction Materials in Norway

Rolf André Bohne

Norwegian University of Science and Technology, NTNU
NORWAY

and

Eirik Rudi Wærner

Hjellnes Consult AS
NORWAY

ABSTRACT

The authorities in cooperation with the AEC-industry in Norway has had a strong focus on collection and treatment of construction and demolition waste over the last two decades. During this period different policies and national action plans has been implemented, in order to increase the sorting, collection, recycling and final treatment of construction and demolition waste from near zero in the early 90's to 75% today. This paper describes the current situation of construction and demolition waste in Norway, and the barriers for further increase of deconstruction and recycling of construction and demolition waste.

Keywords: Deconstruction, Barriers, Solutions, Norway

1. INTRODUCTION

Norway comprises the western part of Scandinavia in Northern Europe. A rugged coastline, broken by fjords and islands, stretches 25,000 kilometers and 83,000 including fjords and islands. Norway has a total area of 385,252 square kilometers, and a population of about 5 million. Norway is the second least densely populated country in Europe, with a population density of 15.5/km^2. The low population density, the narrow shape and long coastline, makes for long transport distances of goods (waste) and people outside and between the cities, which influences the choices of waste handling - both economically and with respect to the environmental impact of the different waste handling alternatives. Most people live in centers in the near coastal areas in southern Norway.

2. BARRIERS FOR DECONSTRUCTION

2.1 Characteristics of the Norwegian building stock

Buildings in Norway are categorized into five major categories, built with three major construction techniques, depending of their age and size. In general, small buildings are made of wood and larger buildings from concrete and brick (a few with steel), but there is a trend towards larger wooden buildings also for commercial buildings.

Table 1: Building type and main construction material

Building type	Wood	Brick/Concrete	Steel
Single houses	X*	x#	
Chained houses	X	x	
Semi-detached house	X	x	
High houses		X	x
Commercial buildings	X	X	x

* Big "X" denotes the most common structural material for that type of building
\# Small "x" denotes the lesser common structural material for that type of building

Another characteristic of the Norwegian building stock is the ownership structure of residential buildings. 80% of residential dwellings are owned by the residents, which makes for a more differentiated structure with respect to decision-making and economic incentives towards renovation and demolition of buildings. Especially with respect to waste handling and recycling of 'construction and demolition'[4] waste the structure of ownership is a challenge.

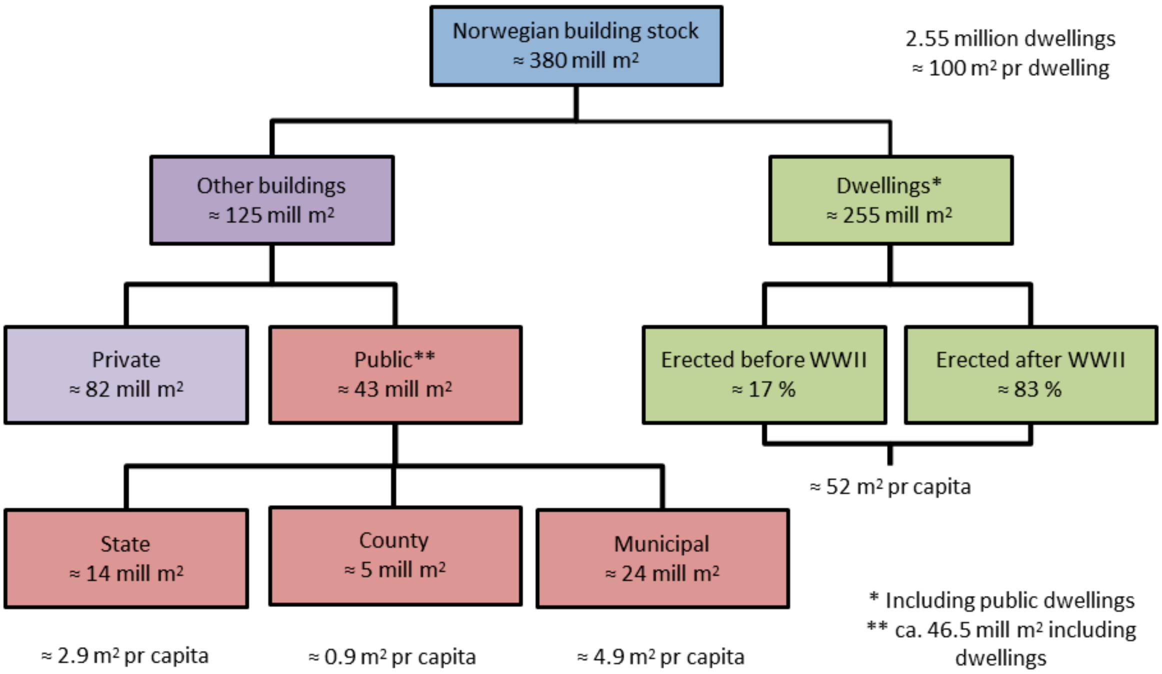

Figure 1: Norwegian building stock 2010 (Bjørberg, Multiconsult 2011)

The ownership structure of the residential buildings, leads to two interesting trends in the Norwegian residential building stock, which both influences the production and handling of construction and demolition waste. Because of tax incentives, it is economic favorable for Norwegians to invest in real-estate. The return of investment is also favorable for renovation. This leads to a high activity in the Norwegian real estate marked, also fueled by a steady population growth. This in turn is followed by a high production of construction- and demolition waste from residential buildings. However, many of these projects are small and often performed by the house owners themselves, and thus are unregulated activities with respect to waste handling. But most of this waste is delivered to public recycling stations, due to their availability and low cost. There is however some differences between urban and rural areas in this respect.

The Norwegian building stock is also relatively new, with 2/3s of the buildings erected after 1960. This is reflected in available data on service life of buildings. A rule of thumb, is that residential houses is not demolished (unless they are hindering development), but renovated, and commercial buildings (including agricultural buildings), are demolished after about 60 years. With most buildings still not old enough to reach these ages, we have limited experience of demolition in Norway. However, the renovation activity is very high and the demolition activity increasing.

Legally, all waste should be delivered to waste handling stations, but there are some extra requirements to be fulfilled if the projects meet the following criteria (KRD, 2010)

[4] In Norway we separate between waste originating from the construction (erection), renovation and demolition of buildings (building materials), and construction waste from ground and road works (soil, gravel, asphalt, rocks etc.). Thus in this report we mean waste origin from the construction (erection), renovation and demolition of buildings when referring to construction and demolition waste.

- All new building projects larger than 300m^2, renovation or demolition projects larger than 100m^2, or construction projects that produces more than 10 tons of waste, has to (compulsory) make a waste handling plan.
- All projects that involves change of buildings, renovation or demolition of buildings larger than 100m^2, or construction projects that produces more than 10 tons of waste, has to make a descriptive study of where harmful substances are mapped (located), and how to safely remove them. There is a general demand that all harmful and toxic wastes to be mapped and treated in accordance with regulations, but there is no responsibility for reporting from projects smaller than 100 m^2 construction projects less than 10 tons.
- There is a general demand for 60% source separation and recycling of construction and demolition waste at site.

2.2 Methods commonly used to remove buildings in Norway for each construction type

Removal of buildings is most common in high density urban areas due to urban development. These projects are normally the start of larger developments, and thus most often executed by large professional projects organizations. The municipalities in the cities are also better organized with respect to planning and waste handling. Most of these projects follow the laws and regulation described above:

- Project initiation
- Mapping and description of harmful substances
- Waste handling plan
- Sanitation of harmful substances
- Selective demolition with source separation (>60%)
- Delivery to approved waste handling facilities

The difference between the majorities of the projects is a direct consequence of the size of the building being demolished. Small wooden buildings are often demolished by hand, with the use of light tools after the selective removal of the windows, doors, fixed furniture and technical installations. Larger buildings are most often demolished from the top down, by use of heavier machines after the selective removal.

Especially the rules and regulations on the identification and removal of harmful substances are world leading, and prohibits the dispersion of these substances into the environment through recycling and destruction.

In more rural areas, demolition most often follows the same patterns, but there are still some examples of buildings being knocked down and the debris delivered unsorted to waste handling

2.3 Barriers for deconstruction to make better use of the C&D waste in Norway

There are few technical barriers to the actual deconstruction process in Norway. Where barriers exist, these are found in the on-site and off-site waste handling.

For small projects, the barriers are mostly related to scale, economy and knowledge. Many of these projects are driven by the (non-professional) house owners themselves on their own dwellings. The C&D waste from these projects follows one of two paths to the waste handling facility. Most often they are delivered to the recycling stations directly in separate fractions (free of charge), or they are collected unsorted in waste container, and then delivered to the recycling stations for sorting (at a substantial gate fee).

For large projects, the most common barriers is knowledge and limited space for source separation at the demolition site, and off-site separation is less effective than on-site sorting.

2.4 Strategies to overcome these barriers in Norway - technical, political and other

75% of the Construction & Demolition waste is delivered to directly to reuse, recycling or energy recovery in 2011. This is improvement from 2004, where only 40% was delivered to reuse, recycling or energy recovery. The target set by the authorities and industry was 80% before 01.01.2012. The target was set in balance of technical possibilities, economy and environmental impact from the waste handling. In some cases landfill was preferable over recycling due to long transport distances.

The increase of delivery to reuse, recycling or energy recovery, is mainly due to four actions:

- A general ban on landfilling organic materials (here: wood)
- Command and control; the compulsory waste handling plan, together with inspections and sanctions (economic). Especially the inspections and sanctions proved powerful tools in increasing delivery to reuse, recycling or energy recovery.
- Knowledge transfer and the voluntary involvement of the industry.
- The establishment of recycling stations, where sorted materials can be delivered for free.

The shortcoming of meeting the target is directly linked to the introduction of the new rules and regulations across the nation. Norway started by introducing regulations on construction and demolition waste around the densely populated Oslo area (the capital and surroundings) in the 1990s. Then, there was as a voluntary arrangement for municipalities to apply the rules and regulations at their own choosing, before it finally was made compulsory for all municipalities. When the knowledge and facilities for construction and demolition waste are established across Norway in the near future, we believe that the target of 80% delivery to reuse, recycling or energy recovery will be met before 2015 (BNL, 2007).

Besides the efforts in sorting and collecting construction waste, there are also considerably efforts in reducing waste production. This is mainly through element builds, prefab and pre-cut, but also by designing new buildings for flexibility during use phase.

3. BARRIERS FOR REUSE AND RECYCLE

In the design of the Norwegian recycling scheme for construction waste, we learned a lot from Denmark, and their experiences from their recycling scheme for construction and demolition waste. In short, the four most important success criteria's was: control of harmful and toxic substances, source separation (clean fractions), knowledge transfer and command and control (economic sanctions) (Bohne, 2005).

75% of the construction and demolition waste is delivered directly to reuse, recycling or energy recovery in 2010 (SSB, 2011). Since the construction and demolition waste delivered to the recycling facilities are without harmful substances, and mostly delivered in clean fractions, the two biggest barriers for reuse and recycling is taken away.

There are other barriers, specific for each waste fraction, which will be described below. The generated waste amounts from construction, rehabilitation and demolition of buildings is shown in Table 2.

Table 2: Generated waste amounts from construction, rehabilitation and demolition of buildings. Tonnes. 2009 and 2010 (SSB, 2011)

	Total	**Construction**	**Renovation**	**Demolition**
Total. 2009	1 701 652	567 338	595 621	538 692
Total. 2010	1 539 420	516 473	540 288	482 658
Waste types				
Wood	220 876	90 817	80 527	49 532
Paper and cardboard	21 557	11 368	8 567	1 622
Plastic	4 178	2 497	1 635	46
Glass	7 818	2 236	4 571	1 011
Metals	70 993	18 260	34 059	18 674
Gypsym	55 326	28 816	24 504	2 006
EEE waste	8 550	1 865	5 197	1 488
Hazardous waste	14 316	1 978	6 487	5 851
Asbestos	*3 698*	*91*	*2 230*	*1 377*
Impregnated wood	*2 566*	*884*	*1 139*	*543*
Other hazardous waste	*8 052*	*1 003*	*3 117*	*3 932*
Bricks and concrete and other heavy building materials	609 528	84 729	192 622	332 176
Polluted bricks and concrete	18 771	-	5 739	13 032
Other waste	21 014	4 462	13 771	2 781
Mixed waste	275 604	107 441	130 106	38 057
Asphalt	210 890	162 004	32 503	16 384

3.1 The top five C&D wastes in Norway

The top five C&D wastes in Norway are: Brick and Concrete>Wood>Asphalt> Metals>Gypsum, each with different technical and environmental barriers for recycling.

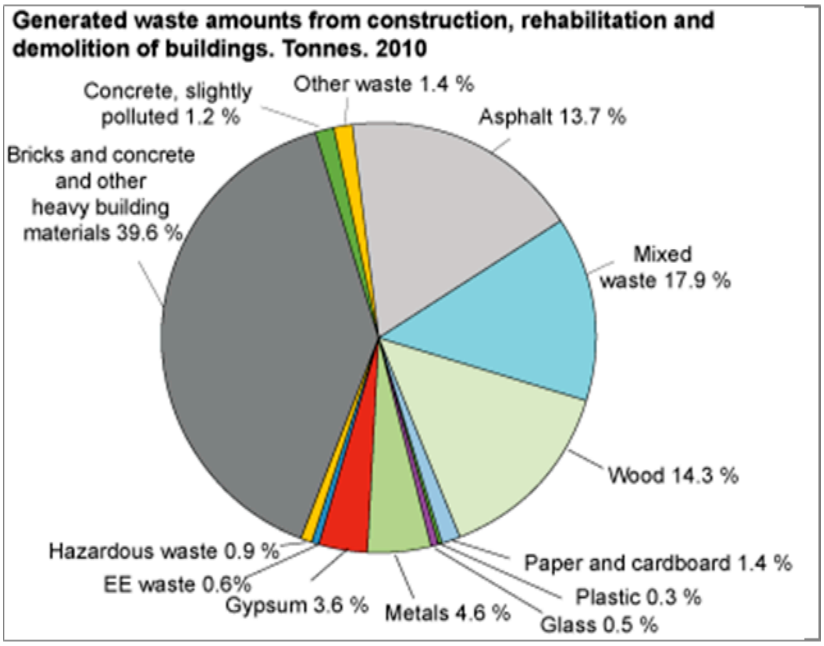

Figure2: Waste fractions from construction and demolition waste in Norway 2010 (SSB, 2011)

3.2 Brick and Concrete

The Brick and Concrete fraction in Norway is defined as waste from construction, renovation and demolition, and thus excludes waste production of building materials. We normally split the Brick and Concrete fraction into:

- Sorted Brick from construction, renovation and demolition,
- Sorted Concrete from construction, renovation and demolition,
- Mixed Brick and Concrete,
- Other mineral based products

Since the fraction is totally dominated by concrete, we will use concrete for concrete and brick hereafter.

There is normally little concrete waste from construction. Only a little leftover from the concrete truck, which most often are dumped in the construction pit.

Depending on the purity (from pollutants), we separate/divide between three categories of concrete (Table 3). Concrete is mainly polluted from PCB in plaster and rendering layers, or from paints.

Table 3: Categories of concrete according to purity from pollutants

Pure concrete	Most concrete is clean. There is no reason for adding pollutants to concrete used in structural components, but there are examples of PCB found also here. There is however, little knowledge of "new" additives and their potential problems.
Low polluted concrete	Pure concrete may be polluted from paint and plaster containing heavy metals or PCB, which raises the levels of these substances above the allowed limits.
Toxic waste	Paint containing heave metals or PCB can contaminate concrete to a level of toxic waste. Rendering layers and painted facades are often found to exceed these levels. NGU reckons that 5% of the concrete waste from demolition falls into this category.

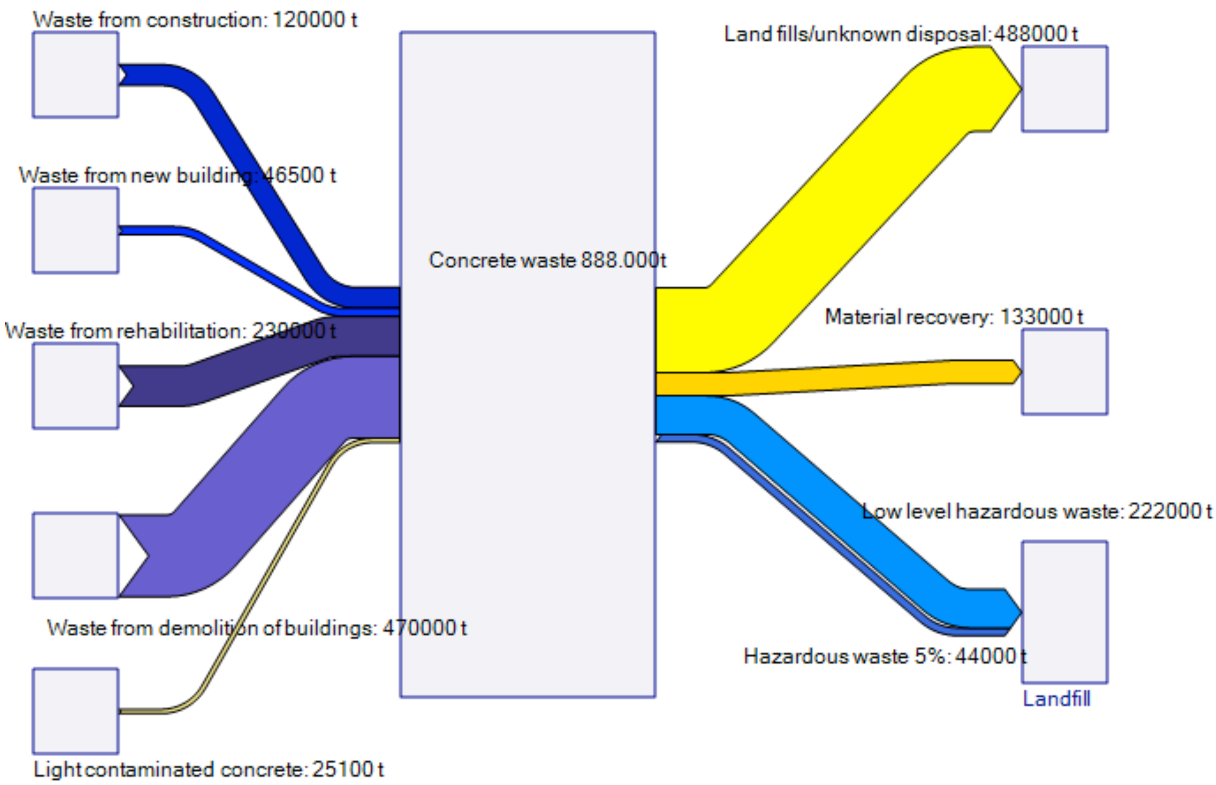

Figure 3: Material flow of brick and concrete waste in Norway (Hjellnes Consult AS, 2012)

3.2.1 Barriers for recycling of concrete

There are several barriers for recycling of concrete, the most important are:

- Painted concrete are most often defined as polluted. There are equipment available for removing the painted layer only, but this option is only economically when the paint is defined as toxic waste, otherwise is less expensive to deliver the low polluted concrete to special landfills.
- Sometimes the entrepreneur dos not have equipment for cutting down the concrete in a way that reinforcement bars can be separated. This reinforced concrete is delivered to landfill. In

some cases the reinforcement bars is separated from the concrete at the waste treatment facility.

- It is often difficult to sell the recycled aggregate. In order to get recycled aggregate in economical viable, it is necessary with on-site processing and direct transport to recipient. If the recycled aggregate has to be stored and forwarded, with increased transport costs, it is often less expensive to use virgin gravel.
- Knowledge of product quality. New road projects often do not consider recycled aggregate as good enough compared with virgin materials, although experiments prove the opposite.

3.2.2 Technical potential for recycling of brick and concrete

There is a technical potential for reuse of 70-90 % of brick and concrete waste.

Most common is to crush the concrete to a specific grain size, and use it in replacement of virgin gravel. The crushed concrete is called 'recycled aggregate'. The Norwegian Road Authority (Statens Vegvesen) has approved the use of recycled aggregate their revised "construction handbook" (Håndbok 018) in 2005. If all recycled concrete was to be used in road construction, it would substitute about 0.5 % of the virgin aggregate used in road constructions.

Brick has often less areas of application that concrete. Many bricks are not burned long enough to be 'frost safe', which makes them less useable in Norway. The heavily burned brick is strong enough frost, and can be used in facades uncovered. Most brick walls are therefore constructed with an outer layer of frost safe bricks, and an inner layer of lesser burned ordinary bricks. A skilled machine operator is capable of separating these fractions during demolition, which makes recycling more profitable. If not, they have to be sorted by hand, or treated as ordinary bricks. Crushed bricks are suitable for filling compound, and are often used as a signal layer due to its color.

3.2.3 Political and other strategies to overcome these barriers

There is ongoing work to overcome the barriers of recycling concrete, especially with regard to low polluted concrete.

There is a strong focus on how and where to use low polluted concrete in a safe way. This will be both more environmental friendly than landfilling and more economical for all stakeholders.

Second, there is ongoing work on the limits with regard to what to be classified as low polluted concrete. These investigations are looking into adjusting the limits with respect when concretes become low polluted. Initial studies suggest that a small change in these limits, allows 25 % more of the concrete to be recycled, without compromising environmental quality. But these studies have yet to be verified.

3.3 Wood

Wood is divided into three fractions:

- Clean stubs from construction, and structural components from renovation and demolition.
- Treated wood (painted, varnished or stained wood, glued wood (chipboards, plywood, glued beams etc.)
- Impregnated wood

Composite materials (laminates, wet room panels, floorings i.e.) composed of wood glued or attached to as paper/cardboard, plastics or other materials are not included in the wood fraction.

Wood waste arises from ground, construction and finishing of buildings. In addition there is wood waste from boxes and pallets. There is also some wooden waste from construction work such as formworks, guide posts, noise deflection walls and fence pales.

As wood is a large waste fraction in Norway, the numbers suggest that not all is collected and sorted as it should, and therefore enters the waste stream via the 'mixed waste' or other routes.

Wood, both clean stubs and treated wood, can be utilized as a material or energy source. Impregnated wood from before 2003 is classified as toxic waste. Most of the collected wood in Norway is today used as biofuel.

