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STUDY OF THE MONGOLIAN CONTEXT AND CDW RECOVERY APPLICATIONS

Country: Mongolia

Project title: Improving resource-efficiency and cleaner production in the Mongolian construction sector through materials recovery

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I. INTRODUCTION TO THE SWITCH – ASIA II PROJECT

The booming construction industry in Mongolia has resulted in the production of massive amounts of Construction and Demolition Waste (CDW). It is estimated that this waste accounts for 20-25% of all overall solid waste produced in Mongolia. CDW is thus one of the largest waste streams in Mongolia. In Ulaanbaatar (UB) and other cities in Mongolia, the construction waste is dumped illegally. A huge part of the construction and demolition work is done by small and medium-sized contractors and subcontractors. Thus, SMEs are producing most of the CDW, and their current unsustainable approaches have negative impacts on human health and the environment in Mongolia.

In Mongolia, CDW management represents a significant challenge because the performance of SMEs in construction and demolition debris management is still poor. There are difficulties which keep SMEs away from good CDW management practices. In addition, CDW Recycling SMEs in Mongolia face a lack of knowledge and the technical capability to deal with negative environmental impacts. Furthermore, there are no specific regulations or certifications for a proper demolition of an End-of-Life (EoL) building, recycling and reuse of CDW in Mongolia.

The construction industry has expanded rapidly in recent years in Mongolia and demand for all types of construction products (from concrete to metals) is set to increase in the coming years. Currently, however, more than 50% of building materials are imported. These products have a high “carbon footprint” because they are made from new raw materials and they are transported long distances. Such imports continue (in spite of the government’s policy to increase local production) due to a lack of affordable local products. The proposed action will support the production of affordable local products made from local C&D waste, to replace imported products, thus reducing the “carbon footprint” of the construction sector and mitigating climate change.

The recycling sector in Mongolia is growing and there are around 40 recycling factories in the country, which process various waste materials, including metal, plastic and glass. Moreover, two recycling plants are being developed to process construction waste, such as concrete and bricks, to convert them into aggregate for roads and construction blocks. Several building materials producers are recycling expanded polystyrene and iron materials. However, lack of Research and Development (R&D), innovations, quality control procedures and standards hamper the expansion of the recycling sector.

The European project SWITCH – Asia II “Improving resource efficiency and cleaner production in the Mongolian construction sector through materials recovery” aims to promote sustainable production and consumption in the construction sector, through supporting SMEs to switch to more resource-efficient practices.

To achieve these objectives, different stakeholders have to be involved: SMEs in the construction industry; Waste collectors; Mongolian state institutions and MUST university.

TU Delft, in cooperation with the Mongolian partners (CCR, MUST and MNRA), conducted a study to identify the most relevant local CDW materials for successful reuse and recycling. This involved conducting a Material Flow Analysis (MFA) of CDW in Mongolia. In cooperation with MUST and the MNRA, TU Delft prepared the MFA and presented the possibilities for using recovered CDW, in accordance with European applications and standards.

Acronyms for involved organisations:

TUD	Delft University of Technology
CCR	Caritas Czech Republic
MUST	Mongolian University of Science and Technology
MNRA	Mongolian National Recycling Association

1.1 Study of the Mongolian context and C&D waste recovery application

CDW is, according to the European Commission (EC), waste that arises from activities as construction and demolition of buildings and civil infrastructure (EC, 2012). The large amount of CDW and the high potential for reuse and recycling of these materials are the reasons why the EC has given this waste stream high attention (EC, 2011a).

The European directive regarding waste (EC, 2008), sets the reuse and recycling rate of CDW to a minimum of 70% by weight to be achieved in 2020. In this study, CDW refers to the waste that appears after construction, renovation and demolition of buildings. In contrast to the definition of CDW of the European Commission, civil infrastructure is not included in this study.

To create a fast progress in CDW recycling and management in Mongolia, it is important to specify the most relevant local CDW materials, which bring higher chance, in terms of technology and economy, for a successful recycling and reuse.

Therefore, conducting a careful Mass Flow Analysis (MFA) related to the CDW in Mongolia is inevitable. Using MFA, it is possible to quantify and trace the CDW materials and distinguish the material categories that are more relevant to the developed EU technologies and regulations.

One of the reasons for conducting MFA, is to identify where the waste materials will be reused. In a circular economy, waste materials are reused and recycled within one sector, preferably on a small scale. This will lead to efficient use of materials, which reduces the environmental impact of products, by reducing raw materials use, energy use and CO2 emissions. In addition, it brings advantages as the supply chain is working together in order to reuse and recycle the materials.

Figure 1, for example, shows the category of the recovered materials from CDW which is re-entering or not to the building industry in the Netherlands.