3.3.1 Barriers for reuse and recycling of wood

There are several barriers for reuse of wood related to form, strength and contaminations (glue, paint, varnish, impregnation and metals).

Direct reuse of doors, windows and construction elements is possible, but little wood is entering this route. There are several reasons for this, but high costs in deconstruction, altered dimensions (longer spans) in modern construction and higher demands for thermal properties for doors and windows; makes reuse a less viable alternative.

Barriers for recycling of wood waste starts in the process of sorting the waste. In construction this is relatively easy to get a clean fraction, free of contamination. But this is more challenging in renovation and demolition projects. There are also challenges in maintaining the mechanical strength of construction wood.

Chipboard producers are possible sinks for wood waste, but there are several challenges:

- Screws, nails and other contamination can cause problems.
- Impregnated wood can contaminate products, so they cannot be used.
- Wood for recycling may have unequal moisture content, which can cause problems in chipboard production.

3.3.2 Technical potential for recycling of wood

There is little technical potential for an increase in reuse and recycling of wood. With the given recycling volume of wood in Norway, the potential is assumed to be non-existing. From a pure technical point of view, limited amounts of wood can be recycled, depending on the purity of the fraction:

- Stubs from new constructions
    - Paper production and chipboard production

- Wood from buildings that are renovated or demolished (treated wood)
    - Careful selective demolition, removal of coatings if possible.
    - Direct reuse or as material to selected purposes
    - Direct reuse of stubs in renovation
    - Reuse of wooden boxes, windows, doors, floor beams and floorboards.
    - Feed into chipboards production or production of other construction elements.

Impregnated wood, is defined as toxic, and thus cannot be reused or recycled.

3.3.3 Political and other strategies to overcome these barriers

In Norway, where we have a long tradition of using wood for heating, there is little meaning of increasing the reuse or recycling of wood, with the increased cost and quality problems of the final products as a result, when this means an increase of virgin wood for heat purposed. Focus is therefore on safe incineration, with filtering of exhaust gasses.

The focus is therefore on research of how we reduce waste production, especially by precut and module based construction.

3.4 Metals

Metal is defined as waste of all types of iron and other metals produced construction, renovation or demolition. The recycling industry distinguish between iron and steel and 'metals', which is all the 'non-ferrous-metals'.

Table 4: Traditional definition of groups of metals

Group	Examples
Complex materials	Complex constructions composed of different metals, wood, plastic, rubber etc.
	Constructions composed of many different compounds, that they must be shredded.
Pure metals	Composed of one type of iron or metal
	• Structural components of steel • Sheets of steel or aluminum • Ventilation shafts • Tubes- and gutter systems of copper, cast iron, steel, aluminum, zinc • armatures, mountings, fittings, fixtures and production equipment of copper, aluminum, steel, nickel etc.
Impure metals	Composed of one type of iron or metal with contamination
	• Reinforcement bars with residues of concrete • Cast iron with residues of led or aluminum oxides • Sheets of metals with different depositions.

Most of the metals have some form of surface protection, which often contains heavy metals. There are no specific rules or regulations in this regard as of today.

Metal recycling is a long established and profitable marked, and 90% of the metals are entering recycling today. This about the technical limit of what can be achieved; there is therefore no work in progress to increase the recycling of metals in Norway.

3.5 Asphalt

Although asphalt a considerable waste fractions from renovation and demolition projects, it is only a fraction of the total production of asphalt waste, and thus it enters the asphalt waste stream road projects. Asphalt waste is regarded as a valuable material and 90% of the asphalt is recycled.

3.6 Gypsum

'Gypsum waste' here means stubs, spill and other gypsum board waste from the AEC-industry. Recycling of gypsum is the crushing, sieving and other treatment of stubs and other gypsum waste from construction, renovation and demolition, which makes the waste suitable as material base for new gypsum based products.

A gypsum board is a composite of gypsum, sandwiched between two layers of cardboard. Some gypsum boards are coated with glass fiber, and some contains additives in order to make them water repellent. A new standard gypsum board is composed of 95% gypsum and 5% cardboard. Some does contain silicon or wax.

The gypsum could be a mixture of natural- and industry gypsum. The cardboard is usually made from recycled fibers.

Gypsum waste from renovation and demolition projects is most often contaminated with residues of wallpapers, glue, paint, screws and nails. The company *Gips Recycling* reports that they sort out ca. 10% from their recycling process, which is composed of cardboard, wallpapers, glue, paint, screws and nails.

There are huge uncertainties in the available data for gypsum waste. Statistics Norway (SSB), report about 55 000 tons, while an expert group estimates 150 000 tons. There are several reasons for this huge variation, but gypsum is currently not accounted for in the national waste statistics, so all numbers are based on calculations. While SSB estimates 4% that of the construction and demolition waste is gypsum, an expert group estimates 16% (Hjellnes Consult, 2012).

Gips Recyling is the only gypsum recycling facility in Norway. They treat 25 000 – 30 000 tons annually. They deliver all their recycling gypsum to Norgips, a producer of gypsum boards located near Gips Recyling.

Norcem (Heidelberg) does also accept gypsum. They have a capacity of 50 000 tons, but they are currently not using the full capacity due to quality problems with the cement produced with recycled gypsum at full capacity, due to contaminations from the waste gypsum.

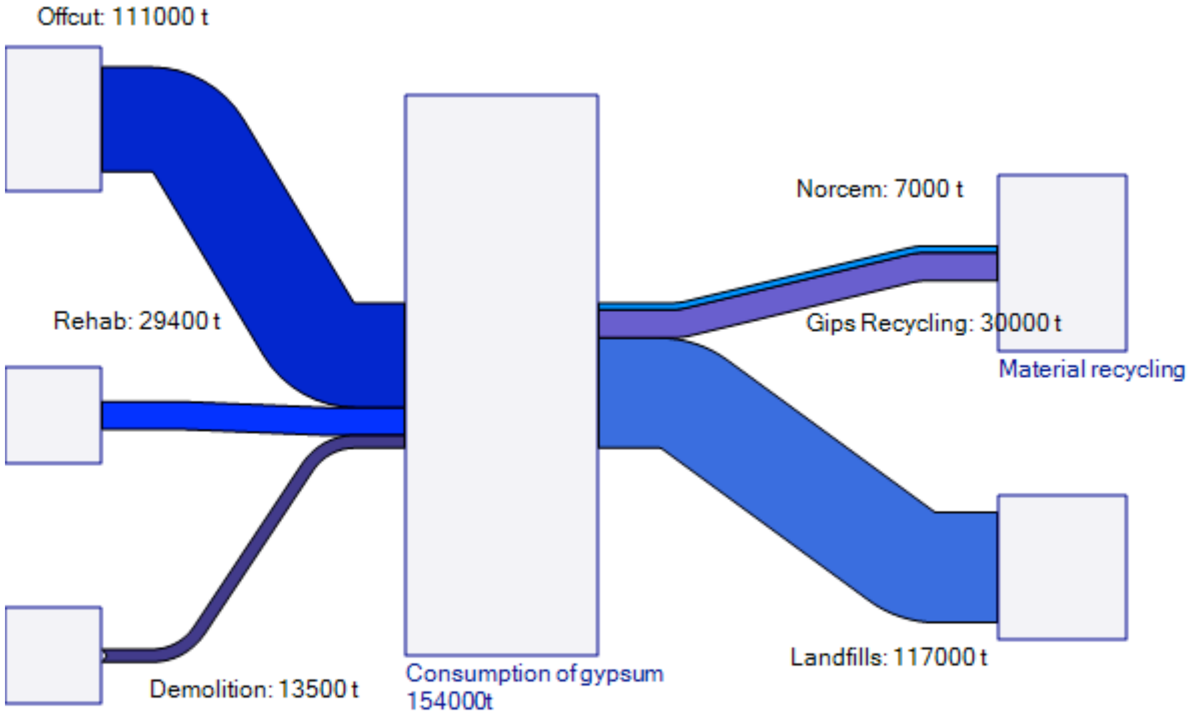

Figure 4: Material flow for gypsum waste in Norway 2010 (Hjellnes Consult, 2012)

3.6.1 Barriers for reuse and recycling of gypsum

The barriers for recycling of gypsum in Norway are due to transport. It is not always environmental or economic viable to transport the gypsum to the recycling facility. There is work in progress to sort out these limitations. Better compression and green return trips is believed to be key issues in order to increase recycling of gypsum.

3.6.2 Technical potential for recycling of gypsum

Technically all gypsum can be recycled, with the exception of gypsum contaminated with oil or other pollutants. The capacity for receiving waste gypsum in the Norwegian marked is about 120 000 tons.

The net benefit of recycling gypsum is offset by transport emissions. Calculations have estimated a maximum transport distance by direct transport by truck to 211 km, and via collection point 158 km. If train is used for transport, unlimited distances are viable. However, the calculations did not take green return trips into their calculations.

3.6.3 Political and other strategies to overcome these barriers

There is work in progress to investigate policies to increase gypsum recycling in Norway. Actions from waste minimization, increased gate fees for gypsum waste, a waste compensation fee on new gypsum boards etc. are being considered. These works have not yet concluded.

3.7 Other C&D wastes in Norway for universal concern

Besides the waste fraction described above, there are some other waste fractions that are of universal concern, especially the mixed waste fraction.

3.8 Mixes waste

The mixed waste fraction is all the waste that is not source separated at the construction, renovation or demolition site, and it contributes 18% of the total waste production.

3.8.1 The composition of mixed waste

There is little knowledge of the composition of mixed waste from construction, renovation and demolition projects. *Norsk Gjenvinning* has some empirical data from what they receive in their mixed waste containers;

- 11% rock and concrete,
- 8-9% gypsum,
- 5% metals,
- the rest is a mix of wood, paper/cardboard, insulation etc.

3.8.2 Strategies to lower the mixed waste production

The overall strategy concerning the mixed waste fraction, is to move most the waste over to source separation, and thus into other waste fraction.

Secondary is to split the mixed waste fraction in two, combustible and non-combustible. Already in many projects, the mixed waste container is replaced with a 'sorted, combustible' container.

3.9 Glass

By glass from construction, renovation and demolishing, we mean 'float glass'. Discarded windows can be found with single glass in wooden frame, double- or triple- glazed window with wooden frame, metal frame or PVC frame.

Laminated glass is made of two or more layers of glass, with foils of polyvinylbutyral between the glasses. The building code requires laminated glass to be used in doors, side fields, and guard rails on balconies, stairs and corridors. Thus laminated glass is believed to increase in use, and then as waste, but it is not believed to occur in significant amount in some years yet.

The regulations specify producer responsibility for double glazed windows produced before 1980, which can contain PCB. The producers and importers have to be members of approved recycling facilities, and pay a fee pr. sold product to this. Producers and importers have organized themselves in a company *Ruteretur* to handle the recycling of windows containing PCB.

Since 2004, it is known that newer windows also can contain toxic substances (asbestos, chlorinated paraffin, tin-organic-complexes, phthalate and poly-siloxane). Current status is that it is not yet known which windows that contain these substances, and work is in progress to map out this. There is yet not established an approved recycling route for these windows, which makes the handling of these expensive. This has caused some problems with pure glass fractions being contaminated with toxic substances.

The reported amounts of unsorted glass is 7 800 tons, which is believed to be too low.

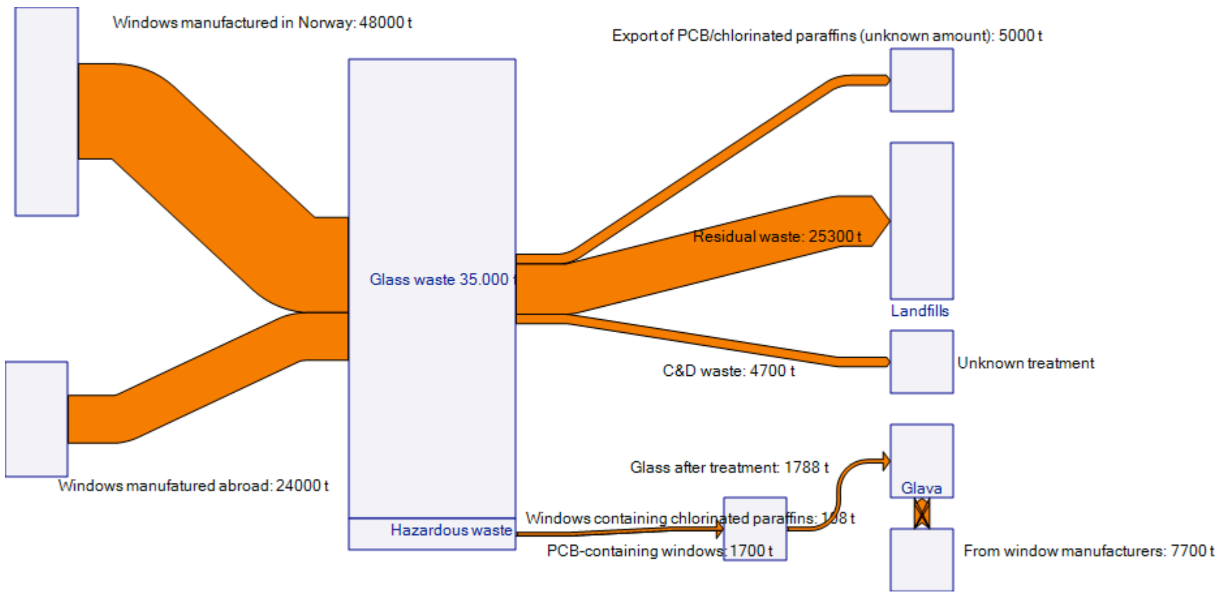

Figure 5: Material flow for waste of float glass in Norway 2010

3.9.1 Barriers for reuse and recycling of glass

Windows from renovation and demolition projects has little value. It is also costly to remove them. Windows with wooden frames must be dismantled, due to the ban on landfill of organic materials.

Windows not included in the Ruteretur arrangement becomes expenditure, since they becomes very expensive to dispose of according to regulations (due to the lack of subsidized industry agreements). Most windows are delivered according to regulations, but there is reasons to believe that many windows are not due to lack of knowledge, or to save costs.

Many of the windows containing chlorinated paraffin are not delivered as toxic waste, but clean fractions. This is due to lack of knowledge among the entrepreneurs, whom distrusts the waste handling companies, and believes they tries to increase their revenues. This reflects the low level of toxic substances in the industry.

Thus there is a weakness in the system, since Ruteretur is only dealing with some of the windows, the windows containing PCB. Measured against the subsidized arrangement concerning PCB, the costs with delivery and treatment of windows containing other substances are considered high. There is established an alternative, *Vindusretur*, which accepts all windows, but they have trouble in penetrating the market.

3.9.2 Technical potential for recycling of glass

The technical potential for recycling of glass is very good. There is two recycling facilities which in different ways separate the PCB containing spacers, so the glass can be recycled. The almost 100% of the glass can be recycled:

- Production of packaging glasses
- Production of float glass
- Filtering of water

- Water jetting/sand blasting
- Aggregate in concrete
- Production of foam glass
- Production of insulation

3.9.3 Political and other strategies to overcome these barriers

There is currently work in progress on making a new regulation, so that all windows have to be treated as toxic waste. Thus all windows will enter the same recycling route. This will allow for better waste handling, and lower recycling cost. This action will if implemented:

- Introduce competition between companies with equal possibilities
- Development of know-how on separating windows of different “toxic” levels
- Increase investments in logistics and transport
- Introduce more actors into recycling of windows
- The development of automated recycling technologies

3.10 Plastics

Plastics are a very mixed waste fraction. The fraction is generally divided into plastic for packaging or other use:

- Plastic for packaging
  - Foils and moisture barriers
  - Bottles and cans
  - EPS
  - Energy plastics (not suitable for recycling)
  - PP-sacks
- Other plastics
  - Cover plates for cables, cable-tubes, signal bands
  - Water pipes, sewage pipes
  - EPS-insulation, foundation plates
  - Roofing, façade covers, profiles, gutter and gutter pipes
  - Membranes
  - Flooring, wallpapers, moldings, roof plates, wall plates
  - Vents and HVAC-equipment

Different plastic materials have different potential for recycling. Plastic is an inhomogeneous group with respect to the various additives necessary to give the plastic the various material properties needed for their intended use (Table 5).

Due to the amounts of chemical additives into the various plastics used in constructions, are most of the plastics from renovation and demolition projects treated as harmful waste. Examples of commonly found additives are heavy metals, softeners (Phthalates) and flame retarders. These are often found in old plastics produces before the implementation of today's regulations on additives.

Table 5: Overview of different plastics types

Thermoplastic	
Polyethylene (PE)	Water pipes, vapor barrier, membranes and electric-cable insulation.
Polypropylene (PP)	Sewage pipes, water pipes and membranes.
Polyvinylchloride (PVC)	Plates, tubes, profiles, façade covers, roofing, wet room- and other wallpapers, foils, flooring, electric-cable insulation, windows
Polystyrene (PS)	Electric-cable insulation, foamed plastic and lighting fixture.
Polyurethane (PUR)	Foamed plastics, grouting compounds.
Other thermoplastics which are not common in constructions: polyamide (PA or Nylon ©), fluorinated ethylene and propene (FEP), polytetrafluoroethene (PTFE or Teflon ©), ethentetrafluoroethen (ETFE), polymethacrylate (PMMA or Plexiglas ®), acrylonitrile plastic (ABS), polycarbonate (PC), polyester (PET).	
Thermoset plastic	
Phenol plastic (PF)	Part of melanin plastic, used in façade covers, interior walls, door handles, electric lining etc.
Unsaturated polyester (UP)	Bath- and shower boots, interior walls, in façade covers, window frames, gutter pipes.
Other thermo plastics which are not commonly used in construction: melamine (MF), epoxy plastic (EP or Araldit ®) and polysiloxane.	

3.10.1 Material flow of plastics

European plastic industry has conducted an survey over plastic wastes and plastic need in 27 EU countries in addition to Norway and Switzerland (Plastics Europe, 2011). The analysis shows that 21% of all plastics are used in constructions, and about 40% of all plastics are used in packaging.

The waste statistics shows 4 200 tons of plastic in 2010 construction and demolition waste or 0.3%. Far from all projects do source separation of plastics, so this number is an underestimation and the potential is much higher. Some plastics follow the mix waste fraction, or are delivered as combustible waste. In projects with that starts with a study and description of harmful substances, most of the plastics is removed and delivered as harmful substances, due to toxic substances.

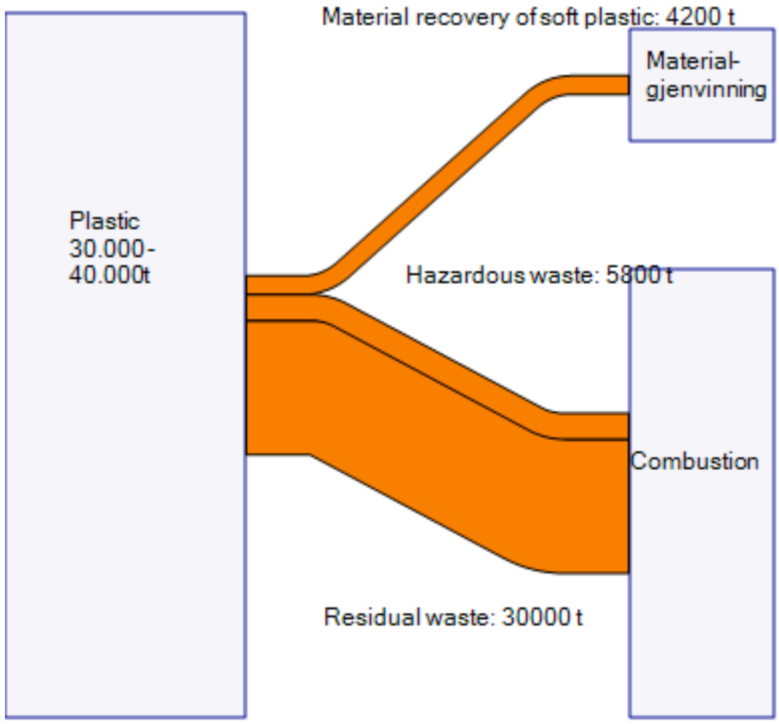

Figure 6: Material flow for plastic waste in Norway 2010 (Hjellnes Consult, 2012)

3.10.2 Barriers for reuse and recycling of plastic

The barriers for recycling of plastics can be summarized in three points:

- Many plastics contains additives that are harmful or toxic
- To be recycled, the waste fraction has to be relatively pure, both hygienic and as a material fraction.
- It is cheaper to incinerate with energy recovery, than recycle

3.10.3 Political and other strategies to overcome these barriers

Plastic waste from demolition projects are only in small amounts, and of little importance to the overall plastic waste fraction. The plastic from these projects are also harder to sort, and does often contain harmful additives. Therefore is focus on renovation and construction projects.

To enhance collection and recycling, focus is on source separation and collection from construction projects especially. Focus is on training personnel in source separation, and on establishing producer responsibilities for plastic products, both for building materials and packaging.

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Barriers for Deconstruction and Reuse/Recycling of Construction Materials in Singapore

Edward Anggadjaja

Centre for Sustainable Buildings and Construction
Building & Construction Authority
SINGAPORE

1. BARRIERS FOR DECONSTRUCTION

1.1 Top-down demolition

1.1.1. Commonly used method to remove buildings (deconstruction / dismantle)

In Singapore the project duration for demolition works is usually quite short (3 to 6 months). Therefore to make way for new developments, building structures will be taken down in the fastest, most economical and convenient way, thereby resulting in difficulty of sorting out the various demolition wastes later on.

The most commonly adopted method of demolition is the top-down demolition approach with the use of heavy machinery (eg. power grapples and shears). With the introduction of the new code of practice on demolition, SS 557, demolition contractors are required to adopt sequential demolition (generally the sequence of demolition being in reverse to the sequence of construction) unless the Qualified Person (normally a Professional Engineer) ascertain that the stability of the building during demolition would be compromised. In fact sequential demolition is not new; however only a handful of demolition contractors adopt this practice as it requires more skillful, systematic planning and allocation of resources.

In Singapore deconstruction/ disassembly is still a relatively new concept and not practiced yet. There is however a pilot project looking into how structural elements of a building could be designed to facilitate dismantling after its end-of-life. This particular project called “Designed for disassembly (DfD) building systems for Singapore” received partial funding from the Ministry of National Development. The two aspects of the work under this project are development of the Information Management System and experimental testing of prototype DfD component and joints. The initial plan was to focus primarily on multi-storey car parks and subsequently, the focus has been shifted to include residential apartment blocks as well.