[1] Report on the assessment of asbestos use in Mongolia. MOH, WHO, HSUM, 2010

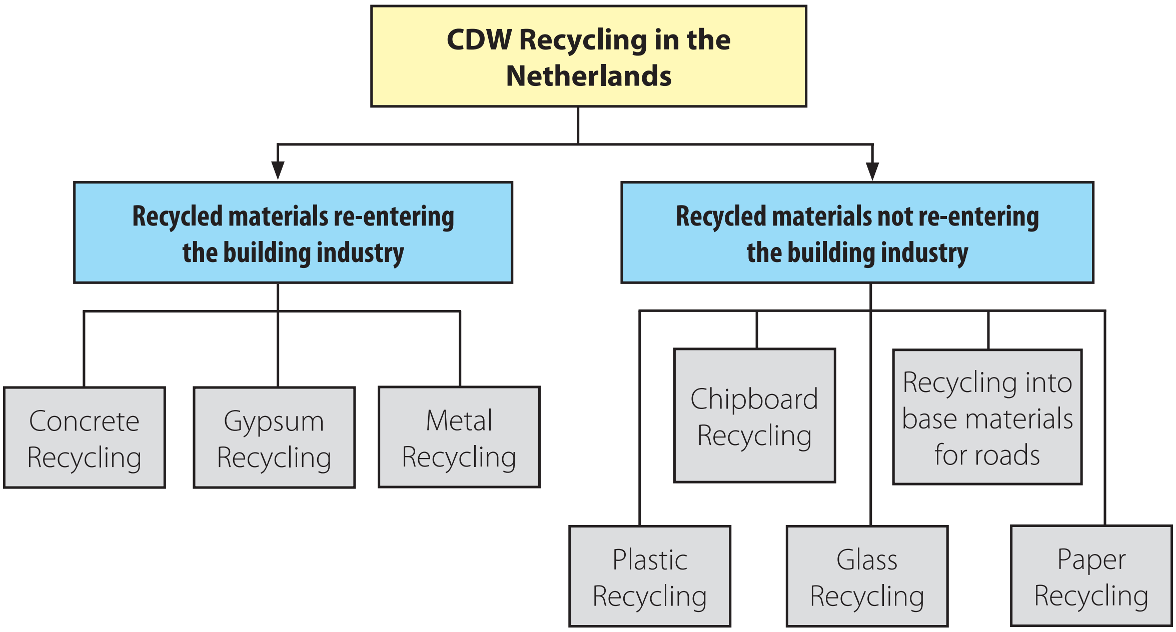


Figure 1 Different groups of recycling industries inside or outside of the building industry in the Netherlands

The main driving force for SMEs and stakeholders to recover and use materials from CDW, is, ultimately, the market demand for the recycle products. As the CDW recycling sector in Mongolia continues to grow, larger amounts of CDW recycled materials will become available. On the other hand, large amounts of recycled materials can only be sold if the general public, construction companies and authorities gain confidence in the quality of products made from recycled waste and if this confidence is translated into a regulatory framework.

The following report aims to provide tailored solutions to the Mongolian recycling industry and promote sustainable production and consumption in the construction sector.

To achieve this goal several aspects must be considered, which are divided into three main groups:

1. Understand the quantities of CDW in Mongolia and present the results by using a MFA of the CDW.
2. Provide an overview of the Mongolian recycling sector.
3. Identify the main gaps in Mongolian CDW legislation and CDW recycling technologies.

Once all the aforementioned information is collected, a series of solutions based on EU technologies and regulations are presented.

2	**Methodology**
3	**CDW flow in Mongolia**
4	**Construction materials sources in Mongolia**
5	**Recycling sector in Mongolia**
6	**Recommendation based on European best practices**
7	**Conclusions**

2. METHODOLOGY

To obtain the information required for creating a comprehensive baseline study a systematic research methodology consists of the following steps is applied:

- **Literature review of studies about quantification of CDW and MFA in developed countries**
  Review of existing body of knowledge comprised of recent peer review journal articles about CDW quantification and reports regarding MFA in EU countries.

- **Interviews with stakeholders in CDW sector and in Recycling sector**
  TU Delft researcher spent seven weeks in Mongolia to understand the sector by interviewing and meeting different stakeholders and obtaining documentation regarding CDW practices and recycling. All the meetings were organized by CCR partner and its members provided the English translation of the collected documents during the field visit.
  Stakeholders consist of governmental departments, private large and medium scale construction groups, third-party representative groups such as Mongolian National Recycling Association (MNRA) and Builders' Association (BA), Government agencies as Inspection Agency and Construction Development Centre (CDC), and professors from Mongolian University of Science and Technology (MUST).
  The interviews were held during April and May 2016, conducted in Mongolian and simultaneously translated in English by an interpreter.
  Some key recycling industries suggested as important by MNRA were visited by the research team, to verify particular point of interest for the research.

- **"Survey for Recycling Company"**
  The survey covered recycling industries (30 industries) and collection points (6 collection points from each district) in site visiting. The survey results were helpful to clarify the following aspects:
  » Current waste flow and different stakeholders in the waste supply chain.
  » Capacity of different recycling industries
  » Location of different factories.
  » Human resources who operate in the recycling sector.
  » Standards used to produce recycle products.

- **Building data collected from UB General Archive**
  The data were obtained by analysing the building catalogue in the UB General Archive. All the necessary information was analysed by a team composed by CCR and MUST members. The final results were sent to TU Delft to complete the MFA.

- **Review of the EU legislation in CDW and EU technologies for CDW recycling within building sector**

All in all, tools used for collecting the necessary information for "Study of the Mongolian context and CDW recovery applications" are presented in Figure 2.

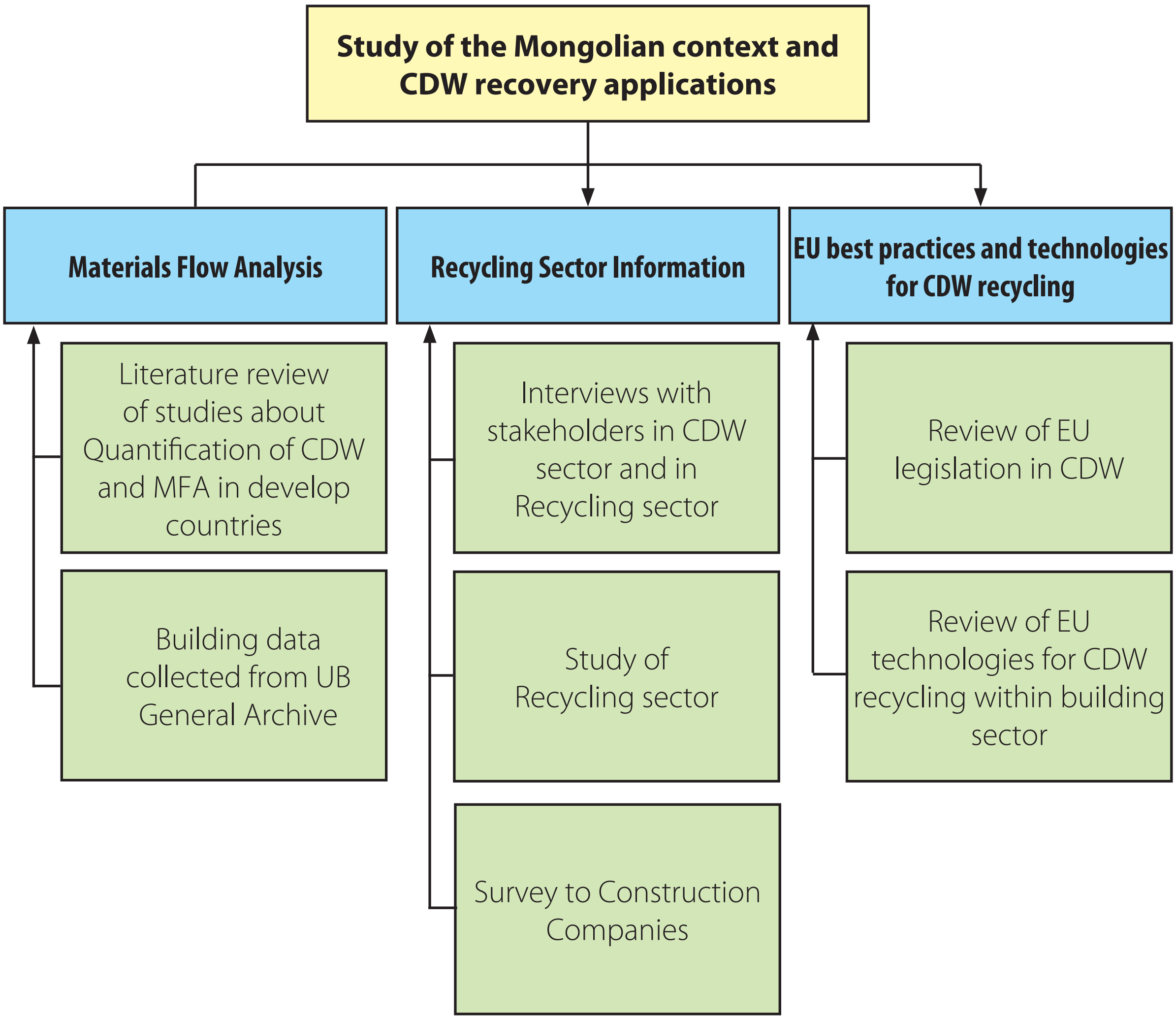


Figure 2 Tools used for collecting the necessary information for "Study of the Mongolian context and CDW recovery applications"

3. CDW FLOW IN MONGOLIA

3.1 Introduction to CDW flow in Mongolia

The construction industry has developed rapidly in last years in Mongolia, due to the increment of urbanization, economic and demand growth. The building and construction materials industry is on the rise, because demand for all types of products, from concrete to metals, is increasing in the next years. So far, building materials supply remains strongly dependent on the import.

In the definition of CDW there are materials such as wood, brick, concrete, asphalt pavement, glass, metals, generated during the construction, remodelling, or demolition of structures. Demolition projects may generate different wastes from construction such as plastic buckets, pipe, cardboard boxes, plumbing, electrical wire that are also sent for disposal or processing.