1.1.2. Barrier for deconstruction

The following paragraphs describe the barriers for adopting deconstruction.

a) Our current design and construction methods do not focus or emphasize on the reusability of the materials when the building’s lifecycle is reached. The connection systems adopted are permanent in nature in which case the building components upon dismantling, would be damaged and rendered not useable.

b) Lack of the technical knowledge and specific guidelines / Code of Practices are also contributing factors impeding the method of deconstruction. Designers and builders are reserved towards using this new concept as the current project specifications and Codes of Practices adopted are basically prescriptive in nature. For cases that deviate from the norm, there are also no guidelines nor proven successful examples which can serve as references at the moment. In addition as the deconstruction methods require the buildings to be designed to facilitate easier dismantling of the building components at the end of its life cycle, specialized connection systems may be required to ensure overall structural stability. Skilled contractors knowledgeable in deconstruction would be required for the safe dismantling as well as the maintenance of DfD buildings. This may also inevitably lead to higher building maintenance cost in the short term or until such a time when the industry professionals are familiar with DfD.

c) Another barrier to deconstruction will be the slightly longer duration required to take down the buildings and salvage the used materials from the buildings. The process to deconstruct and salvage the building components will take a significant longer time compared to conventional demolition methods. This is due to the care required to preserve and maintain the conditions of the materials for reuse. This means that prior understanding between the developers and the project team including the demolition contractors is needed to ensure that the project deliverables are met. Developers would need to clearly specify the project requirements including the realistic timeline in the contract documents so that the demolition contractors tendering for the job are skilled enough to carry out the operation.

d) Yet another challenge for the use of dismantled structural elements is the market demand for these components. Even if the building components could be salvaged, there is a problem of creating demand or market for these "New" building products. Building owners may still be skeptical to specify the use of these products for their newly invested development as they carry the connotation of being inferior in terms of meeting building code requirements and performance specifications.

1.1.2. Strategies

(1) Technical strategies to overcome the barriers

To address the issues above, the following strategies would be adopted:

a) Education and promotion

   Local or international seminars, workshops and conferences can be organised to share best industry practices to cut short the learning curve of the construction professionals to adopt DfD.

b) Revision of existing codes to allow for alternative demolition methodologies or innovations

   The local building codes governing demolition could be reviewed periodically to keep current with technological advances. In the meantime alternative demolition methodologies such as DfD can be considered case by case as long as the structural integrity and safety aspects of the project are not compromised.

c) Pilot studies and/or demonstration projects

   To build up capabilities of the various industry players such as the architects/ designers, builders/ demolition contractors, consultants, developers, in-depth pilot studies and/or demonstration projects on DfD can be carried out to demonstrate proof of concept and feasibility of implementation.

(2) Political strategies to overcome the barriers

a) Policy tools to facilitate deconstruction

   Our building rating tool- the Green Mark Scheme- has been revised and in force since December 2010 to recognise green efforts and innovations adopted by developers. Developers who encourage their builders to adopt DfD could be considered for points under Section 5 of the Green Mark Scheme

b) Public education

   Create awareness of the fact that Singapore lacks natural resources but at the same time through technological means like DfD to optimise material recovery rates, we could recover a substantial quantity of building materials for new developments.

c) Study trips

To shorten the learning curve for adoption of DfD, BCA could also organise study trips to countries which are advanced in DfD technologies or have successfully adopted DfD for some time. BCA could form a delegation comprising key industry stakeholders to visit these countries and learn from their experiences. Such studies would be very beneficial for policy-making, bench-marking purposes and implementation.

(3) Other strategy to overcome the barriers (ex. Ecological Incentive)

a) Monetary incentives to carry out pilot studies/ projects

The government could also explore incentivising contractors to carry out research studies or demonstration projects through the existing funding schemes such as the Sustainable Construction Capability Development Fund (SC Fund). The SC Fund was set up to develop capabilities of key industry players in the construction value chain in recycling waste arising from the demolition of buildings and in the use of recycled materials for construction.

1.2 Controlled demolition

1.2.1. Commonly used method to remove buildings (deconstruction / dismantle)

The other method practiced by a few demolition contractors is called controlled demolition. This involves the use of diamond cutters to remove totally or part of a structure by deliberately cutting/ sawing off the structural elements. This method is more commonly employed in A&A (addition & alteration) works or in areas where A&A works are to be carried out with minimum disruption to business activities.

1.2.2. Barrier for deconstruction-1

Diamond cutters (including machinery parts) are very costly.

1.2.2. Strategies-1

(1) Technical strategies to overcome the barriers

To address the issues above, the following strategies would be adopted:

a) Education and promotion

Local or international seminars, workshops and conferences can be organised to share best industry practices to cut short the learning curve of the construction professionals to adopt DfD.

b) Revision of existing codes to allow for alternative demolition methodologies or innovations

The local building codes governing demolition could be reviewed periodically to keep current with technological advances. In the meantime alternative demolition methodologies such as DfD can be considered case by case as long as the structural integrity and safety aspects of the project are not compromised.

c) Pilot studies and/or demonstration projects

To build up capabilities of the various industry players such as the architects/ designers, builders/ demolition contractors, consultants, developers, in-depth pilot studies and/or demonstration projects on DfD can be carried out to demonstrate proof of concept and feasibility of implementation.

(2) Political strategies to overcome the barriers

a) Policy tools to facilitate deconstruction

Our building rating tool- the Green Mark Scheme- has been revised and in force since December 2010 to recognize green efforts and innovations adopted by developers. Developers who encourage their builders to adopt DfD could be considered for points under Section 5 of the Green Mark Scheme

b) Public education

Create awareness of the fact that Singapore lacks natural resources but at the same time through technological means like DfD to optimize material recovery rates, we could recover a substantial quantity of building materials for new developments.

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To shorten the learning curve for adoption of DfD, BCA could also organize study trips to countries which are advanced in DfD technologies or have successfully adopted DfD for some time. BCA could form a delegation comprising key industry stakeholders to visit these countries and learn from their experiences. Such studies would be very beneficial for policy-making, bench-marking purposes and implementation.

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2. BARRIERS FOR REUSE AND RECYCLE

Concrete and bricks/ masonry make up the bulk of C&D waste constituting about 85-90% of the waste while metals (steel, aluminum etc) make up about 8-10% of it. The rest of the wastes comprise timber (about 2-5%) and others (eg. glass, plastic, gypsum, etc).

2.1 Crushed concrete

2.1.1 Recycle ratio

Reused	98 %
Recycled for raw materials of products	0 %
Recycled for energy source	0 %
Land filled or burned	2 %
Other	0 %
Total	100 %

2.1.2 Products produced from No.1 C&D waste

Currently most of the crushed concrete is used either as a hardcore material for construction of site temporary access roads or simply as a backfill material for general purpose applications. Higher value-added applications include the processing of crushed concrete into recycled aggregates (RA) for various building and construction applications.

RA is commonly used for road works or non-structural applications like precast kerbs and drains. The better grade RA commonly known as recycled concrete aggregates (RCA), are allowed by BCA to be used for manufacturing of structural concrete.

2.1.3.1 Barrier

Lack of project references- in Singapore only 3 projects that use RCA for structural applications

2.1.3.2 Strategy

(1) Technical strategies to overcome the barriers

Same as 1.1.2- i.e through education and promotion, pilot studies/ projects.

(2) Political strategies to overcome the barriers

None.

(3) Other strategy to overcome the barriers (ex. Ecological Incentive)

BCA has set up the Sustainable Construction Capability Fund (or SC Fund for short) to develop capabilities of the industry in recycling of waste (such as crushed concrete) arising from the demolition of buildings and in the use of recycled materials for construction. The fund would facilitate and support the strategic shift needed for the industry to adopt more SC design and practices going forward.

2.2 Metals- steel, aluminum etc

2.2.1 Recycle ratio

Reused	100 %
Recycled for raw materials of products	0 %
Land filled	0 %
Other	0 %
Total	100 %

2.2.2 Products produced from No.2 C&D waste

Steel is recycled back into steel reinforcement bars, meshes, formwork, plates etc

2.2.3.1 Barrier

There are no barriers regarding the recycling/ reuse of steel because of the intrinsic market value of the material. Demolition contractors will recover as much steel as possible from demolition projects and sell them off to recyclers so as to offset their project operation cost.

2.2.3.2 Strategy

(1) Technical strategies to overcome the barriers

None

(2) Political strategies to overcome the barriers

None

(3) Other strategy to overcome the barriers (ex. Ecological Incentive)

None

Barriers for Deconstruction and Reuse/Recycling of Construction Materials in U.S.A.

Abdol Chini and Ryan Buck

Rinker School of Building Construction, University of Florida
U.S.A.

1. BARRIERS FOR DECONSTRUCTION

1.1 Wood Frame Construction

1.1.1. Commonly used method to remove buildings

Wood framed construction is extremely popular in the United States for residential housing. Normally, wood framed structures will have a masonry or concrete foundation and the rest of the structure will be constructed using wood framing. This includes the structural frame, bearing walls, floors, and roof. These wood framed structures also consist of exterior sheathing and many different types of exterior finishes. The interior of most of these structures is consisting of drywall.

The most common method in the United States for removing wood framed structures is demolition. It is the fastest and easiest way to remove a structure and is the preferred method for this type of construction. Because the structure made out of wood and the drywall and sheathing is easy to break apart without doing damage to equipment, it becomes a great choice for contractors. Bulldozers are probably the easiest equipment to use for demolition on single-family house holds and a wrecking ball is a common piece of equipment for larger wood framed construction demolition. Demolition is such a fast process because equipment is doing all of the power and work to remove a building. However, the demolition process destroys most of the material that made up the building and makes it nearly impossible to reuse directly.

1.1.2. Barrier for deconstruction

One major barrier for deconstruction compared to demolition to remove a building is the time factor. It is proven that demolition is faster than deconstruction because in deconstruction the building is taken apart piece by piece to try and recover the materials for reuse. The demolition process is not worried about destroying the material that makes up the building. The main goal of demolition is to remove the building as fast as possible and there is no worry of trying to reuse the materials. The materials can be recycled after the demolition process, but this is a difficult process because all the materials are in many pieces and combined with other materials. This makes it difficult and time consuming to try and recover materials for recycling.

Since time is a valuable resource to contractors and owners and has a price tag attached to it usually when constructing a building, it is challenging to convince owners and contractors to perform work that takes more time and man power. What the contractors and owners need to realize is how much greater potential there is to sort and recover construction materials with deconstruction and how most of the materials keep their economic value once recovered for reuse.

1.1.2. Strategies

(1) Technical strategies to overcome the barriers

The first strategy would be to make deconstruction a better economic option for owner of buildings and contractors. This can be achieved using several different ways. In some cases, deconstruction is already less expensive than demolition. This is because large equipment is needed for demolition, which is more expensive than labor costs. Large equipment is not needed during deconstruction; however, a lot more labor and man hours are needed. Demolition and deconstruction prices can vary with deconstructing being a cheaper option some of the time. But, deconstruction will always take more days to perform than demolition. Some added cost savings from deconstruction can be gained by selling the recovered materials or reusing them on future projects to avoid buying new material. In order to overcome the time difference, deconstruction permitting should be offered that allows for the additional time that deconstruction requires and reduces fees relative to those charged for demolition permits. In general, deconstruction has to become economically more desirable so that the owner doesn't mind using extra days to disassemble a building to save money.

Deconstruction of wood framed construction allows for much opportunity to recover materials. Wood is a highly reusable and recoverable material and is plentiful in this type of construction. The value of the wood can be worth the time spent trying to recover it through deconstruction. There is also ways being developed to increase the productivity of deconstruction. This can decrease the amount of time spent on the deconstruction phase of a project, making it less expensive and a better option. Some of the ways productivity is increasing is by tools that can speed up the deconstruction process. For example, a power tool that can remove nails faster than using the claw of a hammer would increase the speed of deconstruction, especially with wood products. This would save some of the time and cost of the deconstruction process.

(2) Political strategies to overcome the barriers

Some political strategies to overcome the barriers of deconstruction would be to mandate the amount of material that should be recovered in original form that it was initially used. This would force contractors to use deconstruction on at least a portion of the building in order to meet the requirement. The government could also award incentives to builders who can recover high amounts of materials from building removal. This would benefit the builder by encouraging them to use deconstruction methods to achieve awards and benefits as well as the environment by reducing the amount of new resources that are used.

1.2 Steel Structured Buildings

1.2.1. Commonly used method to remove buildings (deconstruction / dismantle)

Steel structured buildings are most commonly used for large commercial buildings. They are composed of steel columns, beams, girders, joists and roof trusses. They sit on concrete foundations and can have many different styles of exterior finishes. The interior finishes of this type of construction consist of drywall applied to steel framed interior partitions. The most common method for removing this type of buildings is through demolition. However, demolition is more difficult and time consuming for building types like this because the steel frame cannot be demolished. Everything around the steel frame is crushed and removed so that just the steel frame is remaining. Then the steel frame is dismantled. This is because the steel frame cannot be knocked out by a wrecking ball. It is possible to demolish the building using explosives and no dismantling is required. However, because dismantling of steel is normally required, it is easier to convince contractors and owners to use deconstruction to remove the entire building.

1.2.2. Barrier for deconstruction

Even though the common way for removing this type of construction requires disassemble, it is still faster to demolish other materials around the steel structure and remove them than to deconstruct the entire building. Normally, buildings with this type of construction are very large buildings and would take much time and labor to perform deconstruction. Most large buildings like skyscrapers are demolished using explosives because it is such a speedy way to remove a large building like that. The one thing about deconstructing a large building is the amount of materials that can be recovered and sold for profit or reused to decrease future purchases of materials.

1.2.2. Strategies

(1) Technical strategies to overcome the barriers

A strategy that could be applied to overcome the barriers for deconstruction on this type of construction would be the incentives to the owner and contractor for recovering lots of material. Also, because deconstruction of the steel frame is already required most of the time, it should be easier to deconstruct the rest of the material around the steel frame. This would allow for much of the material to be recovered and reused directly. The expensive demolition equipment cost would not be needed, which could end up saving money and making up for the extra time it takes to perform deconstruction.

(2) Political strategies to overcome the barriers

Politically, there are ways to encourage deconstruction. By forcing all government buildings that are removed or renovated to undergo deconstruction can set an example in the field and cause others to want to deconstruct, especially, if the deconstruction process is proven to be very successful. Requiring this type of construction to be deconstructed is another political strategy for deconstruction. Also, since demolition can pose more safety threats than deconstruction in large structures, it might be wise to perform deconstruction instead of demolition. The insurance rate for companies could play a role in weather a company removes a building using deconstruction opposed to demolition. If a firm can save money on their insurance that is greater than the difference, deconstruction could be a better option. This would have to be determined by the insurance companies.

1.3 Concrete/Masonry Structures

1.3.1. Commonly used method to remove buildings (deconstruction / dismantle)

These structures are composed of cast-in-place concrete, pre-cast concrete, or Concrete Masonry Unit (CMU) materials. The columns, beams, walls, floors, and other structural elements can be made with cast-in-place or pre-cast concrete. The roof and floors are generally made of lightweight concrete supported by steel bar joists. CMU load bearing walls are common in this type of construction and steel or wood framing can be used for interior walls. Gypsum drywall is popular for interior sheathing and brick or stucco is common for exterior coating. The most popular method for removing this type of structure in the United States is by a demolition process. Concrete and masonry is very difficult to reuse directly. To reuse masonry units, they need to be disassembled and then have the mortar scraped off by hand. This is very time consuming and most contractors will not bother trying to reuse masonry units such as block or brick. Concrete and masonry is able to be recovered and recycled, but deconstruction is not necessary for this to occur. Much of the interior materials in this type of structure can be reused directly such as the drywall and framing. However, once the deconstruction of these materials is preformed and recovered, it makes more sense to demolish the rest of the structure and try to recover the material for recycling purposes because deconstruction of masonry will cost too much money and is not worth the effort.

1.3.2. Barrier for deconstruction

It is important to try and deconstruct the interior and exterior materials around the structure because they are still valuable and can be reused. However, because demolition is so popular with this type of structure, it is difficult to even start with deconstruction. This is because the demolition equipment will be needed for the job anyways. Therefore, the contractor will not save any money by not having to rent the equipment. Contractors usually like to demolish the entire structure because of the time duration it saves.

1.3.2. Strategies

(1) Technical strategies to overcome the barriers

There are not too many strategies to overcome the barrier of deconstruction in this type of construction. Since it is easier and way more cost effective, demolition is the preferred choice. The material is still able to be recovered and recycled after demolition, but the idea of directly reusing it is out of sight.

(2) Political strategies to overcome the barriers

It could be required to deconstruct this type of construction but that would not be ideal for economic reasons because the cost of deconstruction on this type would far exceed the cost of demolition.

2. BARRIERS FOR REUSE AND RECYCLE

2.1 Concrete

2.1.1 Recycle ratio

Reused	0 %
Recycled for raw materials of products	50 %
Recycled for energy source	0 %
Land filled or burned	50 %
Other	0 %
Total	100 %

2.1.2 Products produced from Concrete C&D waste

One of the top five materials in the US that produce construction and demolition waste is concrete. In order to recycle concrete it needs to be recycled for raw materials of products. It is difficult to reuse concrete because once it is cured in place it is set for a unique setting and cannot be reused for a different reason.

The Construction Materials Recycling Association (CMRA) estimated that approximately 90 MMT of concrete is recycled nationally. They used a method that counts the number of concrete crushers in operation and assumes a production rate for each crusher. The EPA estimate that 180 MMT of waste concrete was generated nationally in 2003 (Sandler, 2003). This includes 55 MMT building related and 125 MMT infrastructure related C&D waste.

An estimated 68 per cent of aggregate recycled from concrete is used as road base and the remainder is used for new concrete (6 percent), asphalt hot mixes (9 percent), and low value products like general fill (Deal, 1997). The low usage rate of recycled concrete aggregate (RCA) in new concrete and asphalt hot mixes (15 percent) compared to the higher usage rates in lower valued products is related to real and perceived quality issues. Many State agencies have allowed use of RCA mostly as road base materials and not for high-quality uses such as road surfacing.

The recovered material is crushed and screened at a permanent recycling facility or can be done so at the demolition site (Chini, 2007). The latter approach is preferred because it reduces transportation costs and energy use due to hauling materials. Some States convert existing worn-out concrete roads to rubble-in-place. The old concrete surface is broken up and compacted, and asphalt pavement is placed over the enhanced base.

2.1.3.1 Barriers

A major factor that drives the cost of recycling concrete up is transportation. The main source of transportation in the US is an automobile or truck. This requires the use of gasoline and limits the amount of waste that can be hauled by one automobile or truck. An advantage of using an automobile or truck is the material can be picked up and dropped off at an exact location, unlike railway or other systems. The reason concrete construction and demolition waste is disposed of in the landfill is because recycling plants are not always available near demolition sites and sometimes charge a fee to process the demolition waste. Therefore, it is cheaper to transport waste to the landfills.

2.1.3.2 Strategies

(1) Technical strategies to overcome the barriers

One solution to encourage taking waste to recycling plants would be to increase the cost of disposing concrete waste in a landfill. This would happen for two reasons; the landfill would be running out of space and raise its prices or the government would force landfills to increase their prices on construction and demolition waste. This would drive the cost of landfilling the waste up and encourage more recycling because it would be a cheaper method of disposal.

Another solution would be to create more recycling plants to reduce transportation cost by limiting distance needed to transport the waste. If there were as many recycling plants as landfills, it would be easier to convince owners and contractors to recycle the waste material. There could also be companies that would collect concrete waste and transport the waste in bulk to recycling plants for a lower cost than individual contractors could haul the waste to the recycle plant. These companies would act more like transfer stations and be more convenient for contractors, especially outside of urban areas where fewer recycle plants are located.

(2) Political strategies to overcome the barriers

Politically, the US or State government can mandate the process of recycling concrete by requiring a percent of concrete waste be recycled. In order for this to happen, the topic would have to be brought up, discussed, and voted on through the political process of the US or State government. Another political strategy would be for the State government to require a certain percentage of recycled aggregate to be used in certain types of projects. This would encourage more recycling because the aggregate would cost more if not enough of the waste was getting recycled. This would drive the price received for concrete waste up, thus making recycling concrete waste profitable and encouraging it.

(3) Other strategy to overcome the barriers

A different strategy to lower the transportation cost would be to crush and screen the concrete waste on site, minimizing the amount of waste being hauled and driving down the cost. This process is already used and is preferred, but sometimes it is difficult to crush and screen the waste at the demolition site. This can become difficult due to limited space around the demolition site and it might not be as efficient outside a controlled environment like a recycling plant. If this process could be improved in the future to make it easier by increasing the efficiency and decreasing the amount of work room needed to crush and screen the concrete waste, it could be easier to convince contractors to use this method of recycling. This would increase the percentage of waste recycled by reducing the transportation cost.

For concrete recycling to be profitable, transportation costs need to be kept low, which forces the market to be urban oriented. The availability of feedstock into recycling plants depends on the amount of demolition taking place, which is much higher within older, larger cities. Recycling concrete plants often have the opportunity to charge a fee for accepting concrete debris, especially where depositing materials into landfills are high. This added revenue can compensate for a lower market price for recycled aggregate products.

The future of recycled aggregates will be driven by higher landfill costs, greater product acceptance, government recycling mandates, and a large stock of existing roads and buildings to be demolished. Favorable in-service experience with recycled aggregates and development of specifications and guidelines for their use are necessary for recycled aggregate acceptance. A sustainable recycling aggregate industry requires sufficient raw materials, favorable transportation distances, product acceptance and limited landfill space.

2.2 Wood

2.2.1 Recycle ratio

Reused	? %
Recycled for raw materials of products	48.5 %
Land filled or burned	51.5 %
Other	0 %
Total	100 %

2.2.2 Products produced from No.2 C&D waste

The amount of wood from C&D debris generated, disposed of, and recycled in the US is unknown. Falk and McKeever (2004) estimated that 35.7 MMT of C&D wood waste was generated in 2002, while the EPA has estimated that the annual C&D wood waste to be 25 MMT (Sandler, 2003). Falk and McKeever (2004) also estimated that 17.3 MMT of wood waste was recovered from the national C&D debris stream for recycling or combustion in 2002. Meaning roughly 48.5% was recovered in 2002.