The materials that are included in the Material Flow Analysis (MFA) are grouped by type. In this report, the MFA of the following material categories are studied: "stony material", "wood", "metals", "glass" and "plastics".

Stony material

The majority of CDW is stony material. Different types of stony material are used in buildings. Stony materials consist of concrete, masonry, bricks, gravel, sand-lime brick, roof tiles, asphalt roofing, gypsum based material and rubble. In demolition, a large part of the stony material is the mixed content.

Concrete

Concrete is the basis of the urban environment and development. It is the construction material that is mainly used around the world for any type of building or infrastructure, due to its physical and aesthetic properties.

Block of apartments are primarily constructed of concrete. Concrete is composed of coarse aggregates (crushed stone), fine aggregates (sand), water, cement (hydraulic binder that hardens when water is added) and admixtures. Cement is a hydraulic binder that hardens when water is added.

There are different kinds of concrete, depending on the way it is produced and whether or not additives are included in the concrete. Some examples are: concrete stones, reinforced concrete and autoclaved cellular concrete.

Structural concrete becomes reinforced concrete when it is a composite material consisting of concrete and steel, the first provides the material's compressive strength, the second provides the tensile strength. Steel reinforcement is very important as it makes safe ductile behaviour in earthquakes, typical in Mongolia.

Bricks

The brick is composed traditionally of clay, or it can be composed of clay-bearing soil, sand and lime, or concrete materials. Bricks are produced in numerous classes, types, materials, and sizes which vary with region and time period. Two basic categories of bricks are fired and non-fired bricks. Bricks are used in large quantities in the Mongolia, mainly for masonry, that includes bricks, sand-lime bricks, and mortar, which contains cement, lime and aggregates. The following chapter will analyse in details all the aspect related to CDW management to provide a comprehensive overview of the sector.

Wood

Wood is a structural tissue found in the stems and roots of trees. It has been used for both fuel and as a construction material.

Engineered wood products are becoming an important part of the construction industry. They may be used in both residential and commercial buildings as structural and aesthetic materials. The wood is found as a supporting material, especially in roof construction, in interior doors and their frames, and as exterior cladding.

Metals

There is a large number of different metals that can be distinguished. These are the following categories: ferrous metal and steel, copper, bronze and brass, aluminium, lead, zinc, tin, mixed metals, contaminated metals and cables. Some applications of metal: copper, zinc and lead are used in the building industry in facades and roofs. Copper is also used for tubes. Steel is used for making the construction of the building more stable and in reinforced concrete.

Plastics

Plastic comes in several forms. PVC, EPS and PUR, are the common used plastics in the building sector. The last two are partly covered in the next category "insulation". PVC is used for window frames, floor and wall coverings, piping, etc.

Glass

Glass is used in window frames and doors. By selective demolition, the glass can be separated from other CDW materials. In case glass is not separated on-site, most of the glass will end up in rubble.

3.2 Method of construction of Material Flow Analysis

3.3 The MFA results in Mongolia

3.4 Discussion

3.2 Method of construction of Material Flow Analysis

The aim of this chapter is to understand the materials quantities involved in the Construction and Demolition Waste sector, in order to propose effective solutions tailored to the Mongolia situation.

Material Flow Analysis (MFA) will be used to estimate how many tons of each material are produced from Demolition and Construction activities and how many of these are recycled or sent to the landfills.

MFA is a tool to quantify accurately the right amount of waste produced and it comprises various descriptive and analytical tools to understand the functioning of the physical basis of societies, the inter-linkages of processes and product chains, and the exchange of materials and energy with the environment in order to understand the interaction of human activities and the environment.

Because of the laws of the conservation of matter, the results of an MFA can be controlled by a simple material balance comparing all inputs, stocks and outputs of the process.

To complete a MFA, it is important to follow the procedures:

- Define the problem
- Determine the system boundaries
- Determine which good will be analysed
- Determine the processes involved CDW management

In the case of CDW in Mongolia the abovementioned items correspond with:

- **Problem definition**

CDW in Mongolia, materials analysis, determination of CDW mass flow.

- **Determination of system boundaries**

Boundaries of the problem are represented by construction and demolition activity performed in Ulaanbaatar in next three years (2015-2018).

- **Determination of goods**

Goods are represented by the construction and demolition waste, in particular: stony materials, metals, wood, plastics and glass.

- **Determination of processes**

Processes analysed are divided into demolition, construction and disposal for goods.

The final goal of this study will be to understand the quantities of each material and present them in order to tackle the most important problems, in particular focus will be to find solutions to replace imported materials with recycled products and reducing dependency from the major exporters, China and Russia.
The model below calculates the total amount of each material-**i** $\mathbf{TW_i}$ in tonne/year by the following expression:

$$\mathbf{TW_i=DW_i+CW_i}$$

Where $\mathbf{TW_i}$ is composed of the amount of material-i coming from demolition activity $\mathbf{DW_i}$ and construction activity $\mathbf{CW_i}$, both expressed in tonne/year.

The process for calculating the amount in tonne of brick, concrete, metal, plastic, glass and wood will be by estimating for each "building structural type" found different percentages of each material, then final results will provide the total material stock in Ulaanbaatar.

This material stock could be converted in Demolition waste once a certain building type is demolished and the total number of construction projects active in UB provides the total amount of construction waste. In general, the amount of construction waste is much less than the demolition waste but in the case of Mongolia, where an accurate estimation of the required materials is not always performed, this amount is not a small quantity.

3.2.1 Demolition activity

The model starts from an analysis of the municipal context, in particular of the buildings in the capital Ulaanbaatar and of the main types of structures-**j** with the highest probability of been demolished, Bricks and Concrete structure.

Furthermore, it is necessary to quantify total demolition waste for the different types of structure-**j**, $\mathbf{DW_j}$ in ton/year. To quantify $\mathbf{DW_j}$, different methods have been explored from literature *(Quantifying construction and demolition waste: An analytical review; Z. Wu et al; 2014)* at both regional and project levels. The literature review revealed that Generation Rate Calculation (GRC) is the most popular methodology for estimating CDW amounts.

Different models using the GRC have been reviewed *(Estimation of building-related construction and demolition waste in Shanghai, T.Ding, 2014; Modeling materials flow of waste concrete from construction and demolition wastes in Taiwan, T. Hsiao, 2002; Estimation methods for the generation of construction and demolition waste in Greece, Fatta et al., 2003);* at the end Fatta has been selected because of the similarity with the Mongolian context.

Hence, the applied models for Demolition activities is as follows:

$$\mathbf{DW = ND * NF * SD * WD * D}$$

- **DW** = demolition waste in tonne
- **ND** = No. of demolitions
- **NF** = mean value of no. of floors
- **SD** = surface of each building being demolished
- **WD** = generation rate of each demolition

To refines as much as possible the estimated percentages of each material-i, an accurate study of the different buildings was conducted from the General Archive of UB. Different percentages, $\mathbf{X_{ij}}$, were found for bricks and concrete structure and presented in Table 1.

Materials / Buildings	Brick structure	Concrete structure
% Stone materials	91%	90%
_Concrete	7%	50%
_Ceramics / block mixture	74%	25%
_Concrete / ceramics	10%	15%
% Metal	2%	3%
% Plastic	1%	1%
% Glass	3%	3%
% Wood	3%	3%

Table 1 Percentages of material-i in each of the building structures in UB

The final step it is represented by the quantification of the amount of each material-i studied $\mathbf{DW_i}$ by the following formula:

$\mathbf{DW_i} = \Sigma_j \mathbf{DW_j} * \mathbf{X_{ij}} \forall$ material-**i**

3.2.2 Construction activity

The types and amounts of waste generated on site are directly related to the classification characteristics and construction techniques employed in each building; Construction Waste (CW) will therefore vary between projects. There are usually two procedures for making estimates:

- Quantification procedure to obtain approximate estimates by the use of waste quantification tables.
- Quantification procedure to obtain specific estimates for each project.

Given the plurality of projects actually running in UB, Construction Waste $\mathbf{CW_i}$ coming from each material-i is studied by quantification tables as proposed in Methods for estimating construction and demolition (C&D) waste, C. Llatas, 2013. The methodology in these cases is as follows:

- **Step1:** Quantification tables classified by project type are obtained (construction); uses (residential, non-residential: industrial, commercial, etc.); and similar technologies relevant to the project (structure, masonry, etc.).
- **Step2:** The features of the project are identified: type of project (construction); use (residential, non-residential: industrial, commercial, etc.); and the main technologies (generally in relation to structure: metal, concrete or masonry).
- **Step 3:** The surface area of the project is calculated (in m^2).
- **Step 4:** The total waste amount (volume and/or weight) is obtained from the floor area of the project.
- **Step 5:** The waste composition is obtained (amounts by type of waste).

Waste quantification tables are available from the literature and shown in Tables 2 and Table 3.

Type of construction	Heavyweight		Lightweight	
	Residential	Non-Residential	Residential	Non-Residential
New building construction	120-140	100-120	20-22	18-20

Table 2 Weighted Average Demolition waste generation rates (kg/m3) [Methods for estimating construction and demolition (C&D) waste, C. Llatas, 2013]

Rounded average percentage of waste composition by volume in constructios (%)*	
	Heavyweight construction: masonry, concrete, etc.
15 Packaging Waste	**0.6-0.7**
15 01 01 Paper cardboard pack	**0.02-0.04**
15 01 02 Plastic packaging	**0.05-0.07**
15 01 03 Wooden packaging	**0.5-0.55**
15 01 04 Metallic packaging	**0.02-0.03**
15 01 06 Mixed packaging	**<0.01**
17 C&D Waste	**0.3-0.4**
17 01 01 Concrete	**0.15-0.2**
17 01 03 Ceramic-bricks	**0.1-0.13**
17 01 07 Mixed concrete ceramics	**0.02-0.03**
17 08 02 Drywalls	
17 09 04 Mixed C&D waste	**0.03-0.04**