Construction and demolition wood waste can be used to produce multiple types of products. The best use for C&D wood waste would be direct reuse and the most efficient way to recover wood for direct reuse is deconstruction. By performing deconstruction of a building the contractor is able to salvage the pieces of wood intact. Also, it is possible to remove nails and other connectors that might be in the wood. This process could become very useful, especially if building dimensions became more standard. This would allow for more standard sizes of wood to be reused over again without having to be cut or sized down. For example, if the height of two by fours are eight feet tall on the building that is being deconstructed, they would be able to be used again for another building if that buildings walls were designed at the same height as the building being deconstructed. This can apply to all types of wood products used in construction. However, deconstruction takes more time to perform and many contractors believe it costs more money. Also, wood from deconstruction has to be inspected and cleared before it can be reused on another project. The easiest way for this to be done is by having a certified inspector on the job site that can inspect and clear the wood directly during deconstruction. This would allow for all the wood that is reusable to be hauled off the site and stored for another project, and the wood that is determined not usable can be recycled. This would maximize the amount of wood that is recoverable and recyclable and decrease the amount of wood that ends up becoming landfilled.

During the construction phase, small wood waste scraps that have been cut off from a piece of wood are normally thrown into the dumpster and landfilled. This is because in most construction workers opinions the tiny pieces of wood cannot be used for anything and it is normally easier for them to throw the pieces in the trash dumpster than the recycle bin on the job site. Unused wood on construction sites normally get stored by the contractor and used for their next project. Therefore this wood doesn’t go to waste at all.

Wood that is not recovered for direct reuse can be recycled to produce many different products. Some of the products produced from recovered wood are specialty items such as custom cabinetry, furniture, and wood flooring. All of these items actually increase the economic value of the wood recovered because these items are much more expensive. Therefore, it can turn out to be a great return for recycled wood products. Other products that can be produced from recycled wood are items like mulch. Demolition wood scraps can be recovered and grinded down to create mulch. However, mulch should be one of the last options for wood waste because once the wood is turned into mulch it is not recoverable and the lifespan of the wood has ended. Feedstock is another popular use for recycled wood. It is used to produce engineered wood products such as particle board. Other products that are made from recycled wood are animal bedding, fibers for manufacturing, and biomass fuel.

If wood is treated with chromated copper arsenate (CCA) for prevention against insects, it may need to be disposed of differently. CCA treated wood can be hazardous and should not be recycled. While recyclers attempt to pull treated wood from their recycling piles, many pieces are undetected and recycled into mulch. If CCA treated wood is incinerated for boiler fuel, the ash left behind can contain high levels of arsenic (Solo-Gabriele et al., 2002).

2.2.3.1 Barrier

One major barrier that stands in the way of recycling and reusing wood waste is the lack of effort by contractors and owners for recycling. All construction sites have at least one, if not multiple dumpster, but most construction sites do not have recycle dumpsters. Also, many of the workers are in habits of just throwing all the waste in the landfill dumpster because it is easier and less time consuming. The same concept applies to the laborers that are in charge of housekeeping on the job site. This is mainly due to a lack of instruction by the general contractor on the job site. Most of the wood waste on a job site should be recoverable or able to be recycled in some way. The main reason so much of it not get recycled is because there is not enough opportunity or instruction to recycle the wood waste.

2.2.3.2 Strategy

(1) Technical strategies to overcome the barriers

A solution to overcome this barrier would be to educate contractors and owners and encourage them to recycle more. It is becoming much more important to recycle as much as possible. Now days recovered wood is in higher demand because much of the virgin stocks of wood have been over exploited, thus making it more expensive. There also has to be some kind of incentive for contractors and owners to recycle wood products. If they are trying to get their building green certified this would be an incentive to recycle the wood waste on the job site. The cost would be another incentive to encourage recycling. If it cost more to dump the wood waste in a landfill than it did to recycle it, contractors would chose the less expensive route to save money on the project. If the contractor has their laborers separate and dump wood waste into a recycling dumpster instead of the landfill dumpster this will help tremendously.

(2) Political strategies to overcome the barriers

A political strategy to encourage the contractors and owners to recycle wood waste would be to force them to recycle a percentage of waste materials on every construction project. This would encourage and increase recycling on all projects and all types of materials. Also, the government has to require contractors to take recycling education courses to encourage them to recycle more than they do now. This could show them how to manage their job sites and train their crew to recover more materials for reuse and recycling. The government could also give incentives such has cash bonuses for projects that recycle a large amount of waste or to contractors for recycling a certain amount of waste every year.

(3) Other strategy to overcome the barriers

Encouraging deconstruction to contractors over demolition on wood structures is a great strategy to reuse materials. Deconstruction does take more time to perform than demolition, but much more wood will be able to be recovered making up the cost difference in the extra time spent taking the building apart. The contractor can stockpile and store all the recovered wood from deconstruction and use it on the next project. This eliminates having to buy wood for the next project, especially if the structure for the new project is similar to the project that was deconstructed.

2.3 Drywall

2.3.1 Recycle ratio

Reused	0 %
Recycled for raw materials of products	28 %
Land filled	72 %
Other	0 %
Total	100 %

2.3.2 Products produced from No.3 C&D waste

The amount of waste drywall generated in the US has been estimated by various sources. The USEPA estimates that most drywall waste is generated from renovation (10 MMT), new construction (1.5 MMT), demolition (0.9 MMT), and manufacturing (0.3 MMT) (Sandler, 2003). The US Geological Survey estimated that more than 3.6 MMT of gypsum waste that was generated by wallboard manufacturing, wallboard installation, and building demolition was recycled in 2010 (USGS, 2010).

Drywall is very popular for interior use of buildings in the United States. It is made up of a sheet of gypsum, which is covered on both sides by a paperboard backing and a paper facing. Recycled gypsum can be used in several different applications. The main use is to produce new manufactured gypsum drywall products. This allows the gypsum to be used again in the construction industry and cuts down on the use of mined gypsum. Recycled gypsum can also be used as an ingredient in the production of Portland cement. This is another reason for why the construction industry should try to recycle C&D waste, such as drywall, and allow the recycled material to be reused in production of other construction materials. This can reduce the cost of construction materials and helps the construction industry to be more sustainable as a whole.

Gypsum is a major ingredient in fertilizers and crop products as well. Recycled gypsum can be applied to soils to improve soil drainage and plant growth. Gypsum contains nutrients for plants that increase growth and makes a great ingredient to produce fertilizer products. A great way to recycle drywall on a construction site at a low price is to bring a mobile grinder to the site and grind up the scrap drywall. Then use the grinded gypsum to apply to the landscape of the job site. This will reduce the cost of hauling off the gypsum drywall, storing, or disposing of it in a landfill. It also can prevent the landscaper from buying fertilizer for the plants on site.

Drywall is generally processed for recycling by removing the paper facing and paperboard to recover the sheet of gypsum. However, when the gypsum is recycled and used for agricultural use, the paper is often not removed because it decomposes. These are the main markets for gypsum uses.

2.3.3.1 Barrier

Drywall is often not recycled because it is very difficult to recover once it is mixed with other materials. It becomes mixed with other materials, especially in the demolition process of structures. It is difficult and time consuming to separate drywall waste from other C&D debris and therefore produces a barrier for recycling gypsum material.

2.3.3.2 Strategy

(1) Technical strategies to overcome the barriers

The main strategy to overcome this problem of C&D waste materials becoming mixed up and difficult to recover is to separate the materials individually and sort them. This can be accomplished by performing deconstruction during renovation or removal of structures. Deconstruction allows for the removal and separation of the materials so they are not mixed up in the demolition process. This can increase the percentage of drywall recovered and encourage recycling throughout the construction industry. However, many contractors chose demolition over deconstruction due to the ease and the amount of time saved.

(2) Political strategies to overcome the barriers

Political strategies to overcome the barrier that is causing gypsum to be landfilled instead of recycled would include the passing of laws or ordinances to control the recycling of C&D waste. These laws could include many things such as a disposal ban, a disposal tax, a percentage recycling requirement, material recycling requirements, and other requirements. The government could require a certain percentage of gypsum waste be recycled. The government could also use education as a great tool to encourage recycling.

(3) Other strategy to overcome the barriers

Other strategies that could be used are to limit the amount of drywall that can be landfilled or ban any gypsum from being disposed of in the landfill at all. According to Chini, The presence of gypsum drywall in landfills has been linked to the production of hydrogen sulfide (H2S). Hydrogen sulfide can produce foul smells that is unwanted in some landfills due to the complaints landfills might receive from communities located nearby. Therefore, many landfills don’t accept gypsum products or limit the amount. The landfills could also increase the cost to dispose of drywall and would therefore make recycling a more economical option.

2.4 Asphalt Roofing Shingles

2.4.1 Recycle ratio

Reused	? %
Recycled for raw materials of products	? %
Recycled for energy source	0 %
Land filled or burned	0 %
Other	0 %
Total	100 %

2.4.2 Products produced from No.4 C&D waste

In U.S., approximately 10 MMT of waste asphalt roofing shingles (ARS) are generated per year. Re-roofing jobs account for 9 MMT and manufacturing scrap generates another 1 MMT (CIWMB, Shingles). While many studies have been performed on the viability of recycling asphalt shingles, there is no consensus of exactly how much is actually recycled.

Asphalt shingles contain approximately 35% asphalt, 45% sand, and 20% mineral filler (Newcomb et al., 1993). They are typically disposed of in landfills, but can be recycled into asphalt concrete. Fiberglass-backed and felt-backed roofing shingle wastes can be used in related bituminous applications, such as granular base stabilization, patching materials, or in hot-mix asphalt concrete (Newcomb et al., 1993). Asphalt shingle waste is produced by re-roofing jobs where old asphalt shingles are torn off and disposed of, in demolition debris, and scraps from new roof shingles that need to be cut and sized to fit properly on a roof. Recycled asphalt roof shingles can be used to produce asphalt pavement, aggregate base and sub base, cold patch for potholes, and new roofing. Some hot mix asphalt manufacturers are hesitant to use shingles from C&D debris-generating projects due to possible contamination. This is because asbestos can sometimes be detected in old asphalt roofing shingles. Some of the top manufacturers from 1963 to 1977 for roof shingles produced shingles that contained asbestos. Therefore, it is still a possibility today that asbestos exists in roofing shingles.

2.4.3.1 Barrier

One of the main problems asphalt roof shingles are not recycled more is because there is not a large market for them. Old worn out roof shingles are not ideal for recycling because the quality and condition they are in after being on the roof for many years is not the greatest. Old shingles have been exposed to the sun's ultraviolet rays and when are removed often have nails and other debris attached to them. Scraps of new shingles that have been cut off or scraps from asphalt shingle manufacturing plants are much more desirable for recycling. The threat of asbestos makes old worn out roofing shingles less desirable. However, because roofs need to be replaced so often, there is a large amount of asphalt roofing shingles that make up C&D waste. Also, the cost to landfill asphalt roof shingles is often less expensive than recycling.

2.4.3.2 Strategy

(1) Technical strategies to overcome the barriers

A strategy to avoid large amounts of asphalt shingles from ending up in the landfill every year is to find other uses for the recycled shingles. Tear-off shingles are the shingles that are difficult to recycle. If any tear-off shingles contain any amount of asbestos, it cannot be recycled and will have to be disposed of properly. The amount of manufactured scrap shingles that gets recycled and reused to make other shingles and used in asphalt hot mix is a high amount. However, large amounts of used tear-off shingles are removed from roofs across the United States annually and need some alternative way to be disposed of besides being landfilled. Tear-off shingles cannot be directly reused because they have already reached their maximum life span as a shingle, but can still be used to produce other products. In order to allow for more recycling of asphalt shingles, there needs to be a larger market for asphalt.

(2) Political strategies to overcome the barriers

Laws and regulations can require and increase the amount of recycle that occurs in the United States. State and local governments can require amounts of recycled material that can be used for certain applications. For example, many state transportation departments have specifications that allow for recycled roof shingles to be used in pavement materials. Allowing recycled materials to be used and encouraging their applications create a larger market for the recycled materials. A larger market increases the demand of the material and because there is a lot of roofing shingle waste that is produced every year the supply is able to meet the demand. The government can help control the market for roof shingles by requiring a percentage of recycled asphalt roof shingles to be used in asphalt mix. This mix can help fix and improve roadways with pot hole patches and new asphalt roadways.

(3) Other strategy to overcome the barriers

High transportation cost and low disposal fees are major reasons why roofers and contractors tend to landfill asphalt shingles instead of recycling them. Recyclers often charge processing fees and such to recycle the material on top of the transportation fee to haul the waste material to the recycling plant. In order to encourage recycling of materials, there has to be an economic incentive for the contractor to recycle instead of landfill the waste. This can be done by increasing the tipping fees that landfills charge to dispose of waste.

2.5 Steel

2.5.1 Recycle ratio

Reused	? %
Recycled for raw materials of products	85 %
Land filled	15 %
Other	0 %
Total	100 %

2.5.2 Products produced from No.5 C&D waste

When it comes to recycling, steel is far ahead of any other building material in the United States. “Each year, steel recycling saves the energy equivalent to electrically power about one-fifth of the households in the United States for one year” (Steel Recycling Institute). The steel industry’s overall recycling rate is nearly 85%. This includes the recycling of cans, automobiles, appliances, construction materials, and many other steel products. All new steel products contain recycled steel. In 2011, almost 65 MMT of steel were recycled or exported for recycling (Steel Recycling Institute). According to the Steel Recycling Institute 98 percent of structural beams and plates and

70 percent of reinforcing steel were recycled in 2009. Recycled steel can be melted down and be added to other steel mixes to make other steel products.

Steel can also be reused directly. Direct reuse is the best use for steel because it reduces the amount of energy need to make new steel out of the recycled steel. However, direct reuse is difficult to achieve because there are many different sizes of structural steel and they normally come in unique lengths.

2.5.3.1 Barrier

There isn't much of a barrier standing in the way of recycling steel. Most steel is recycled in the United States and it is very efficient. However, if direct reuse of the same size structural steel can be used again, it would save energy and cost. This would be a hard task because every building has a different structural load that is unique and therefore many different types of steel are needed at many different lengths.

2.5.3.2 Strategy

(1) Technical strategies to overcome the barriers

One strategy would be to design more buildings that are similar in shape and structure. This would allow for more common sizes to be used and it would be much easier to reuse structural steel. In order to make this strategy work, the designers would have to be convinced to stick to more basic structural designs. The aspect that makes this difficult is that all structures have their own unique load that needs to be supported. However, it is possible to categorize steel structures in different styles that have a range for the load that is needed to support.

(2) Political strategies to overcome the barriers

Since steel is so recyclable, not many political strategies are going to be brought up any time soon in the government to require steel to be directly reused. However, if energy conservation becomes a key issue, the government might start to make requirements that cut down on the energy use to produce steel from recycled steel. This is highly unlikely in the near future, but is possible.

(3) Other strategy to overcome the barriers

An ecological incentive for contractors would be to directly reuse the recovered steel from a deconstruction project on their next project. This would reduce the cost of transporting the steel to the plant and also get rid of the purchasing cost for the pieces of steel. The steel would have to meet the specification requirements and be approved for use before it goes into the new structure. However, this could be a great way for contractors and owners to save money while reducing the amount of energy used to make new steel.

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ANNEX 1

Overcoming the barriers to deconstruction and materials reuse in New Zealand

John B. Storey and Maibritt Pedersen

Centre for Building Performance Research, Victoria University of Wellington

ABSTRACT

This paper discusses the ways in which deconstruction and materials reuse could contribute to achieving significant reductions in landfill waste. It outlines the general and New Zealand specific barriers to realisation and discusses ways in which these barriers might by overcome.

KEYWORDS: Deconstruction, Barriers, Solutions, New Zealand

INTRODUCTION

New Zealand is a country of 4 million people, living in an area of 268,021 square kilometres, which is roughly equivalent to the state of Oregon in the USA. It consists of two main islands, is 1600 kilometres (1000miles) in length and is located some 1300 kilometres (800 miles) east of Australia. Auckland is the only conurbation of more than one million people although there are two other conurbations with populations of more than 350,000 and a further three with populations in excess of 100,000 people. These centres are distributed along the entire length of New Zealand, although three quarters of the population lives on the slightly smaller north island. Away from the generally quite small central business districts (CBDs), urban settlement is dispersed and mainly of one or two storey light timber frame construction. Construction within CBDs employs the full range of building materials and construction systems utilised internationally. Population is dispersed and travel distances can be quite large.

Main population centres in New Zealand

The NZ government, in their recently released policy document *The New Zealand Waste Strategy – Towards Zero Waste and a Sustainable New Zealand*[i], requires a 50% reduction by weight in construction and demolition waste going to landfills by 2008, but it has as yet no force in law and offers no strategies for accomplishing this objective. The Ministry for the Environment expect to produce a consultative regulatory document sometime in 2004 and may enact legislation on this topic thereafter but there is no certainty.

Although the often quoted figure for construction and demolition waste in New Zealand is only 17%[ii] of municipal solid waste generation, this figure does not include C&D waste taken to privately owned 'cleanfill' dumps or illegal dumping of C+D waste and does not include figures from all Territorial Authorities. Dumping charges vary widely, with some being free for hardfill and in other situations over $NZ 100 per load. Often cleanfill dump rates are very much cheaper than municipal landfill rates[iii]. So the actual figure for C+D is much higher than the 17% quoted.

Currently the government's main motivation for reducing C+D waste is to reduce pressure on landfills. The primary idea behind the notion of deconstruction is the careful disassembly of existing buildings to maximise the value and quantity of recovered equipment, elements, components and materials for reuse or recycling so if widely adopted it can provide a significant way to enable the New Zealand Government to realise its stated intentions with regard to C+D waste.

De-construction of existing buildings is more labour intensive than demolition and provides increased employment opportunities, which is also supports government policies.

The implementation of waste minimisation policies is the responsibility of local Territorial Authorities in New Zealand rather than the direct responsibility of Central Government, and over half of the Territorial Authorities(TAs) in New Zealand have in fact gone a step beyond the government policy document and declared that they will aim to have zero waste by 2015. Unfortunately none of the TAs responsible for the main urban centres have yet agreed to this proposition. However, it is an encouraging sign for the future and the notion continues to receive the encouragement of Central Government.

The concept that we can reduce waste generation and resource depletion and maximize the utilization of our existing material investments does not seem to be part of government thinking at this point in time. Nevertheless it obviously makes good sense from a national perspective both economically and environmentally to do so. So the signs are positive with regard to waste minimisation in New Zealand but the linkages to deconstruction and the opportunities for resource conservation through, materials and component recovery which are implicit in de-construction strategies do not seem to have yet been widely recognised. There are in fact quite a number of barriers to the widespread adoption of de-construction strategies in New Zealand, none are insurmountable give the current governmental and local authority interest and support in this sector.

The current government in New Zealand has already made a commitment to further innovation and scientific research through the 'Science and Innovation policy of 2002'[iv]. It states: 'A key goal of this policy is to actively promote economic transformation. It also aims to further our understanding of our environment, and effectively contribute to solving the social challenges we face.'[v] This is a potential starting point for researchers or innovators to secure funding.

Legislation

Existing legislation related to construction and demolition waste minimisation is spread throughout a number of acts, policies and targets. A helpful way for people to realise their responsibilities would be the creation of a comprehensive document encompassing all environmental policy related to the construction industry so it becomes clear and useful.

The lack of specifications for reused components and the difficulty in acquiring council approval for building consents is cited as a barrier to their incorporation into new development[vi]. Often local councils will be unsure or will not approve[vii] recycled components especially in relation to structural use and energy efficiency considerations. Certainty in terms of achieving New Zealand Building Code compliance with reuse materials and components needs to be thoroughly researched systems put in place to remove this barrier for people wanting to reuse components salvaged from demolition jobs. The development of accepted standard specifications and certification for reused components and materials would save time and confusion in the approval process.

The *New Zealand Waste Strategy* was published in 2002. A target of 50 % reduction of the 2005 C+D waste figure going to landfill by 2008 was included as one of the stated aims, however The Ministry for the Environment who prepared and promulgated the document states:

'The strategy acknowledges the limits of the information on which the targets are based. It indicates that the targets should be considered as "goal statements rather than mandatory requirements". The targets are to be reviewed by December 2003. In the meantime councils are encouraged to set their own targets in line with those in the strategy. This request recognises that it may be impractical for local targets to be the exact equivalent of the provisional national targets.'[viii]

The annual amount of C+D waste is currently unclear and really the first job is to establish an accurate database. Central government is encouraging this. The target date for completion of this phase of the work is 2005 but there is no legislation to back up this request. The Ministry for the Environment is currently evaluating which areas of waste reduction are priority targets for incorporation into legislation in the next 12 to 18 months. With regard to the target set for construction and demolition waste, the Ministry has stated that:

'This target is one of the secondary stream of targets in the Strategy, in that reduction is not expected to be achievable immediately. The Ministry has initiated a Waste Management Planning project that will provide a base for this work to proceed in the near future.'[ix]

The Ministry acknowledges that no action has yet been undertaken in this area.[x] It is unclear why the Ministry regards C+D waste as a second priority issue. It is generally perceived that the waste strategy needs be enforced by some level of legislation, and followed up by additional transitional support and funding.

Without common national guidelines, technical backup and a legislative base from which to operate, each local authority establishes and implements waste minimization and management strategies within their local area. These schemes vary widely in terms of their effectiveness, and can and are changed at the political whim of both elected officers and non-elected officials. However the publication of the national waste strategy has highlighted the issue indicated central government thinking on the issues and initiated considerable and widespread debate concerning C+D waste amongst local authorities.

Currently construction and demolition waste has only been addressed seriously by a few of the councils, in particular those of the larger cities such as Auckland, North Shore, Hamilton and Christchurch.[xi] Some smaller councils have also made attempts to address construction and demolition waste by working in close collaboration with neighbouring councils primarily to establish a larger market for recovered materials and components. These councils tend to be in higher density areas or in areas which are adjacent to the main centres but some progress has been made to form a viable consortium to address the issues of C+D waste in the rural areas in the very north of New Zealand. For some areas, particularly in the smaller, more isolated areas of the country, or where little development is occurring, construction and demolition waste is less of a percentage of the total waste stream and therefore is regarded as less of a priority to target for action.[xii]

Markets

Unless there is a market for recovered materials there is very little point to de-construction so any barriers to establishing, maintaining and developing markets strikes at the very heart of the viability of de-construction.