Table 3 Rounded average percentage of waste composition by volume in construction (%) [Methods for estimating construction and demolition (C&D) waste, C. Liatas, 2013]

To calculate the total amount of construction waste in tonne/year, the total surface SC in m2 is then multiplied by weighted averages CDW generation, WG. Hence, the formula to obtain construction waste is given by:

$$\mathbf{CW_j = SC * WG} \qquad \forall \text{ category of building-}\mathbf{j}$$

Finally, the amount of each material wasted in construction $\mathbf{CW_i}$ is obtained by splitting the total amount in tonne/year by the rounded average percentage of waste composition $\mathbf{X_{ij}}$ calculated by:

$$\mathbf{CW_i = \Sigma_j\, CW_j * X_{ij}} \qquad \forall \text{ material-}\mathbf{i}$$

3.3 The MFA results in Mongolia

Demolition waste quantification

Future demolition waste is obtained from the number of End-of-Life buildings which are going to be demolished according to UB Municipality. By following the aforementioned procedures, from a total of 32 concrete buildings and 275 brick buildings it is obtained:

- **DW Brick** = 1,359,072.00 tonne
    - » **NF** = mean value of no. of floors that building has = 3,96
    - » **SD** = surface of each building being demolished = 975 m^2
    - » **WD** = generation rate of each demolition = 0.8 m^3 / m^2
    - » **D** = density of waste = 1.6 tonne / m^3
- **DW Pre-cast** = 97,335.71 tonne
    - » **NF** = mean value of no. of floors that building has = 3.69
    - » **SD** = surface of each building being demolished = 644 m^2
    - » **WD** = generation rate of each demolition = 0.8 m^3 / m^2
    - » **D** = density of waste = 1.6 tonne / m^3

The specific amount of each material-i is presented in the following Table 4.

	DW [t]	% DW
Concrete	130,373.95	9%
Bricks	937,099.62	64%
Mixed concrete	136,815.87	9%
Metal	30,101.51	2%
Plastic	14,564.08	1%
Glass	43,692.23	3%
Wood	43,692.23	3%
Total	**1,456,407.71**	**100%**

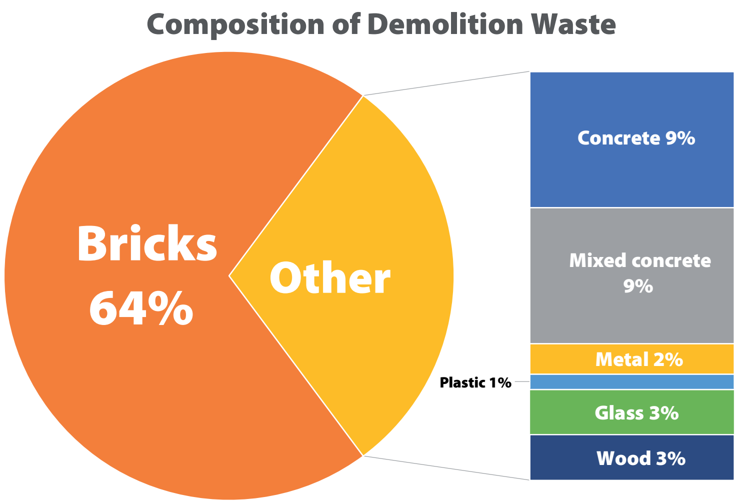


Table 4 Specific amount of each material-i from demolition activity

Construction waste quantification

UB is facing an important transformation in the last years and number of construction sites has started to increase again after a small interruption during 2013-2015. The following Figure 3 shows the number of active construction sites for each district.