There are two distinct market sectors related to resource recovery, each with their own characteristics and issues. Markets for low volume, high value, rare, unique or antique architectural components appear to be well established or developing, and are largely self supporting economically. This sort of recycling occurs nationally almost irrespective of the size and financial circumstances of the locality. Many of these recyclers will pass customers on to other similar organizations if they do not have the items the client requires. Native timber and bricks are also often held in the salvage yards of demolition contractors. The market for such items is flourishing and it is often difficult to meet demand. Equipment and machinery is often recovered from buildings and often pre-sold before removal.

Some recovered materials are high volume, low volume, such as concrete. The market for such materials in New Zealand is currently restricted and is mainly in Auckland where there is a shortage of readily accessible, local aggregate. For more geographically isolated areas with low or dispersed populations it is more difficult for the salvaged goods market to grow due to the scale of economy and the inherent physical and economic problems of transporting heavy and bulky items to larger centers. [xiii] Growth in these areas would require subsidies which would have the effect of distorting the market and would be unlikely to find favour in current conditions. It may be possible for interested local authorities to combine together on a regional basis to increase the volume of materials being recovered, make it financially viable to purchase more efficient recovery equipment, which could travel around the region as necessary to building sites or temporary holding dumps and use the recovered materials their own projects. The obvious advantage in this approach is that transportation of the heavy unprocessed C&D waste is kept to a minimum, and in more isolated areas premiums for storage may be less than in the major cities. Direct sales for the processed material from the site of processing will mean transportation is again minimised and should be encouraged. They might also provide free or very low cost dumping of separated clean C+D waste which would facilitate future recovery once volumes or market conditions permitted this[xiv]. Some of the smaller northern councils have already formed collaborative forums on waste minimisation to ensure greater markets and increased cooperation.[xv] Grants from central government might be necessary to encourage the smallest or most remote local authorities to initiate and maintain a waste minimisation programme as service to the community even if it was not financially viable.

Another possible solution to this problem of small spread out community and markets is to encourage innovation. One of the problems identified by some of the councils, particularly those involved with the Zero Waste programme is that the collection, sorting and treatment of waste is less of an issue that finding uses for it afterward.[xvi] If new and diverse, localised uses for waste C&D material can be identified and developed this may help to solve the problem of how to deal with waste in smaller communities. Some councils have hired consultants for local market opportunity research,[xvii] and some are currently in the process of looking into opportunities in their own regions. The authors are involved in teaching a university course in which one of the assignments is to invent and develop a new material or product using waste.

There would appear to be resistance amongst the general public and designers and even amongst many builders to use pre- used materials. This is a world wide problem and is of course not a single problem but a series of interlinked issues which collectively have the effect of inhibiting the use of pre-used materials and components and making their use the exception rather than the rule at least in new buildings.

With the public there seem to be two contradictory influences at work. New Zealand has in general terms the same consumerist attitudes and perceptions as the rest of the westernized society. The notion that pre-used is inferior and that wear makes items undesirable and unfashionable seems pervasive and is perhaps the inevitable result of years of advertising which has consistently lauded the new and fashionable.

This is counteracted to a certain extent in New Zealand by the perception that many new building materials are not as durable as older materials. This is particularly true of items such as native hardwood which is now only available in recycled form. This recycled timber is much sought after and commands high prices. There seems to be little resistance to the use of pre-used items in alterations to existing buildings where there is a need to match what is already there. However the market for pre-used items in new buildings remains small but this may be more a result of what owners think of as being appropriate rather than a resistance to the reuse of materials. There is no known research concerning whether people living in older houses have a different attitude to the reuse of materials compared with those living in new houses in New Zealand. Such research could be very important in establishing a wider market for pre-used materials as education could then be targeted into correcting misapprehensions amongst the public at large.

Amongst designers the imperatives appear to be somewhat different. Certainly designers are very fashion conscious and may well be resistant to the employment of obviously pre-used materials and components unless they, as designers, are making a deliberate design statement. A growing number of designers are in fact using pre-used materials in this way, but we are still talking about a tiny fraction of the materials used in new buildings.

When materials are not seen in the final work the issue is generally one of liability. Most specifications while not specifying 'new' materials do call up the notion of them being 'the best of their kind and in compliance with the performance and durability requirements of the New Zealand Building Code'. If new materials are used and have been assessed as being code compliant then even should they fail designers and structural engineers generally feel confident that they not be held liable for material failures. However with reused materials the situation is not nearly so strait forward. Many designers feel that they are taking an increased personal risk and few are willing to do this in the absence of any pre-used materials testing or certification schemes in New Zealand.

Clients too may feel the need for the reassurance that certification brings to the employment of pre-used materials. There is a need for a grading and certification scheme at least for timber in New Zealand if markets in this area are to expand. This would also help to still the concerns of building inspectors who are often rather dubious about the employment of 'second-hand' materials and components, especially when employed in structural or drainage/plumbing situations.

For builders the main issue is the extra time and effort it takes to access and prepare pre-used materials in sufficient quantity, sizes and quality. It is far easier and more convenient for them to ring up a builder's merchant. The obvious answer might be for builder's merchants to stock pre-used materials and components but this is unlikely to happen in the foreseeable future as the two main chains of builder's merchants are owned by large, diversified companies who produce or import many new building materials and so have a vested interest in selling new product, preferably their own. Therefore builders or designers have to access pre-used materials from small specialist outlets which tend to carry relatively small amounts of stock. A builder may have to access several different suppliers and even then matching materials seen in the finished work can be very difficult.

As can be readily appreciated clients and designers need to be quite determined to use pre-used materials and components if they are to be employed in new buildings as the principal benefit is resource conservation rather than cost saving and the extra time, effort and risk involved to the designer is rarely recognized in fee payments. Yet unless the demand is there the market will not grow and de-construction will remain the exception rather than the rule.

As central government and many local authorities are committed to waste reduction, which is synonymous with resource conservation then they need to help the market to grow. If they insisted that a proportion of pre-used materials were used in all public works then market conditions would change overnight, the exception would become the rule. If the market demand was there many of the other problems and issues either fall away or there would be enough commercial interest to solve them. Certification of pre-used materials could either be organized through industry groups or the Building Industry Authority which promulgates building controls in New Zealand. Research into pre-used materials and recycled/ virgin mixes would add certainty. Some of this might need to be from public good research funds but once a market was established commercial organizations would probably fund research their in their own market sector.

Several demolition contractors have identified that a major driver for increasing materials salvage comes from the local government.[xviii] Some demolition contractors have stated that if specific quotas for amounts of recycled material to be used in new roading or development and in turn such quotas were introduced into the demolition or deconstruction phase of development it would lead to a more stable and stronger market for the C&D salvage market.[xix] This does in fact already happen in some areas of the country but it is occurring only in pockets. It needs a concerted national push and coordination by central government if such measures are to have a major effect.

It is unlikely in the New Zealand context that legislation would be enacted that would require private buildings to incorporate pre-used materials. So persuasion is required,

education to explain the benefits to the community and the individual of resource conservation and to correct misapprehensions help concerning the long term viability of pre-used materials and to turn around the public's negative impressions concerning 'second hand' materials.

One of the 'information and communication measures and actions' of the NZ Waste Strategy strategy programs, is to 'develop and implement programs for public information and education'[xx]. It is perceived that there is a lack of resources to effectively deal with waste and waste minimisation education. Environmental education that does occur is usually localised and many councils and community groups would like to see more direct central government leadership in this area with the provision for and encouragement of standardised national environmental education in the primary, secondary, tertiary and continuing professional development areas. [xxi]

There is a perceived lack of New Zealand specific information and case study examples concerned with implementing de-construction. The government could fund the production of such documentation as part of its information and education strategy.

The Construction and Demolition Industry

The construction and demolition industries in New Zealand are largely unregulated at present. This means there are no enforced professional standards, or codes of ethics in place[xxii]. This is beginning to be addressed particularly by the demolition industry through the NZ Demolition Contractors Association's push for nationally recognized qualifications and the development of a standard code of ethics.[xxiii] However NZDCA is generally perceived as an Auckland organization rather than a nationally representative organization by many demolition contractors in other parts of the country.

There is a general lack of networking within the industry which may be a result of the contractors operating in a very competitive market, the localized nature of most demolition contracting organizations and great disparities in the skill levels across the industry.[xxiv] Survival is the prime motivator for most demolition contractors and issues such as waste minimization and environmental responsibility are generally not seen as a priority[xxv] The building industry as a whole is very fragmented and hierarchical, with little meaningful dialogue between architects and designers or builders and demolition contractors. Increased cooperation and networking may facilitate greater understanding of life cycle issues in design and construction and help to engender a greater level of collective environmental responsibility by the industry particularly relationship to achieving a greater understanding of the direct impact design has on demolition.

Several demolition contractors contacted have stated that if buildings and internal components were easier to disassemble there would be greater materials salvage and possible reuse[xxvi]. This call for increased design for deconstruction and disassembly is an issue that designers, and tertiary architecture and design teaching establishments need to take on board. Currently however there is little discussion of these issues in tertiary institutions or within CPD environments. Very little research is currently being carried out concerning suitable designs and construction practices. It is probably true to say that the design professions and most tertiary educators in New Zealand are ignorant of life-cycle resource conservation and deconstruction and demonstrate little will to take these issues aboard. In the absence of leadership from either the professions or tertiary providers on this issues it may be that regulation may be required to ensure progress. However there are some individuals and organisations who have demonstrated an interest and one step forward may be to simply provide a vehicle for cross industry dialogue to occur perhaps leading to the development of a pan industry organization to address the whole issue of waste minimization and resource recovery. It is known that a number of research proposals are currently being considered by central government in this sector.

Economic Factors

In the last few years there has been an increase in salvage undertaken in the demolition industry. The primary driver in all cases is economic rather than environmental[xxvii]. The main barrier to further development in this area is also however economic. There is considerable variation from region to region concerning the economics of resource recovery.[xxviii]

In some of the larger centers such as Auckland and Christchurch where an increase in salvage has been noted among demolition contractors[xxix], one of the main sources of profit is in the on-selling of the salvaged materials and the avoidance of high tipping fees. This is particularly relevant in Auckland where salvage rates of up to 95% are achieved by the larger companies such as Ward demolition.[xxx] In some cases in the highly competitive market, tenders are offered at a price lower than the cost of demolition with the profit coming from the salvage sold.[xxxi]

In centers such as Wellington however, the lower cost of raw materials means a less stable and profitable salvage market. This, combined with the increased health, safety and operational requirements and lower landfill charges makes comprehensive resource recovery less viable in most commercial situations. Salvage in these circumstances is restricted to only the highest value materials such as native timber, metals, lime mortared brickwork and some easily removed fixtures and fittings.[xxxii]

Strengthening the salvage market through some of the options already discussed, such as recycled component quotas would help to turn this situation around but often the real problem in the commercial sector is the unwillingness of developers to allow sufficient time for deconstruction rather than demolition to occur. In many cases developers are working with borrowed money, at high interest rates and endeavour by every method possible, to shorten their loan period and so maximise their profits. Demolition requires a resource consent in New Zealand and some local authorities are considering the introduction of the requirement of for mandatory waste minimisation plans to be lodged and adhered as a condition for granting resource consent [xxxiii]. Such a procedure will only be meaningful however if markets are available for the recovered materials. The notion of a percentage of the materials from the demolished building being reused in the new building which replaces the preexisting building has not been considered by even the most forward thinking local bodies as yet.

Many of the larger demolition companies have a large workyard and storage of recovered materials prior to sale did not appear to be an issue. However in small communities it may be that local authorities will need to be proactive in the provision of sorting stations, storage facilities, and perhaps organize the processing and on sale of recovered materials.

Moratoria or relief from local taxes can also be an effective way of ensuring the economic viability of recycling organization particularly at startup.

Another option which is common in other countries but is currently relatively rare in New Zealand is for demolition jobs to be advertised, ahead of time. Salvagers, community groups and the public are allowed to take as much as they can, using their own time and labour, paying as they leave with their acquired wares. This is a form of on site selling which is successful in a variety of different forms. There are however health and safety issues involved and with the strict regulation of these matters in New Zealand this is not seen as a preferred option in most circumstances. However prior notice would allow individuals and organizations to identify the salvaged items they wish to purchase for removal by professionals. One major organization in Auckland, Nikau Deconstruction Engineers Limited, has a sales manager who secures sales for large, specialised or unusual equipment before the job even begins, so that goods can be transported straight from the site, thus avoiding additional transportation and storage costs. Sometimes these sales will go offshore to places like Malaysia.[xxxiv]

Technical Issues

Often lack of detailed information on the actual materials and construction systems employed in a building adds to the uncertainty of deconstruction which may affect both its technical and economic feasibility. While the original contract drawings are usually available and will give much valuable information, substitution of materials noted in the specification is common, as are unrecorded changes which occur during the life of the building. There is no easy, workable answer to this problem except to stress the need for a careful and thorough pre-demolition survey by skilled staff. Currently all buildings require a pre-demolition survey to establish whether or not there are any hazardous materials incorporated into the works and so that a plan for its removal can be established and agreed as part of the resource consent process and this could be easily extended into a condition survey which would verify or reveal variances between the archived documentation and the reality in terms of materials and construction.

There has been some discussion concerning the possibility of applying the notion of extended producer responsibility (EPR) to building products which would mean that the original manufacturer would be responsible for recycling their' products, and the national waste management strategy document sees this as a long term possibility. Superficially this is an attractive notion, however unlike cars and other consumer products building products often have an extended lifespan and their manufacturers may well go out of business long before building products come to the end of their lives. Often the components or systems used where EPR might be most sensibly employed are manufactured overseas which would make enforcement difficult if not impossible. There are however some possibilities in relation to items with a short lifespan such as proprietary equipment. This might be a particularly effective solution if these items were leased rather than bought which is an increasingly common way of dealing with interior fit out elements and could easily be extended to services installations, and kitchen and bathroom equipment.

Quite a number of new materials coming into New Zealand from overseas are given subsidies in their country of origin and this makes it difficult for recovered materials and products to compete. This is particularly difficult for a country like New Zealand to deal with as it seeks to avoid subsidies and tariffs.

The use of composite materials chemical bonding and other non-reversible building techniques continues to expand. All such methodologies make the de-construction of the building more difficult. This is a fundamental problem which could be addressed by insisting that all manufacturers of such systems develop a safe, cost effective method of dis-assembly before they are allowed to market their product. Such a law is unlikely to be initiated in New Zealand but possibly could be introduced by the European Union.

Universal Barriers to Deconstruction

Barrier	How this relates to NZ	Solutions
1 Legislation:		
Current standard specifications	Standards give the impression that new materials must be specified.	Development of standard specifications etc., which incorporate reused/recycled Document and publish examples of the successful use of reused and recycled components Government and local council as examples in new development.
The tightening up of Health and Safety legislation	Increased OSH regulations may effectively prevent the hands on nature of deconstruction through time delays and additional safety equipment costs.	*NZ:* Cooperation between OSH and environmental architecture advocates ensuring maximum safety and environmental practice. Subsidies for implementation of OSH requirements in deconstruction.
The lack of a grading system for reused components	Native timbers and bricks are generally used in non-structural situations.	Development of a grading system Training in the grading of reused materials. Liability issue addressed
2 Education/research:		
Designer/public/builder attitude: 'new is better' and new buildings are permanent.	The majority of building materials specified and used in NZ are new. Design for deconstruction uncommon	Education for architects in life cycle considerations and holistic design principles. General education of public, designers and builders. Easy to use guides in the use of salvaged materials/design for deconstruction. Publishing and compilation of research into quality aspects of reused goods.
lack of design for deconstruction	International research is not always applicable to NZ. There is a lack of example cases built in NZ. Design for deconstruction is not taught at architecture	Education of architects and designers through CPD / competitions / conferences / exhibitions / case studies etc. Education at architecture schools. Development and sharing of teaching resources and case study examples.

	schools	*NZ:* Republication of the NZIA life cycle environmental impact charts to the internet
Lack of information and tools to implement deconstruction.	There is a lack of NZ specific documents or information kits for the implementation of deconstruction, specific feasibility studies or clear NZ example cases.	Compilation of guides, development of implementation ideas. Clear ways to implement NZ Waste Strategy targets are needed. Increased pilot studies and test cases Strategic planning to address barriers.
Difficulty in securing funding for research	The Ministry for the Environment. The Science and Innovation Policy	Governments and funding agencies need to make waste minimisation a priority.
3 Economics/Market:		
Guaranteed quality/quantities of reused materials are difficult.	Smaller areas of NZ are more geographically isolated. The scale of economy is not large enough to sustain a large salvage market.	Increased networking of salvage businesses/builder's merchants. Increased deconstruction *NZ:* See NZ specific barriers section
Lack of financial incentive for deconstruction		Implementation of economic incentives and deterrents to encourage deconstruction.
The benefits of deconstruction are long term and collective	Current climate of first cost only economic development.	Enforceable legislation and increased requirements in building consent approvals Government set measurable and monitored targets Increased education on environmental building impacts for developers.
Market pressures - the current climate of 'as fast as possible'	Limited time to salvage maximum materials in the demolition stage. Deconstruction takes longer.	Subsidies to demolition contractors – transitional only Salvage operations to work alongside but independently of demolition contractors. Transferal of environmental responsibility to developers.
The high cost of transport and storage of recycled components and materials.		Market networking. Direct sales from site.
It is difficult to access or apply economic assessment tools for de-construction or LCA in some cases.	There are no NZ specific deconstruction evaluation tools or national feasibility studies.	Collection of existing tools in one place. Possibly website. Development of non-region-specific tools or more flexible parameters.

		NZ: The development or adaptation of deconstruction economic viability tools for NZ A deconstruction economic viability feasibility study for NZ
Lack of communication and networking in the C&D industry	Unregulated, and largely uncooperative, hierarchical C&D industry.	Greater communication, networking and collaboration. Increased conferences, email discussion groups, networking, professional articles publications etc.
Deconstruction needs a more skilled workforce than demolition	Unregulated demolition industry Lack of case jobs to train on.	Increased opportunities for training and transition from traditional demolition to deconstruction. Cooperation between the construction and demolition sectors.
4 Technical Issues:		
Most existing buildings are not designed to be deconstructed.	This is true in NZ.	Research and development to find ways to effectively deconstruct these buildings. Implementation of design for deconstruction techniques into learning establishments a priority.
Increased use of insitu technology, chemical bonds and plastic sealants etc.	Commonly used in new buildings in NZ. Most concrete structures have insitu components.	Research viable alternatives to these techniques. Development of ways to separate these bonds
Uses for some salvaged materials are undeveloped.	Finding uses for some recycled or salvaged materials is difficult	Increased research focusing on problem materials.
Lack of documentation	Records of materials used in construction are not kept.	Better recording of materials used Storage of records in the actual building

NZ specific barriers

Barrier	Solutions
Confusion as to what Government / NZIA etc legislation is, relating to environmental responsibility	Compilation of all NZ environmental policy/targets etc related to construction Clarification of The NZ Waste Strategy targets
Waste management is a local council responsibility. This means there is no national direction.	Increased central government support and direction
Inconsistent units of measurement in local waste data	Clear, standardised units to be developed to make a national database
C&D waste minimisation is not a priority for some local councils / central government	Support given to councils to move towards greater waste minimisation (zero waste) Education seminars. lobbying of central government to change the priority waste rankings Reports to identify barriers to increased C&D waste minimisation and market opportunities.
Low tipping rates (including cleanfill).	Tipping rates need to come into line with the true cost of disposal. Use of 'The landfill full cost accounting guide' MfE Many local governments have already introduced 'user pays' waste schemes and increased tipping fees.
Some new materials are cheap	NZ has no control over foreign systems or subsidies. True cost research to establish taxes for imported materials either at import or retail stage. Central and local governments to specify materials which do not undercut the salvage market.
NZ's small, dispersed population and geographic isolation.	Cooperation between smaller areas to increase markets. Mobile recycling / processing plants Identification of local market opportunities.
NZ is in a high seismic activity region.	Research into systems that work in seismic areas.

[1] Ministry for the Environment *The New Zealand Waste Strategy, Towards zero waste and a sustainable New Zealand.* Ministry for the Environment, Wellington, New Zealand, 2002.
[1] Ministry for the Environment, *National Waste Data Report, May 1997,* Ministry for the Environment, Wellington, New Zealand, 1997
[1] For example in the Tauranga District, tipping rates are approximately $98 per tonne at landfill and approximately $10 per tonne at the cleanfill.
Kliskey, Murry, Solid Waste, Senior engineering Officer, Tauranga District Council, *personal phone conversation,* 31/01/03.

[1] Labour Party New Zealand, *Science and Innovation Policy 2002,* http://www.labour.org.nz/fb.asp?url=http://www.liveupdater.com/labourparty/LABOURpol-economy.asp
[1] Labour Party New Zealand, *Science and Innovation Policy 2002,* http://www.labour.org.nz/fb.asp?url=http://www.liveupdater.com/labourparty/LABOURpol-economy.asp
[1] Owles, Randel, General Manager, Ward Demolition, Auckland *personal correspondence,* 22/01/03
[1] New building and renovation requires a building consent, which is approved by local authorities in NZ in accordance with the non prescriptive *NZ Building Code*.
[1] Ministry for the Environment, *National Targets for Priority Waste Areas,* http://www.mfe.govt.nz/issues/waste/content.php?id=97
[1] Ministry for the Environment, *National Targets for Priority Waste Areas,* http://www.mfe.govt.nz/issues/waste/content.php?id=97
[1] Ministry for the Environment, *National Targets for Priority Waste Areas,* http://www.mfe.govt.nz/issues/waste/content.php?id=97
[1] Christchurch City Council has set up 'Target Zero'. This is a resource efficiency/waste minimisation initiative working with Christchurch businesses to save money and reduce environmental impacts. They have set up a construction waste minimisation directory, conducted construction waste reduction case studies, and commissioned reports into the C&D waste stream and recommendations from consultants.
Phillips, Laine, Resource Efficiency Advisor, Christchurch City Council, *personal phone conversation,* 22/01/03.

Christchurch City Council, *Target Zero*, http://www.ccc.govt.nz/TargetZero/

REBRI – Resource Efficiency in the Building and Related Industries is an initiative jointly funded by the Auckland Regional Council, Auckland City Council, BRANZ and the Ministry for the Environment.

Auckland Regional Council, *REBRI,* http://www.arc.govt.nz/arc/environment/waste-&-recycling/rebri.cfm

Christchurch City Council, *Target Zero*, http://www.ccc.govt.nz/TargetZero/

[1] David Reece, Engineer/Services Manager, Opotiki District Council, *personal correspondence,* 22/01/03

[1]Bradshaw, Deborah, Policy Planner, Nelson City Council *personal correspondence*, 22/01/03

Kearney, Matt, Refuge Consultant, Far North District Council, *personal correspondence,* 22/01/03

Longworth, Mike, Resource Engineer, Masterton District Council, *personal correspondence*, 22/01/03

Reece, David, Engineer/Services Manager, Opotiki District Council, *personal correspondence,* 22/01/03

[1] This issue was sited as a major barrier by representatives from the Nelson City Council, Far North District Council, Masterton District Council, and Opotiki District Council. All of these councils are relatively small in the NZ context.
Bradshaw, Deborah, Policy Planner, Nelson City Council *personal correspondence*, 22/01/03

Kearney, Matt, Refuge Consultant, Far North District Council, *personal correspondence,* 22/01/03

Longworth, Mike, Resource Engineer, Masterton District Council, *personal correspondence*, 22/01/03

Reece, David, Engineer/Services Manager, Opotiki District Council, *personal correspondence,* 22/01/03

[1] The Auckland region councils work for example together in various ways, meeting, sharing information and supporting each others', or collaborative projects. Some of these councils are large city based councils such as the North Shore City Council. Others like the Rodney District Council are smaller without a large city based population.
Harris, Julie, Zero Waste Officer, Rodney District Council, *personal telephone conversation,* 22/01/03
[1] Reece, David, Engineer/Services Manager, Opotiki District Council, *personal correspondence,* 22/01/03
Schafer, Helen, Zero Waste Coordinator, Porirua District Council, *personal correspondence,* 22/01/03

[1] Phillips, Laine, Resource Efficiency Advisor, Christchurch City Council, *personal phone conversation,* 22/01/03.

[1]Edge, Allan, Director, Southern Demolition, Christchurch *personal correspondence,* 22/01/03

[1] Owles, Randel, General Manager, Ward Demolition, Auckland *personal correspondence,* 22/01/03

[1] Ministry for the Environment *The New Zealand Waste Strategy, Towards zero waste and a sustainable New Zealand.* Ministry for the Environment, Wellington, New Zealand, 2002, pp 30
[1] Schafer, Helen, Zero Waste Coordinator, Porirua District Council, *personal correspondence,* 22/01/03

[1] Edge, Allan, Director, Southern Demolition, Christchurch *personal correspondence,* 22/01/03

[1] Carter, Helina, Service Manager, New Zealand Demolition Contractor's Association, *personal correspondence,* 22/01/03
[1] Kendrick, Terry, Director, Harbour City Demolition, Wellington *personal correspondence,* 22/01/03
Edge, Allan, Director, Southern Demolition, Christchurch *personal correspondence,* 22/01/03

Ross, Steve, Manager, Nash and Ross Contractors Ltd, Dunedin, *personal correspondence,* 22/01/03

[1] Kendrick, Terry, Director, Harbour City Demolition, Wellington *correspondence,* 22/01/03
[1] Kendrick, Terry, Director, Harbour City Demolition, Wellington *correspondence,* 22/01/03
[1] Owles, Randel, General Manager, Ward Demolition, Auckland *personal correspondence,* 22/01/03

Edge, Allan, Director, Southern Demolition, Christchurch *personal correspondence,* 22/01/03
Ross, Steve, Manager, Nash and Ross Contractors Ltd, Dunedin, *personal correspondence,* 22/01/03
[1] Kendrick, Terry, Director, Harbour City Demolition, Wellington *correspondence,* 22/01/03

Owles, Randel, General Manager, Ward Demolition, Auckland *personal correspondence,* 22/01/03

[1] Owles, Randel, General Manager, Ward Demolition, Auckland *personal correspondence,* 22/01/03

Edge, Allan, Director, Southern Demolition, Christchurch *personal correspondence,* 22/01/03

[1] Owles, Randel, General Manager, Ward Demolition, Auckland *personal correspondence,* 22/01/03
[1] Carter, Helina, Service Manager, New Zealand Demolition Contractor's Association, *personal correspondence,* 23/01/03
[1] Kendrick, Terry, Director, Harbour City Demolition, Wellington *personal correspondence,* 22/01/03
[1] This is being investigated as part of the 3 year proposal by Auckland, Waikato and Canterbury councils, however we are not allowed to publish any details of this until it is confirmed so a reference becomes difficult.

[1] Carter, Helina, Service Manager, Nikau Deconstruction Engineers, Auckland *personal correspondence,* 23/01/03

ANNEX 2

Survey of Deconstruction Operations by Building Materials Reuse Organizations in the US

Brad Guy

School of Architecture and Planning, The Catholic University of America

U.S.A.

Introduction

This survey of deconstruction operations by both non-profit and for-profit entities was sent to building materials reuse stores across the US via an online survey service. There were 21 respondents. Some questions were not answered by all respondents and certain questions allowed multiple answers, therefore the number of responses varied. Answers are aggregated in order to maintain confidentiality regarding respondents' operational procedures.

Characteristics of Respondents

The respondents were 60% non-profit organizations, and 40% for-profit. This provides the background that the operational procedures reported in the survey were used in both organizational contexts. The average number of full-time employees who spent part of their time in deconstruction activities was 6.8 employees per organization. The smallest number of employees in a responding organization who spent time on deconstruction was 1 (new start-up), and the largest number was 25.

Experience and Numbers of Deconstruction Projects

All the respondents (100%) conducted deconstructions as part of their reuse facility operations. The average age of deconstruction operations was 4.9 years as of 2008. The longest that a responding operation had conducted deconstructions was 14 years and the shortest period of operation was 1 year (new start-up). The average annual number of salvage or deconstruction projects per organization was 37, with the smallest at 1 project (new start-up) and the largest was 200 projects per year. The median number of projects was 16 per year. If one excludes the organization that conducts 200 salvage/deconstruction projects per year, as an outlier, the most projects per a single organization was 75 projects per year, and the average number of projects per year was 27. It is important to note that projects can range from a small 'strip-out' lasting a few hours to a full-house deconstruction lasting days or weeks.

Deconstruction Clients

Approximately 50% of the responding organizations mainly work in urban areas. The majority of deconstruction project clients are private homeowners; 78.9% of respondents provided deconstruction services to **private middle-income home owners**; 73.7% provided services to **private high-income home owners**; and 68.4% provided services to **commercial building owners**. Public agencies were served by 42.1% of the responding organizations. Private homes are attractive markets for deconstruction services as sources of residential building products that in turn are readily reusable by the general public for residential rental property repairs and owner-occupant do-it-yourself projects. When the deconstruction service is operated by a non-profit organization or affiliated with a non-profit, the donation of the recovered materials by the homeowner can become a tax-deductible non-cash charitable contribution. This tax-deduction in turn is an economic incentive for the use of higher-cost deconstruction services as compared to demolition. In the absence of this incentive, it is notable that 42.1% of the responding organizations still provided services to government agencies.

Disposal Costs

One of the factors that support deconstruction as a means to remove buildings is the cost of construction and demolition debris disposal. Deconstruction avoids disposal costs through materials recovery, therefore the higher the local disposal costs the more economically attractive deconstruction becomes. None of the respondents operated where the disposal cost was less than $40 per ton for construction and demolition debris, and **73.7% of the respondents operated where disposals costs ranged from $40 to $80 per ton**. The remaining 26.3% of the respondents operated where disposal costs exceeded $80 per ton. High disposal costs favor deconstruction services, but nonetheless the majority of these respondents operate deconstruction services in spite of disposal costs that are not at the highest range. This highlights that while disposal costs are important, the efficiency of operations, wage levels, and value of salvage are also equally if not more important once disposal costs reach a certain threshold such as $40 per ton.

Procuring Projects

Deconstruction projects are obtained by a variety of means, however four main methods were reported by the respondents: **word of mouth via contractors** (100% of organizations); **word of mouth via homeowners** (94.7% of organizations); **organization website** (84.2% of organizations); and **reuse store customers** (78.9% of organizations). Although only 42.1% of respondents reported conducting deconstruction projects for government agencies, 68.4% reported obtaining projects through local government sources. A majority (52.4%) of respondents reported obtaining projects via advertisements. This information provides some guidance for best use of resources and outreach – to target building contractors for projects such as renovations, have a website, and recognize the reuse store as a means to advertise deconstruction services, via information about the service at the store, and the presence of stocks of materials sold at the store that come from deconstruction projects.

Deconstruction Procedures

The remainder of the survey was devoted to technical details about the organizations' deconstruction operations. In general the 'picture' that is painted of the most common procedures used by the responding organizations is as follows. Please see the appendix for the full survey responses.

- If the deconstruction operation works to obtain materials from external sub-contractors, it typically engages in only loading and transporting the materials from the project site.
- The salvage and deconstruction work, whether on-site deconstruction and/or processing on or off-site, is mainly carried out by **paid employees**. In addition warehouse processing of de-nailing lumber is also mainly done by employees.
- The second-most commonly reported labor source for deconstruction and/or processing is paid contractors.
- The deconstruction process is typically conducted using **hand-labor only**, without the use of heavy equipment.
- If panelization, i.e. cutting wood-frame assemblies into panels for removal by heavy equipment is used, it is for roofs and exterior walls.
- If equipment is used to assist the deconstruction process the most common piece of equipment is a **telescopic forklift**, also known as a hi-lift or high-reach forklift. It is worth noting that a telescoping fork-lift can also be used in a yard with sufficient maneuvering room.

- The most common method for loading and removing salvage is to **park a trailer or truck at the site and load it as work progresses**, and then remove the truck or trailer when a full load is obtained.
- By a small margin, the second-most common method of materials removal is to process and leave materials on-site until a full load is obtained, and then load the truck or trailer and remove it at that same time.
- The most common method of processing lumber is to **de-nail and package the materials on-site and remove as stacked and bundled** ready for storage in the reuse facility.
- By a small margin, the second-most common method is to de-nail the lumber materials and stack loose, un-bundled for delivery to the reuse facility. The distinguishing feature between these two methods is that in the un-bundled method the loading at the deconstruction site can take place without a forklift. A forklift can still be used to unload at the reuse facility with either bundled or un-bundled lumber as long as it is stacked in preparation for using the forklift.
- The most common method for removing non-lumber materials such as architectural elements from the site is either loose or boxed loosely and thereby using hand-labor to load and unload. The distinction here is relatively clear between non-structural salvage 'soft-strip' that does not produce significant lumber and full-house structural deconstruction which produces significant quantities of lumber.
- The most common means of transport for salvaged materials is a **stake-bed truck**.
- The second-most common means of transport for salvaged materials is either a trailer or a box truck. When a trailer is used the most popular size is 16' length.
- If a forklift is used for unloading salvaged materials at a warehouse or reuse facility the most common rating is from 1.25 to 2.5 tons or in other words from 2,500 to 5,000 lbs capacity.
- The use of volunteers and temporary labor is reported by the respondents considerably less than use of employees. For deconstruction activities, slightly more respondents **use volunteers for deconstruction and processing on-site** as compared to those reporting use of temporary labor.

Survey Responses

Notes: "Response Count" is total number of responses to the question.

Question 1

Does your organization conduct building deconstruction projects or receive deconstructed materials? (includes removal of structural elements)		
Answer Options	**Response Frequency**	**Response Count**
Yes	100.0%	20
No	0.0%	0

Question 2

How many years have you been engaged with building deconstruction?		
Answer Options	**Response Average**	**Response Count**
Years	4.89	19

Question 3

How many deconstruction projects do you do or get deconstructed materials from in an 'average' year?		
Answer Options	**Response Average**	**Response Count**
Number	37.00	18

Question 4

Is your organization?		
Answer Options	**Response Frequency**	**Response Count**
For-profit	40.0%	8
Non-profit	60.0%	12

Question 5

Number of full-time equivalent employees who spend any part of their time conducting deconstruction?		
Answer Options	**Response Average**	**Response Count**
Number	6.80	20

Question 6

What is your service area?		
Answer Options	**Response Frequency**	**Response Count**
Urban	50.0%	10
Suburban	30.0%	6
Rural	20.0%	4

Question 7

What are the population(s) you mainly provide deconstruction services to? (choose all that apply)		
Answer Options	**Response Frequency**	**Response Count**
Private Middle-income	78.9%	15
Private High-income	73.7%	14
Private commercial	68.4%	13
Public agencies	42.1%	8
Non-profit organizations	31.6%	6
Private Low-income	26.3%	5

Question 8

What are construction debris disposal costs in your area? (choose one)		
Answer Options	**Response Frequency**	**Response Count**
Less than $40/ton	0.0%	0
$40 - $80/ton	73.7%	14
$80 - $100/ton	10.6%	1
Over $100/ton	15.8%	3

Note: For purposes of comparing a price per container to a price per ton, on average a 20 cubic-yard (CY) container will contain approximately 5 tons of debris, a 30 CY container will contain 7.5 tons, and a 40 CY container will contain 10 tons.

Question 9

How do you obtain deconstruction projects? (choose all that apply)		
Answer Options	**Response Frequency**	**Response Count**
Word of mouth via building contractors	100.0%	19
Word of mouth via private homeowners	94.7%	18
Organization website	84.2%	16
Reuse store customers (yours or others)	78.9%	15
Local government	68.4%	13
Advertisement to general public	52.6%	10
Word of mouth via commercial building owners	47.4%	9
Realtors	47.4%	9
Housing or other non-profit partners	47.4%	9
Other organizations' websites	26.3%	5
Other	5.3%	1

Question 10

Do you engage in on-site sales?		
Answer Options	**Response Frequency**	**Response Count**
Yes	36.8%	7
No	63.2%	12

Question 11

If you also work with external private contractors for deconstruction services how do you typically obtain the materials? (choose all that apply)		
Answer Options	**Response Frequency**	**Response Count**
Load and transport only from deconstruction sites	66.7%	8
Process, load and transport materials from deconstruction sites	50.0%	6
Receive deliveries only from deconstruction sites	33.3%	4
Transport only from deconstruction sites	25.0%	3

Question 12

Who does the majority of your on-site deconstruction activities? (choose all that apply)		
Answer Options	**Response Frequency**	**Response Count**
Employees	85.0%	17
Private contractor	20.0%	4
Volunteers	15.0%	3
Temp labor	10.0%	2

Question 13

How are building structures typically dismantled in your projects?		
Answer Options	**Response Frequency**	**Response Count**
Hand-removal only	70.0%	14
Panelize and hand-separate	25.0%	5
Panelize	5.0%	1

Question 14

If you panelize buildings – which parts of building? (choose all that apply)		
Answer Options	**Response Frequency**	**Response Count**
Roof	33.3%	4
Walls (exterior)	25.0%	3
All of the above	16.7%	2
Walls (interior)	8.3%	1
Floors	8.3%	1

Question 15

What is your preferred or most commonly used heavy equipment for deconstruction? (choose all that apply)		
Answer Options	**Response Frequency**	**Response Count**
Telescopic fork-lift (reach or hi-lift)	44.4%	8
None	33.3%	6
Skid-steer (Bobcat)	27.8%	5
Aerial lift (man-lift)	22.2%	4
Track-hoe	11.1%	2
Front-end loader	5.6%	1

Question 16

For bigger projects, do you? (choose one)		
Answer Options	**Response Frequency**	**Response Count**
Not applicable	44.4%	8
Use the same piece of equipment to dismantle and load	33.3%	6
Use separate equipment to dismantle and to load	22.2%	4

Question 17

For very large and long-term projects how do you load and remove materials? (choose all that apply)		
Answer Options	**Response Frequency**	**Response Count**
Do you park truck/trailer to load as you go and remove only when full?	44.4%	8
Do you process until you have a full load and then load and remove in one event?	38.9%	7
Do you load truck/trailer and remove loads on a time-based schedule (daily, weekly?)	33.3%	6
Other	16.7%	3

Question 18

What extent of wood-framing processing on average occurs on-site? (choose one)		
Answer Options	**Response Frequency**	**Response Count**
De-nailed pieces, packaged (bundled or strapped)	38.9%	7
De-nailed pieces, loose (not bundled or strapped)	33.3%	6
Un-de-nailed pieces	22.2%	4
Panels (moved elsewhere for processing)	5.6%	1

Question 19

Do you use de-nailing guns or other specialized wood processing equipment on-site?		
Answer Options	**Response Frequency**	**Response Count**
Yes	84.2%	16
No	15.8%	3

Question 20

If you use equipment other than a de-nailing gun to process lumber on-site, what is it?	
Answer Options	**Response Count**
1. We use 20 CY cans to load and move materials to yard for processing. 2. Hammers, cat's paws, pliers. 3. Burke bar.	3

Question 21

Who does the majority of processing on-site? (choose all that apply)		
Answer Options	**Response Frequency**	**Response Count**
Employees	77.8%	14
Private contractor	16.7%	3
Volunteers	16.7%	3
Temp labor	11.1%	2

Question 22

How do you typically package architectural elements (fixtures, cabinets, doors, windows, etc.) for transport from site?		
Answer Options	**Response Frequency**	**Response Count**
Loose or boxed (hand-load/un-load)	81.3%	13
Stacked and strapped or loosely stacked in racks/boxes (requiring equipment to load/un-load)	18.8%	3
Other	0.0%	0

Question 23

How do you typically package lumber for transport from site ?		
Answer Options	**Response Frequency**	**Response Count**
Stacked and strapped or loosely stacked in racks/boxes (requiring equipment to load/un-load)	52.6%	10
Loose or boxed (hand-load/un-load)	47.4%	9
Other	0.0%	0

Question 24

How do you package brick, stone, and block for transport from site?		
Answer Options	**Response Frequency**	**Response Count**
Palletized loosely (requiring equipment to load/un-load)	56.3%	9
Loose or boxed (hand-load/un-load)	43.8%	7

Question 25

How do you recycle metals from site?		
Answer Options	**Response Frequency**	**Response Count**
Process and remove to recycling facility	83.3%	15
Outsource to metal scrapper for site removal	16.7%	3

Question 26

Preferred or most commonly truck use for transporting deconstruction materials? (choose all that apply)		
Answer Options	**Response Frequency**	**Response Count**
Stake-bed truck	73.7%	14
Trailer	52.6%	10
Box truck	52.6%	10
Roll-off container	10.5%	2
Other	5.3%	1

Question 27

For box-truck, stake-bed or trailer what size do you most commonly use?		
Answer Options	**Response Frequency**	**Response Count**
16’	44.4%	8
20’	22.2%	4
24’	16.7%	3
12’	11.1%	2
Over 24'	5.6%	1
N/A	0.0%	0

Question 28

Which types of deconstruction materials processing occurs at warehouse / store? (choose all that apply)		
Answer Options	**Response Frequency**	**Response Count**
De-nailing lumber	61.1%	11
Cleaning appliances, cabinetry, sinks, toilets, etc.	44.4%	8
Testing appliances, electrical, lighting, etc...	38.9%	7
Manufacturing value-added items from raw materials (furniture, bird houses, picture frames, kindling, etc.)	22.2%	4
Repairing items (broken cabinetry, etc...)	16.7%	3
None	11.1%	2
Dismantling panels	5.6%	1
Removing lead-based paint	5.6%	1
Repairing appliances	0.0%	0

Question 29

Who performs the majority of processing activities at warehouse / store? (choose one)		
Answer Options	**Response Frequency**	**Response Count**
Employees	81.3%	13
Temp labor	12.5%	2
Volunteers	6.3%	1
Private contractor	0.0%	0

Question 30

If use one for unloading at warehouse, what size or rating forklift do you use?		
Answer Options	**Response Frequency**	**Response Count**
1.25 to 1.5 ton	40.0%	4
2.25 to 2.5 ton	30.0%	3
4 ton	10.0%	1
5 ton	10.0%	1
9 ton	10.0%	1

ANNEX 3
Design for Reuse of Building Materials in the U.S.A.

Brad Guy

School of Architecture and Planning, The Catholic University of America
U.S.A.

Summary

The reuse of building materials is recognized as a means to reduce environmental impacts when substituting for new materials and avoiding waste. Reuse is also readily practiced on a daily basis in formal and informal ways for economic and social benefits. In spite of these benefits and the presence of formal and informal systems of reuse, the reuse of building materials in the US Green Building Council Leadership in Energy and Environmental Design LEED™ green building rating system is one of the least attempted or achieved credits. A survey was completed among US architects, designers, governmental officials and operators of reused building materials firms in February-March, 2009 in an attempt to understand the attitudes of architects towards reused materials and the lack of the use of reused materials in LEED™ building projects. A goal of this survey was to be able to make recommendations to the US Green Building Council and the US green building industry to increase the use of reused materials. Alternatively, it may be that the obstacles or drivers for the use of reused materials are outside the influence of the LEED™ rating system.

Keywords: deconstruction, reuse, recycling, building materials, LEED

1. Introduction

It is generally perceived that reusing materials is an effective means to reduce the environmental impacts of building materials and prevent waste. Reuse extends the life of an object for continued functional service past its first use. The U.S. Environmental Protection Agency (US EPA) has established the hierarchy of reduce, reuse, and recycle, and considers reuse to be a form of source reduction, preferable to recycling or other forms of waste management [1].

When a building is renovated or demolished, materials and products may be removed and / or destroyed in these processes that have remaining service life. This premature end-of-service can be overcome by salvage or deconstruction to recover the materials in a manner that will allow them to be used elsewhere on the project site or off-site. These materials may be able to perform the equivalent function of a new product for an extended period, even if not the full service life of a new product. A product used in a building design life scenario of 25 years that can achieve a service life of 50 years through a second use will result in a 50% reduction in manufacturing environmental burden on a yearly basis, or in other words a two-fold increase in utility over its actual life for an equivalent environmental input. The difference between *design* service life, *predicted* service life, service life, and *actual* life for a building or components can be integral to the efficient or inefficient use of material resources and their ability to be reused [2].