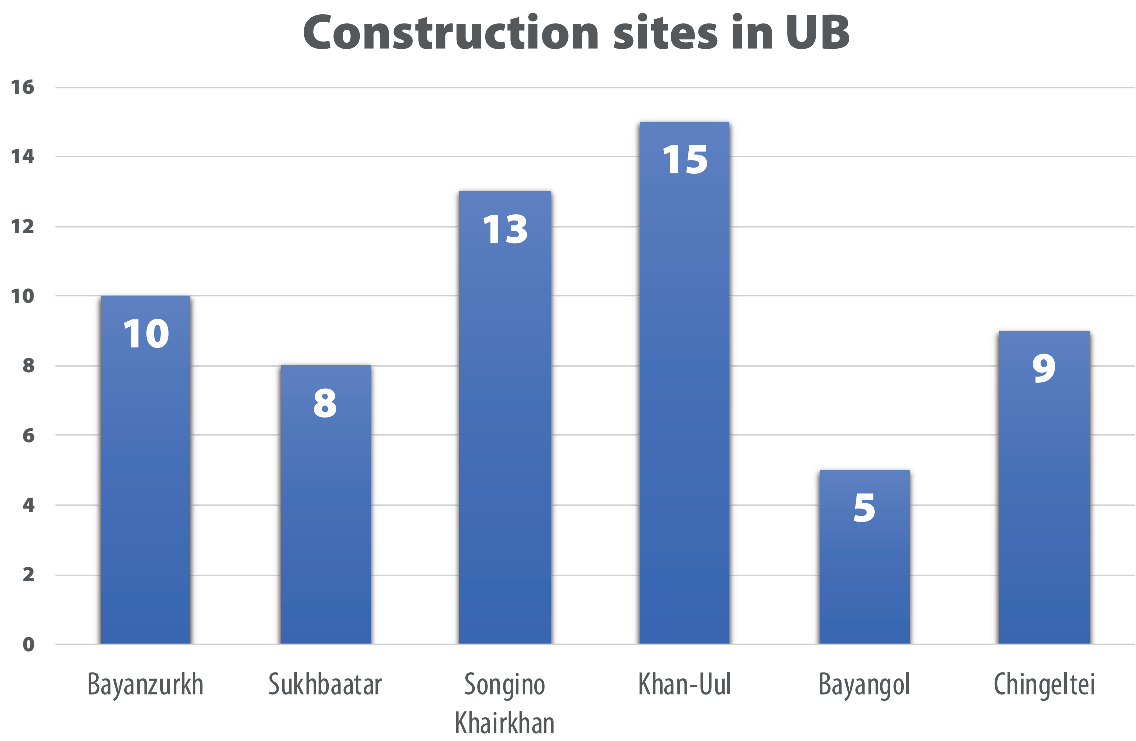


Figure 3 Number of construction sites in each district

Actually, 60 construction sites are open in UB with an average surface of 700 m^2.

Multiplying the total surface for WG = 130 kg/m^2, construction waste $\mathbf{CW}$ is obtained and amount of each material $\mathbf{CW_i}$ is calculated using the aforementioned method.

	CW [t]	% CW
Concrete	1,092	20%
Bricks	709.8	13%
Mixed concrete	436.8	8%
Metal	109.2	2%
Plastic	273	5%
Glass	0	0%
Wood	2,839.2	52%
Total	**5,460**	**100%**

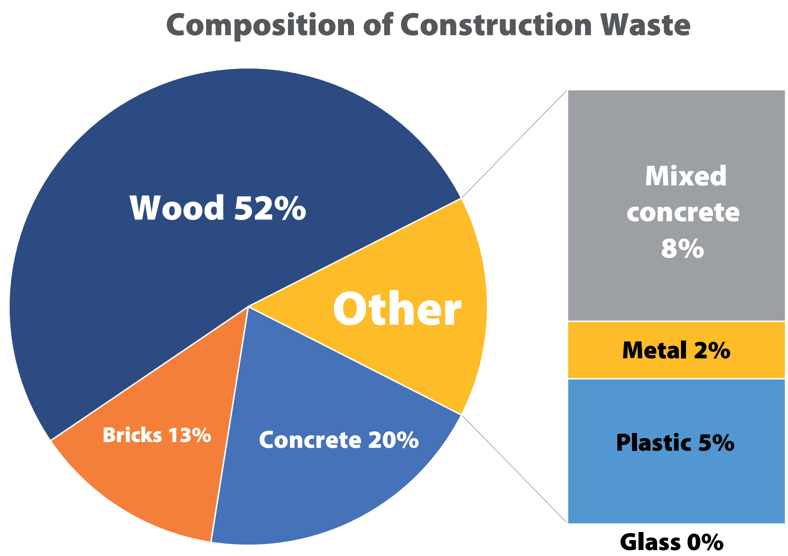


Table 5 Tonnes of CDW amount from each district of UB

The final result is shown in the following Table 5 and presented also as graph to highlight its composition. All the waste produced is going to disposal sites and it can be noticed that wooden materials represents the biggest amount mostly because of wooden packing used at the construction site.

3.4 Discussion

To summarize the results obtained from quantification of CDW, UB is expecting a total of 1,461,867.71 tonne CDW over the next years. It is important to notice that Concrete and Bricks account for the large majority of the total amount and as expected, construction waste is marginal compared to demolition activity.

Statistics show that the amount of CDW is booming every year in months March, September and October. Thus, it is obvious that the weather is a determinative factor in Mongolia to run the construction or demolition projects.

Nowadays, all the CDW produced goes into the different landfill sites in the city but a large proportion is landfilled illegally due to a lack of proper inspection.

Illegal disposal of construction waste can occur at construction sites or anywhere else. A number of construction sites have reported that construction waste from the construction activity is buried under the site itself. Demolished building materials also are often disposed following the same mechanism. Otherwise illegally disposed construction waste ends in areas along the construction truck route. This route is often route between construction sites, and construction material producers, including gravel quarries.