If the predicted service life of a reused product has been exceeded in the first use life span, then it may not be able to provide an equivalent performance to a new product in the same use. Reuse of materials in different uses than the original intended design function can avoid the issue of service life altogether. Examples in this category might be the reuse of a door as a table, or an exterior window sash as an interior cabinet door. In both cases the reuse will not be required to provide the durability performance of the original intent for the product. This approach provides for greater flexibility and hence more opportunities for reuse and a greater service life overall.

Avoiding the purchase of new goods by repair of existing products or the purchase of surplus or reused goods at lower prices is practiced daily in informal and formal systems. E-bay (www.ebay.com), Craigslist (www.craigslist.org), and Freecycle (www.freecycle.org) are examples of popular Internet-based US national systems for the person-to-person exchange or sale of second-hand goods. Used books are a well-known form of reuse with both second-hand books shops and electronic sales through Amazon.com for example. Thomas found that in the US, for every one new home sold, five existing homes are sold, and that approximately for every one new automobile sold, two and one-half used cars are sold [3]. As of May, 2010, the Habitat for Humanity International (HfHI) organization reported 707 ReStores in the US and Canada [4]. A study by Michael, et al, in 2005, identified 215 ReStores [5]. This is a 329% increase over a period of 5 years. According to the The HfHI ReStores website:

"ReStores sell reusable and surplus building materials to the public… most focus on home improvement goods like furniture, home accessories, building materials and appliances. ReStore resale outlets accept donated goods which are sold to the general public… proceeds help local Habitat affiliates fund the construction of Habitat homes within their communities" [6].

In life cycle assessment (LCA) methods reuse and recycling can be modeled as an end-of-life waste management strategy of a material and / or in terms of the utilization of the reused or recycled material as an input to a 'new' material or product. In the case of recycled feedstock for the manufacture of the new product, its contribution is avoided impacts determined by the difference in environmental burdens of the new materials creation and the recycled materials processing – for the percent of recycled materials in the product [7]. The reuse of a product (if assume that its use avoids the purchase of a new material) is in effect 100% recycled content.

Recycled feedstock may or may not result in a reduced environmental burden from new materials, depending upon the intensity of the recovery and recycling processes and the materials for which it substitutes [8]. Reuse will typically result in lower environmental impacts based on processing impacts. Either recycled feedstock or reuse can result in higher environmental impacts compared to new materials or for other options for the use of the material when there is an excessive transportation burden associated with the reuse [9].

2. Green building standards and reuse

2.1 US green building standards

Major national US green building standards or codes include:

1) US Green Building Council Leadership in Energy and Environmental Design (LEED™) 2009 [10]

2) ASHRAE 189.1-2009 Standard for the Design of High Performance Green Buildings [11]

3) International Code Council International Green Construction Code v2.0 (IGCC) [12]

4) ANSI/GBI 01-2010 Green Building Assessment Protocol for Green Buildings [13]

5) ICC 700 National Green Building Standard [14]

Materials-based credits in these green building rating systems codes typically incorporate the use of reused materials or recycled-content building materials as a prescriptive measure. ASHRAE 189.1-2009 rewards recycled-content but not reused materials. The IGCC rewards "Used Materials" under the provisions of the *International Code Council Performance Code for "*alternative materials and methods". ANSI/GBI 01-2010 provides credit for "Off-site Salvaged Materials". ICC 700 National

Green Building Standard rewards the use of “Salvaged Materials”. All of these standards or codes also have a provision for use of LCA for the materials-use of the building.

In a materials or whole-building comprehensive life cycle assessment (LCA) perspective, a recycled-content product which has high environmental impacts in its original form may allow for greater threshold of processing in order to realize environmental benefit, whereas an original product of low environmental impacts may not achieve an equivalent benefit from recycled feedstock beyond a certain processing input threshold [15].

As LCA methods are further developed and incorporated into green building standards, the attribute of reused or recycled-content will disappear, to be replaced by the environmental impacts of global warming potential, water use, resource depletion, and multiple ecological or human toxicity impacts, among other environmental impact categories. In the current time, the prescriptive measures of reused material or recycled-content are relatively easy to understand and document in comparison to conducting LCA studies.

2.2 The low rate of achievement of materials reuse in LEED™

Excluding the prerequisite P1 Storage and Collection of Recyclables, which is a building operation credit, there were seven credits in the Materials and Resources category in LEED v 2.2 that relate to the design and construction of the building [16]. Credits 1, 2, 3, 4, 5 each have multiple points available for tiered levels of achievement in that category.

- MRc 1 Building Reuse
- MRc 2 Construction Waste Management
- MRc 3 Material Reuse
- MRc 4 Recycled Content
- MRc 5 Regional Materials
- MRc 6 Rapidly Renewable
- MRc 7 Certified Wood

In spite of the environmental and potential economic benefits of reused materials, and green building standards as an incentive for reuse, it is one of the least attempted or achieved strategies in the LEED™– New Construction (NC) rating system to-date. In an analysis of credit achievement rates for 100 randomly chosen LEED™-NC v2.2 projects shown in Table 1, it was determined that credit MRc 3 Materials Reuse was the least attempted or achieved credit in the Materials and Resources category [17].

The average rate of achievement of the first tier for multi-tier points credits and the single point credits was 48%. The first-tier credit achievements for MRc 3 Material Reuse and MRc 4 Recycled Content in this study of 100 LEED™ projects were as follows:

- MRc 3.1 was attempted by 10% of projects with a 90% success rate, resulting in 9% achievement.
- MRc 4.1 was attempted by 89% of projects with a 97% success rate, resulting in 86% achievement.
-

The MRc 4 Recycled Content Materials credit uses the same metric as the MRc3 Materials Reuse credit. This metric is based on the percent of total value of material and was purposefully created to facilitate the documentation for this credit. In order to avoid the calculation of the total value of all materials, a project may use a default value of 45% of total project costs as the total materials cost.

The project team must then only calculate the value of the types of materials for which it is seeking credit.

Table 1 MR credit achievement of 100 randomly chosen LEED™-NC v 2.2 projects

MR Credit	P1	1.1	1.2	1.3	2.1	2.2	**3.1**	**3.2**	4.1	4.2	5.1	5.2	6	7
achieved	100	14	5	0	89	65	**9**	**6**	86	46	88	72	12	38
denied	0	3	1	1	1	7	**1**	**1**	3	4	2	5	1	2
attempted	100	17	6	1	90	72	**10**	**7**	89	50	90	77	13	40
%														
achieved / attempted	100	82	83	0	99	90	**90**	**86**	97	92	98	94	92	95
denied / attempted	0	18	17	100	1	10	**10**	**14**	3	8	2	6	8	5
attempted / 100	100	17	6	1	90	72	**10**	**7**	89	50	90	77	13	40
achieved / 100	100	14	5	0	89	65	**9**	**6**	86	46	88	72	12	38

Given that LEED™ is the dominant green building rating system in the US, it has a powerful impact on both defining green building and in driving markets for green building goods and services [18]. However given the lack of achievement of the material reuse credits in LEED™, it becomes a question whether LEED™ has had much impact on encouraging reuse of materials in the green building market. In an attempt to investigate the relationship between reuse of materials, the use of LEED™ by architects, and constraints to material reuse, a survey was conducted in February-March, 2009.

3. Background and development of survey

3.1 Precedents for building materials reuse challenges and opportunities

Using reused or reclaimed materials pose unique challenges compared to any new material. This may explain why the credit categories for new materials even with enhanced environmental performance via attributes such as recycled-content, rapidly renewable materials, regional sources, and lumber certified by the Forest Stewardship Council are more readily attempted in LEED™. A significant reduction in environmental impacts of the built environment will not be attained unless greater utility is made from existing buildings and existing materials not just new materials with enhanced environmental performance.

A series of studies and surveys by the author over a period of years have been undertaken to attempt to correlate economic, social and environmental factors to the reuse of building materials.

3.1.1 Factors influencing reuse

Previous surveys of the deconstruction and reuse industry have provided general perspectives into the issues of building materials reuse. Insights generated by the author from practical experience, analysis of US Economic Census data, and industry surveys in the US include:

- Reused building materials stores are low-margin businesses or non-profits and limited by the variability of their supply at any given time, which in turn is limiting to traditional design and building practices.
- The market for reused materials is correlated with high poverty and low median income of those seeking low-cost materials which in turn are offered "as-is" without warranties or other performance guarantees.
- The most direct "subsidy" for the reused building materials industry is high disposal fees.
- Environmental claims are a significant driver for reused building materials.
- Education and outreach are two priorities for increasing the reuse of materials.

3.1.2 **Characterization of deconstruction and reused building materials establishments**

In a telephone survey by the University of Florida of over 1,400 deconstruction and reuse companies, in spring 2003, questions were asked related to demolition, deconstruction, used building materials and value-adding activities using reclaimed materials in order to better understand the "state of the industry." The percentage listed is the percentage of respondents who gave the responses listed in Table 2.

Table 2. Survey of US demolition, deconstruction, reused building materials companies, 2003.

What do you think is the biggest obstacle for the deconstruction and reuse / recycling building materials industry?	
Education	19.4%
Markets (matching supply and demand)	13.9%
Costs of labor	11.1%
Environmental regulations	11.1%
Perceptions of low quality	8.3%
Storage needs	8.3%

These previous studies provided questions for a series of surveys over several years to the attendees at the Building Materials Reuse Association (BMRA) US conferences in 2004 and 2007. In addition, the survey which is the subject of this paper also included the same questions regarding challenges to the reuse of building materials, Table 4. Using this consistent set of parameters has allowed for comparisons over time.

Table 3. Obstacles to building materials reuse.

	2004	2007	2009
Lack of public's knowledge	-	-	38%
Time to conduct deconstruction	25%	21%	35%
Obtain viable projects	8%	8%	24%
Low disposal costs	11%	14%	18%
Time / costs for hazardous materials abatement	9%	10%	18%
Lack of knowledge / costs of environmental health & safety	10%	6%	12%
Insurance / liability / bonding	11%	12%	11%
Disreputable / unsafe companies	11%	3%	6%
Methods of construction	6%	11%	5%

4. Materials reuse survey, 2009

In 2009 a survey was undertaken by the author in consultation to Public Architecture, Inc. to ascertain some of the factors that influence the reuse of building materials. The target for the survey was architects / designers, the building materials reuse industry, and then local governmental agencies. The factors listed in Table 3 were included as choices in the survey, along with the opportunity to write in other choices.

The survey was conducted from February to March, 2009. Invitations were emailed to approximately 1,400 entities in the categories of: 1) designer / builder (500); 2) government agency (100); 3) deconstruction / reuse firm (800). The survey was placed on the Survey Monkey on-line service (www.surveymonkey.com). In the group "architect / designer" there were 198 respondents, a 39.6% response rate. These firms self-reported specialty as: architecture – 143; design / build 9; architecture/engineering – 28; interior design - 13; landscape architecture – 10; and consulting - 18. This totals to more than 198 because some firms replied with more than one specialty. In the group of "deconstruction / reuse store" there were 132 respondents, a 16.5% response rate. In the group of "governmental agency" there were 29 respondents, a 29% response rate.

4.1 Architects

Approximately 75% of respondents had completed at least one reused materials project. Over 40% of respondents had completed 2 to 5 projects using salvaged materials, and 25% reported never using reclaimed materials.

Chart 1. Percent of firms using reused materials by number of projects.

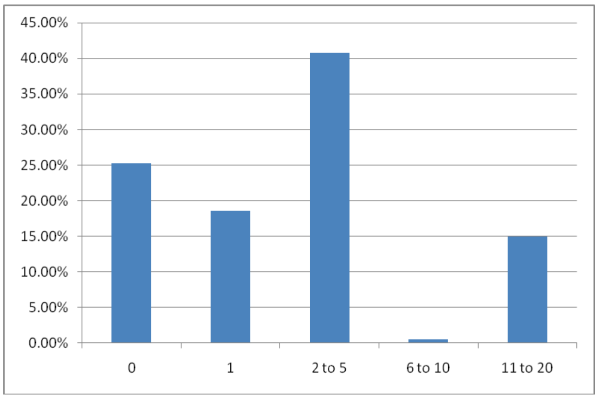


Chart 2. Challenges to reused materials by architects who have used reused materials at least once.

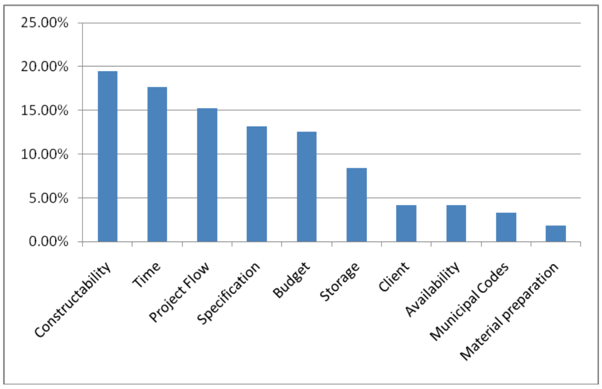
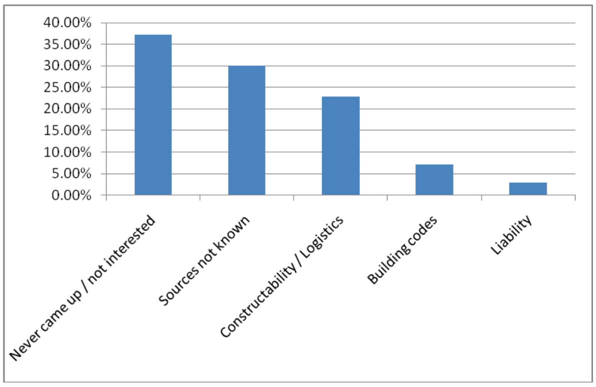


Chart 2. Illustrates the challenges to using reclaimed materials from the perspective of the architects who have used reused materials. "Constructability" ranked first, 19% of responses, followed by "time", 17% of responses, and "project flow", 15% of responses.

Firms who reported never having used salvage materials, Chart 3, cited as the principal reason that reused materials "never came up" or the client was "not interested", 37% of responses. The second most frequently cited reason was "sources not known", 30% of responses, followed by "constructability / logistics", 23% of responses.

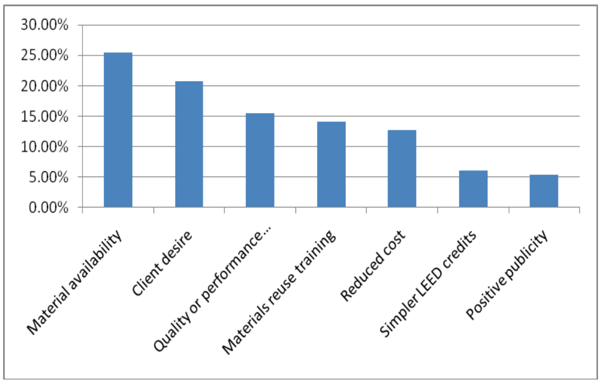
Chart 3. Challenges to using reclaimed materials by architects who never used reused materials.



After accounting for lack of client interest, "sources not known" is cited as the greatest challenge to architects who have not used reclaimed materials. This might suggest that lack of knowledge of sources is a barrier to entry but not a barrier to implementation once the architect has done at least one project, Chart 2.

This is borne out by Chart 4 which illustrates that for architects who have never completed a project, the first priority would be in knowing the availability of materials.

Chart 4, Types of support that would incentivize use of reclaimed materials for firms who never used reclaimed materials.



Influences on decision to use reclaimed materials and the perceived benefits gained are relatively consistent for firms who have used reclaimed materials at least once, Chart 5 and 6. Approximately 17-18% of responses were for aesthetics and reduced environmental impacts. Reduced materials costs ranked 3rd in both cases, 12-14% of responses. The achievement of LEED™ credits ranked 5th in importance in both cases. Availability of materials is not cited as a major influencing factor for firms who have used materials on at least one project

Chart 5. Influences on decision to use reclaimed materials per percent of firm noting listed factor.

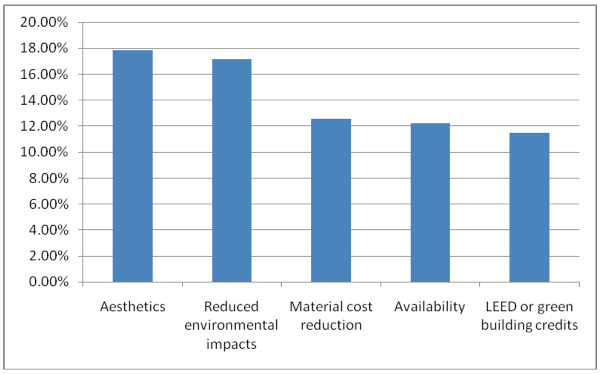
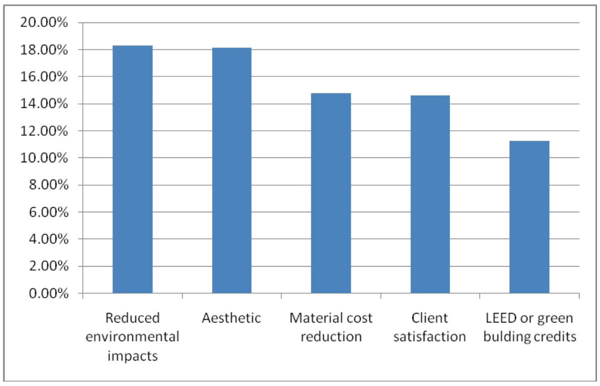


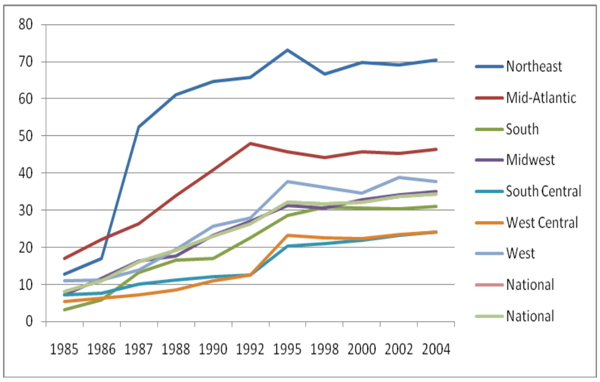
Chart 6. Benefits gained from use of reclaimed materials per percent of firm noting listed factor.



One potential factor for the reuse of materials might be the presence of high disposal costs that in turn will increase the quantity, variety and possibly the quality of reclaimed materials. The Northeast and Mid-Atlantic regions of the US have the highest average solid waste disposal fees, Chart 7. The State of California has had significant regulations regarding the diversion of waste from landfill including construction and demolition (C&D) debris since 1989, with the California Integrated Waste Management Act of 1989 (AB 939). However, California does not have the highest disposal fees.

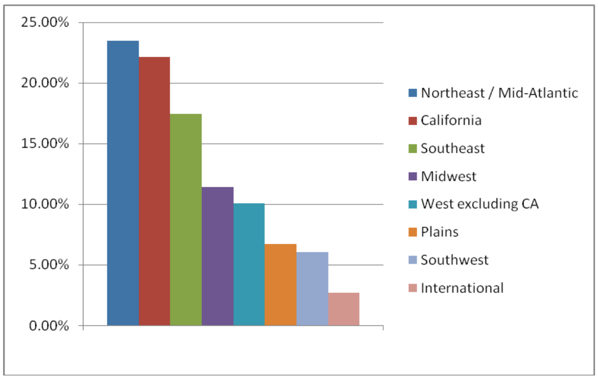
The ABA 939 law mandated local municipal governments in California to meet a total solid waste diversion goal of 50% by 2000 This historical legislation included provisions for creating a robust infrastructure in the State of California for the recovery, reuse and recycling of building materials. [19].

Chart 7. Waste disposal fees per ton by US region [20].



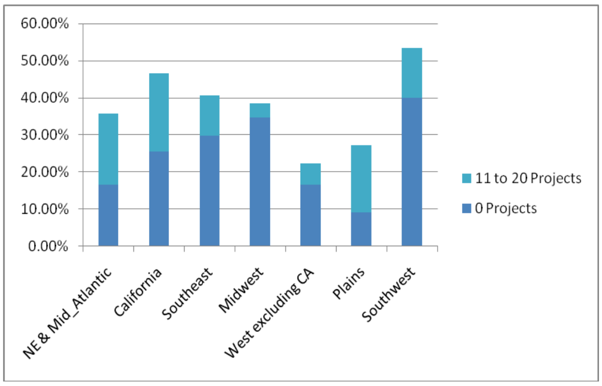
The respondents who used reused materials at least once were located approximately 23% in the Northeast / Mid-Atlantic; 22% in California; 17% in the Southeast; 11% in the Midwest; and 10% in the West excluding California, Chart 9. The two regions with the highest tipping fees and the State with the strongest legislation regarding C&D debris diversion comprised 55% of the respondents who used reused materials at least once.

Chart 8. Percent of firms by region who have used reused materials.



California and Northeast / Mid-Atlantic firms also reported the highest percentage who have done 11 to 20 projects with salvage, Chart 9, at a total of 40% of firms. The Southwest region reported the highest percentage of firms who had never done a project with salvage, followed by the Midwest.

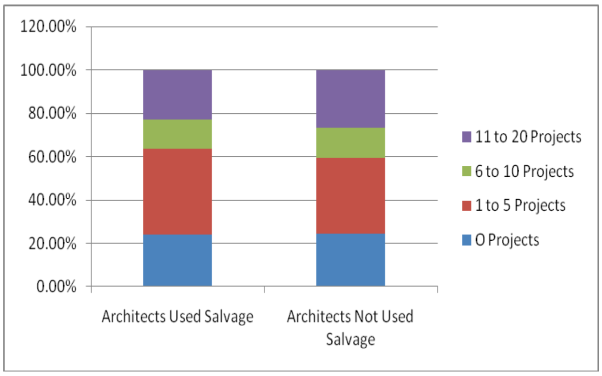
Chart 9. Distribution of number of salvage-use projects by region for firms.



4.2 LEED™ projects and reuse by firms

A comparison was made between firms who have used reused materials at least once and those who have never used reused materials, and their rate of completion of LEED™ projects. The supposition was whether or not LEED™ influences design to reuse materials among architects who regularly complete LEED™ projects compared to those architects who regularly do not complete LEED™ projects. There was no major distinction in the distribution of number of LEED™ projects completed between firms who have used salvage and those that have not used salvaged materials, Chart 10. Approximately 11% of firms who had never used reused materials reported completing 11 to 20 LEED™ projects. Approximately 12% of firms who had used reused materials reported completing 11 to 20 LEED™ projects.

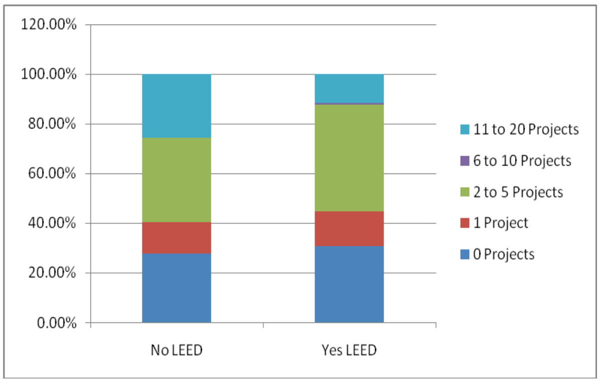
Chart 10. Distribution of numbers of LEED™ projects completed by firms who have or have not used salvaged materials.



A comparison was next made between firms who have completed at least one LEED™ projects and none, and their use of reused materials in projects. Those firms who completed at least one LEED™ project, responded as having never done a project with salvage to a greater extent than firms who did not complete a LEED™ project. Those firms who completed at least one LEED™ project also responded as having done fewer projects with reused materials than firms who have not completed a LEED™ project, Chart 11.

This survey did not ask for the exact number of either LEED™ or reused materials projects, however based on the percentages of the given range of LEED™ projects completed, firms who have not completed a LEED™ project completed more projects using salvage.

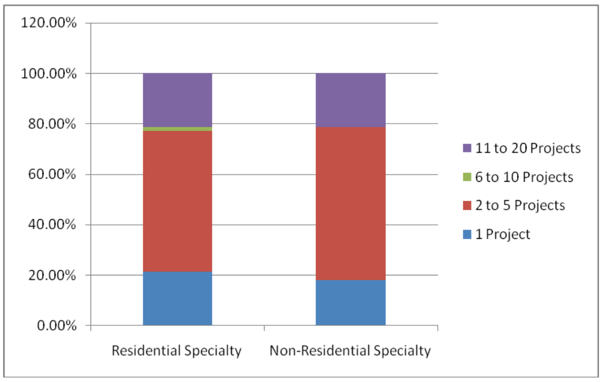
Chart 11. Distribution of numbers of salvage-use projects completed by firms who have or have not completed a LEED project.



One possible explanation for more firms who have never done a LEED™ project completing 11 to 20 projects using reused materials more often than firms who have done a LEED™ project, might be the type of work that firms specialized in. Residential buildings have opportunities for greater flexibility by Owners for materials and methods of construction than commercial buildings. The LEED™ standard for new commercial buildings has been in existence since 1998 [10]. This would suggest that firms would have had opportunities over a longer period to use reused materials in LEED™ commercial projects. The LEED™ for Homes standard has been in existence since 2007 and so while perhaps more amenable to the use of reused materials, there are fewer projects than LEED™ for commercial buildings [10].

The comparison between firms who used salvaged materials and their specialty as either residential or non-residential follows.

Chart 12. Comparison of the rate of completion of reuse projects between firms who indicated they used reused materials on at least one project, and also listed single or multi-family residential as a specialty compared to those firms who did not indicate single or multi-family residential as part of their work.



For these firms who used reused materials on at least one project, the focus on either non-residential or residential appears to make little difference in their completion rate of projects with reused materials.

5. **Conclusions**

A survey was completed of architecture and design firms in the US and their attitudes and familiarity with using reused materials. In addition, the number of LEED™ projects completed by the firms was included as a parameter to examine any relationship between LEED™ project completion and the use of reused materials. As described, the completion of LEED™ projects and use of reused building materials appeared to have no strong relationship. The evidence appears to suggest that reused building materials are more frequently employed in non-LEED rated projects. There were however correlations between firms who used reused materials and their location in regions of the US with either strong legislation regarding C&D waste diversion or high solid waste disposal costs.

Firms that report never having completed a project using reused materials cite lack of knowledge of the availability of reused materials as a principle obstacle. However for those firms who have completed at least one project, the knowledge of availability of materials apparently no longer is an important factor. Instead, once this basic knowledge is gained, the issues that affect the incorporation of reused materials become construction-related issues. Firms consistently indicate that the influences and benefits of using reclaimed materials are aesthetic and environmental benefits regardless of LEED™ credits, and the potential for lower cost materials is not a major benefit. Although LEED™ itself has been adopted by many local governments for their own buildings and in some cases for private sector construction of buildings over a certain size, it allows for many options to achieve Materials and Resources credits [21]. As an optional credit, and a requirement of 5% of materials value for the first-tier of credit, the use-rate of reused materials is very low in the LEED™ standard, relative to other credits. High disposal costs and legislation requiring C&D diversion from landfill appear to be more directly correlated to increasing use of reused materials than the achievement of LEED™ credits. The aesthetic value of reused materials also appears to be a major driver and this factor is not rewarded in LEED™. Although there are considerable environmental benefits to the reuse of materials, there are no benefits if the tactic is not employed at all because the credit threshold of 5% of total materials values is not achieved. The US Green Building Council may realize more LEED™ projects with Material Reuse if it were to lower the threshold of the first level of achievement for MRc 3 to 1%, and to develop assistance to first-time users for source of materials in their specific regions. Once firms have used reused materials, the achievement of points more readily in the LEED™ system may encourage building Owners and Contractors as well to participate in overcoming the construction-related obstacles to incorporating reused materials into projects.

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Barrier	How this relates to NZ	Solutions
1 Legislation:		
Current standard specifications	Standards give the impression that new materials must be specified.	Development of standard specifications etc, which incorporate reused/recycled Document and publish examples of the successful use of reused and recycled components Government and local council as examples in new development.
The tightening up of Health and Safety legislation	Increased OSH regulations may effectively prevent the hands on nature of deconstruction through time delays and additional safety equipment costs.	*NZ:* Cooperation between OSH and environmental architecture advocates ensuring maximum safety and environmental practice. Subsidies for implementation of OSH requirements in deconstruction.
The lack of a grading system for reused components	Native timbers and bricks are generally used in non structural situations.	Development of a grading system Training in the grading of reused materials. Liability issue addressed
2 Education/research:		

Designer/public/builder attitude: 'new is better' and new buildings are permanent.	The majority of building materials specified and used in NZ are new. Design for deconstruction uncommon	Education for architects in life cycle considerations and holistic design principles. General education of public, designers and builders. Easy to use guides in the use of salvaged materials/design for deconstruction. Publishing and compilation of research into quality aspects of reused goods.
lack of design for deconstruction	International research is not always applicable to NZ. There is a lack of example cases built in NZ. Design for deconstruction is not taught at architecture schools	Education of architects and designers through CPD / competitions / conferences / exhibitions / case studies etc. Education at architecture schools. Development and sharing of teaching resources and case study examples. *NZ:* Republication of the NZIA life cycle environmental impact charts to the internet
Lack of information and tools to implement deconstruction.	There is a lack of NZ specific documents or information kits for the implementation of deconstruction, specific feasibility studies or clear NZ example cases.	Compilation of guides, development of implementation ideas. Clear ways to implement NZ Waste Strategy targets are needed. Increased pilot studies and test cases Strategic planning to address barriers.
Difficulty in securing funding for research	The Ministry for the Environment. The Science and Innovation Policy	Governments and funding agencies need to make waste minimisation a priority.
3 Economics/Market:		
Guaranteed quality/quantities of reused materials are difficult.	Smaller areas of NZ are more geographically isolated. The scale of economy is not large enough to sustain a large salvage market.	Increased networking of salvage businesses/builder's merchants. Increased deconstruction *NZ:* See NZ specific barriers section
Lack of financial incentive for deconstruction		Implementation of economic incentives and deterrents to encourage deconstruction.

The benefits of deconstruction are long term and collective	Current climate of first cost only economic development.	Enforceable legislation and increased requirements in building consent approvals Government set measurable and monitored targets Increased education on environmental building impacts for developers.
Market pressures - the current climate of 'as fast as possible'	Limited time to salvage maximum materials in the demolition stage. Deconstruction takes longer.	Subsidies to demolition contractors – transitional only Salvage operations to work along side but independently of demolition contractors. Transferal of environmental responsibility to developers.
The high cost of transport and storage of recycled components and materials.		Market networking. Direct sales from site.
It is difficult to access or apply economic assessment tools for de-construction or LCA in some cases.	There are no NZ specific deconstruction evaluation tools or national feasibility studies.	Collection of existing tools in one place. Possibly website. Development of non region-specific tools or more flexible parameters. *NZ:* The development or adaptation of deconstruction economic viability tools for NZ A deconstruction economic viability feasibility study for NZ
Lack of communication and networking in the C&D industry	Unregulated, and largely uncooperative, hierarchical C&D industry.	Greater communication, networking and collaboration. Increased conferences, email discussion groups, networking, professional articles publications etc.
Deconstruction needs a more skilled workforce than demolition	Unregulated demolition industry Lack of case jobs to train on.	Increased opportunities for training and transition from traditional demolition to deconstruction. Cooperation between the construction and demolition sectors.
4 Technical Issues:		
Most existing buildings are not designed to be deconstructed.	This is true in NZ.	Research and development to find ways to effectively deconstruct these buildings. Implementation of design for deconstruction techniques into learning establishments a priority.

Increased use of insitu technology, chemical bonds and plastic sealants etc.	Commonly used in new buildings in NZ. Most concrete structures have insitu components.	Research viable alternatives to these techniques. Development of ways to separate these bonds
Uses for some salvaged materials are undeveloped.	Finding uses for some recycled or salvaged materials is difficult	Increased research focusing on problem materials.
Lack of documentation	Records of materials used in construction are not kept.	Better recording of materials used Storage of records in the actual building

NZ specific barriers

Barrier	Solutions
Confusion as to what Government / NZIA etc legislation is, relating to environmental responsibility	Compilation of all NZ environmental policy/targets etc related t Clarification of The NZ Waste Strategy targets
Waste management is a local council responsibility. This means there is no national direction.	Increased central government support and direction
Inconsistent units of measurement in local waste data	Clear, standardised units to be developed to make a national dat
C&D waste minimisation is not a priority for some local councils / central government	Support given to councils to move towards greater waste minim Education seminars. lobbying of central government to change t Reports to identify barriers to increased C&D waste minimisatic
Low tipping rates (including cleanfill).	Tipping rates need to come into line with the true cost of dispos Use of 'The landfill full cost accounting guide' MfE Many local governments have already introduced 'user pays' w tipping fees.
Some new materials are cheap	NZ has no control over foreign systems or subsidies. True cost research to establish taxes for imported materials eithe Central and local governments to specify materials which do no

NZ's small, dispersed population and geographic isolation.	Cooperation between smaller areas to increase markets. Mobile recycling / processing plants Identification of local market opportunities.
NZ is in a high seismic activity region.	Research into systems that work in seismic areas.

[i] Ministry for the Environment *The New Zealand Waste Strategy, Towards zero waste and a sustainable New Zealand.* Ministry for the Environment, Wellington, New Zealand, 2002.
[ii] Ministry for the Environment, *National Waste Data Report, May 1997,* Ministry for the Environment, Wellington, New Zealand, 1997
[iii] For example in the Tauranga District, tipping rates are approximately $98 per tonne at landfill and approximately $10 per tonne at the cleanfill.
Kliskey, Murry, Solid Waste, Senior engineering Officer, Tauranga District Council, *personal phone conversation,* 31/01/03.

[iv] Labour Party New Zealand, *Science and Innovation Policy 2002,* http://www.labour.org.nz/fb.asp?url=http://www.liveupdater.com/labourparty/LABOURpol-economy.asp
[v] Labour Party New Zealand, *Science and Innovation Policy 2002,* http://www.labour.org.nz/fb.asp?url=http://www.liveupdater.com/labourparty/LABOURpol-economy.asp
[vi] Owles, Randel, General Manager, Ward Demolition, Auckland *personal correspondence,* 22/01/03
[vii] New building and renovation requires a building consent, which is approved by local authorities in NZ in accordance with the non prescriptive *NZ Building Code*.
[viii] Ministry for the Environment, *National Targets for Priority Waste Areas,* http://www.mfe.govt.nz/issues/waste/content.php?id=97
[ix] Ministry for the Environment, *National Targets for Priority Waste Areas,* http://www.mfe.govt.nz/issues/waste/content.php?id=97
[x] Ministry for the Environment, *National Targets for Priority Waste Areas,* http://www.mfe.govt.nz/issues/waste/content.php?id=97

[xi] Christchurch City Council has set up 'Target Zero'. This is a resource efficiency/waste minimisation initiative working with Christchurch businesses to save money and reduce environmental impacts. They have set up a construction waste minimisation directory, conducted construction waste reduction case studies, and commissioned reports into the C&D waste stream and recommendations from consultants.
Phillips, Laine, Resource Efficiency Advisor, Christchurch City Council, *personal phone conversation,* 22/01/03.

Christchurch City Council, *Target Zero*, http://www.ccc.govt.nz/TargetZero/

REBRI – Resource Efficiency in the Building and Related Industries is an initiative jointly funded by the Auckland Regional Council, Auckland City Council, BRANZ and the Ministry for the Environment.

Auckland Regional Council, *REBRI,* http://www.arc.govt.nz/arc/environment/waste-&-recycling/rebri.cfm

Christchurch City Council, *Target Zero*, http://www.ccc.govt.nz/TargetZero/

[xii] David Reece, Engineer/Services Manager, Opotiki District Council, *personal correspondence,* 22/01/03

[xiii]Bradshaw, Deborah, Policy Planner, Nelson City Council *personal correspondence*, 22/01/03

Kearney, Matt, Refuge Consultant, Far North District Council, *personal correspondence,* 22/01/03

Longworth, Mike, Resource Engineer, Masterton District Council, *personal correspondence*, 22/01/03

Reece, David, Engineer/Services Manager, Opotiki District Council, *personal correspondence,* 22/01/03

[xiv] This issue was sited as a major barrier by representatives from the Nelson City Council, Far North District Council, Masterton District Council, and Opotiki District Council. All of these councils are relatively small in the NZ context.
Bradshaw, Deborah, Policy Planner, Nelson City Council *personal correspondence*, 22/01/03

Kearney, Matt, Refuge Consultant, Far North District Council, *personal correspondence,* 22/01/03

Longworth, Mike, Resource Engineer, Masterton District Council, *personal correspondence*, 22/01/03

Reece, David, Engineer/Services Manager, Opotiki District Council, *personal correspondence,* 22/01/03

[xv] The Auckland region councils work for example together in various ways, meeting, sharing information and supporting each others', or collaborative projects. Some of these councils are

large city based councils such as the North Shore City Council. Others like the Rodney District Council are smaller without a large city based population.
Harris, Julie, Zero Waste Officer, Rodney District Council, *personal telephone conversation,* 22/01/03

[xvi] Reece, David, Engineer/Services Manager, Opotiki District Council, *personal correspondence,* 22/01/03
Schafer, Helen, Zero Waste Coordinator, Porirua District Council, *personal correspondence,* 22/01/03

[xvii] Phillips, Laine, Resource Efficiency Advisor, Christchurch City Council, *personal phone conversation,* 22/01/03.

[xviii]Edge, Allan, Director, Southern Demolition, Christchurch *personal correspondence,* 22/01/03

[xix] Owles, Randel, General Manager, Ward Demolition, Auckland *personal correspondence,* 22/01/03

[xx] Ministry for the Environment *The New Zealand Waste Strategy, Towards zero waste and a sustainable New Zealand.* Ministry for the Environment, Wellington, New Zealand, 2002, pp 30

[xxi] Schafer, Helen, Zero Waste Coordinator, Porirua District Council, *personal correspondence,* 22/01/03

[xxii] Edge, Allan, Director, Southern Demolition, Christchurch *personal correspondence,* 22/01/03

[xxiii] Carter, Helina, Service Manager, New Zealand Demolition Contractor's Association, *personal correspondence,* 22/01/03

[xxiv] Kendrick, Terry, Director, Harbour City Demolition, Wellington *personal correspondence,* 22/01/03
Edge, Allan, Director, Southern Demolition, Christchurch *personal correspondence,* 22/01/03

Ross, Steve, Manager, Nash and Ross Contractors Ltd, Dunedin, *personal correspondence,* 22/01/03

[xxv] Kendrick, Terry, Director, Harbour City Demolition, Wellington *correspondence,* 22/01/03

[xxvi] Kendrick, Terry, Director, Harbour City Demolition, Wellington *correspondence,* 22/01/03

[xxvii] Owles, Randel, General Manager, Ward Demolition, Auckland *personal correspondence,* 22/01/03

Edge, Allan, Director, Southern Demolition, Christchurch *personal correspondence,* 22/01/03
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[xxviii] Kendrick, Terry, Director, Harbour City Demolition, Wellington *correspondence,* 22/01/03

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[xxix] Owles, Randel, General Manager, Ward Demolition, Auckland *personal correspondence,* 22/01/03

Edge, Allan, Director, Southern Demolition, Christchurch *personal correspondence,* 22/01/03

[xxx] Owles, Randel, General Manager, Ward Demolition, Auckland *personal correspondence,* 22/01/03

[xxxi] Carter, Helina, Service Manager, New Zealand Demolition Contractor's Association, *personal correspondence,* 23/01/03

[xxxii] Kendrick, Terry, Director, Harbour City Demolition, Wellington *personal correspondence,* 22/01/03

[xxxiii] This is being investigated as part of the 3 year proposal by Auckland, Waikato and Canterbury councils, however we are not allowed to publish any details of this until it is confirmed so a reference becomes difficult.

[xxxiv] Carter, Helina, Service Manager, Nikau Deconstruction Engineers, Auckland *personal correspondence,* 23/01/03

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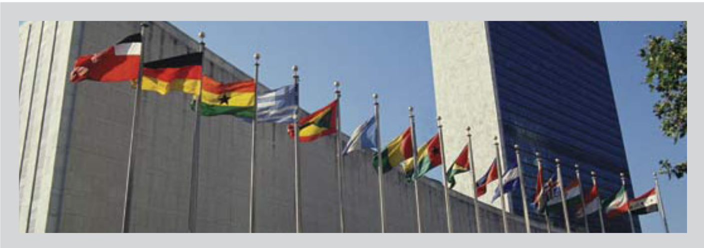

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CIB General Secretariat
Kruisplein 25-G
3014 DB Rotterdam
The Netherlands
Phone: +31-10-4110240
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CIB Task Groups and Working Commissions		**CIB Priority Themes** SC	IDDS	RU	**GEN**	**Areas of Scientific Interest** BT: BCT	BT: BPh	BBE: DB	BBE: BE	BP: MOE	BP: LPP
TG59	People in Construction									●	
TG72	Public Private Partnership									○	●
TG74	New Production and Business Models in Construction		●							●	
TG78	Informality and Emergence in Construction									●	
TG79	Building Regulations and Control in the Face of Climate Change	●		○			○	○			●
TG80	Legal and Regulatory Aspects of BIM		●								●
TG81	Global Construction Data									●	
TG82	Marketing in Construction									●	
TG83	e-Business in Construction									●	
TG85	R&D Investment and Impact				●						
TG86	Building Healthy Cities	○		●					●		
TG87	Urban Resilience: Benchmarking and Metrics	○		●					●		
TG88	Smart Cities	○		●					●		
TG89	Construction Mediation Practice										●
W014	Fire Safety			○		○		●			
W018	Timber Structures					●					
W023	Wall Structures					●					
W040	Heat and Moisture Transfer in Buildings						●				
W055	Construction Industry Economics									●	
W056	Sandwich Panels					●	○	○			
W062	Water Supply and Drainage	○				○	●	○	○		
W065	Organisation and Management of Construction		○							●	
W069	Residential Studies							●	●	●	○
W070	Facilities Management and Maintenance					●		●		●	○
W078	Information Technology for Construction		●							●	
W080	Prediction of Service Life of Building Materials and Components	○				●		○			
W083	Roofing Materials and Systems	○				●	○	○			
W084	Building Comfortable Environments for All							●	○		
W086	Building Pathology					●		○		●	
W089	Education in the Built Environment				●						
W092	Procurement Systems									●	●
W096	Architectural Management		○					○		●	
W098	Intelligent and Responsive Buildings	○	○			○		●			
W099	Safety and Health in Construction					○		○		●	
W101	Spatial Planning and Infrastructure Development	○		●					●		
W102	Information and Knowledge Management in Building		○		●					○	
W104	Open Building Implementation	○						●	○	●	
W107	Construction in Developing Countries									●	
W108	Climate Change and the Built Environment	●		●		○	○	●	●		
W110	Informal Settlements and Affordable Housing	○		●				●	○		
W111	Usability of Workplaces					○		●		○	
W112	Culture in Construction									●	○
W113	Law and Dispute Resolution										●
W114	Earthquake Engineering and Buildings	○		●		●		○			
W115	Construction Materials Stewardship	●				●		●			
W116	Smart and Sustainable Built Environments	●		●		●		●			
W117	Performance Measurement in Construction									●	○
W118	Clients and Users in Construction									●	
W119	Customised Industrial Construction									●	
W120	Disasters and the Built Environment	●		●				●	●		

Extend of Involvement of Task Groups and Working Commissions	
○ (grey)	Same of the Activities and Outcome of this Task Group or Working Commission may be of special importance to the respective Theme or Area
● (green)	Activities and Outcome of this Task Group or Working Commission in principle always are of special importance to the respective Theme or Area

Abbreviations of defined Themes and Areas

Priority Themes	
SC	Sustainable Construction
IDDS	Integrated Design and Delivery Solutions
RU	Resilient Urbanisation

Areas of Scientific Interest	
GEN	GENERAL ISSUES: Innovation, Information, Education
BT	BUILDING TECHNIQUE
BCT	Building and Construction Technologies
BPh	Building Physics
BBE	BUILDINGS AND THE BUILT ENVIRONMENT
DB	Design of Buildings
BE	Built Environment
BP	BUILDING PROCESS
MOE	Management, Organisation and Economics
LPP	Legal and Procurement Practices

CIB General Secretariat
Kruisplein 25G
3014 DB Rotterdam
The Netherlands
E-mail: secretariat@cibworld.nl
www.cibworld.nl

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