4. CONSTRUCTION MATERIALS SOURCES IN MONGOLIA

4.1 Introduction to materials supply chain

The construction industry has expanded rapidly in recent years in Mongolia and demand for all types of construction products (from concrete to metals) is expected to increase in the coming years.

Currently, more than 50% of building materials are imported. Therefore, imported products made from new raw materials are transported for long distances, resulting in high "carbon footprint" and significant contribution to climate change.

Although the government follows the policy of increasing the local production of building materials, it still faces problems. The main reason is that the local products are not able to compete with imported ones in terms of price and profitability.

Tables 6 presents the amount of building materials which are locally produced or imported from other countries.

Materials	Percentage od locally produced	Percentage of imported
Concrete, reinforced concrete, civil engineering precast concrete mixture, chemical additives for concrete	100%	0%
Ceramic brick, block	100%	0%
Lightweight concrete, lightweight filter, ACC blocks	100%	0%
Concrete filter materials, construction sand, construction stone	100%	0%
All types of plastic windows, doors	100%	0%
Thermal insulation mineral wool board EPS, XPS, PUR type of polystyrene foam panels, composite structures magnesium and OSB panels, bars and sandwiches plate	75%	25%
PVC, HDPE, PPR PE types of plastic pipes underground montage hose, electrical wire threading pipes and wiring box	100%	70%
Cement, Lime, mineral powder	30%	70%
Casting, steel bars	30%	70%
Dry and wet mixtures for interior	30%	70%
Steel and cast iron pipe and its connection tools, heating, ventilation accessories	0%	100%
Ceramic finishing, plumbing, ceramic products, artificial stone	0%	100%
All types of glasses	0%	100%
Different types of floor and doors	25%	75%
Steel bars, steel hiring of nails and screws	70%	30%

Table 6 List of materials used in construction and percentage of imported quantity

In Mongolia, about 770 factories are active to produce building materials among which 571 factories are located in UB. This number corresponds with about 60% of the producers in the whole country. Figure 4 shows the number of building material producers in UB distinctly.

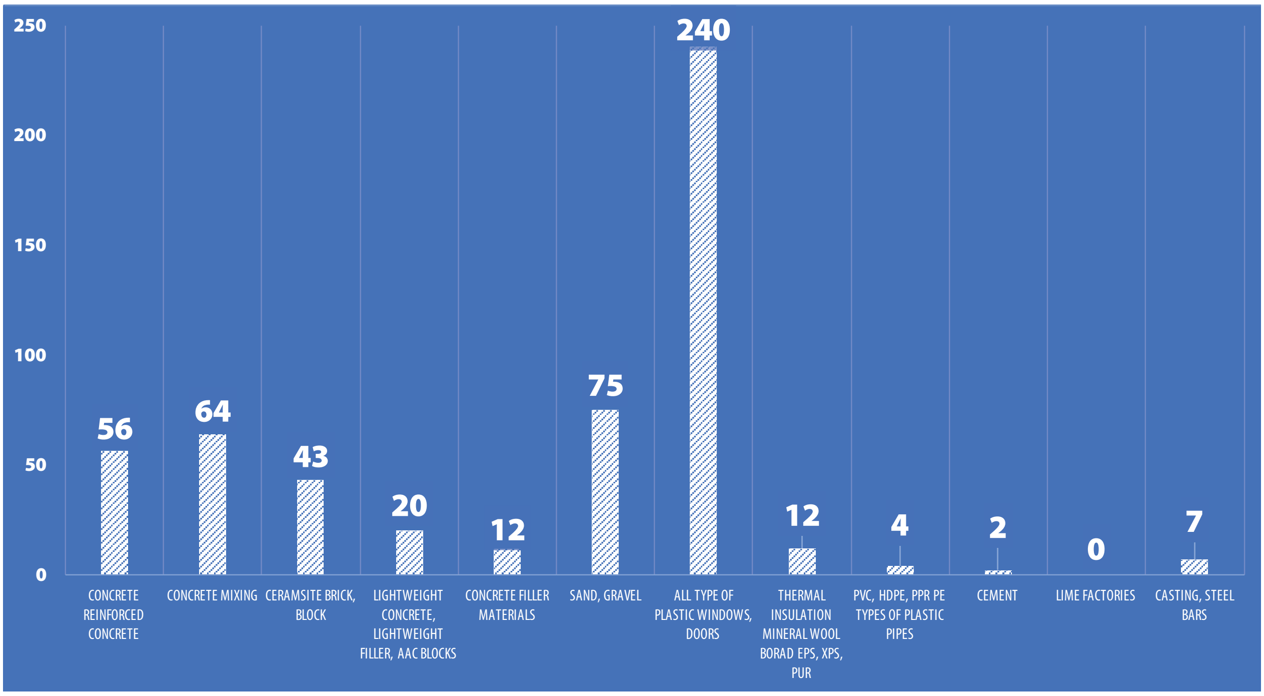


Figure 4 Number of construction material producers in UB

The following chapter aims to present a comprehensive study of construction materials industry and highlight the major barriers, in order to adopt recycled materials as replacement of new ones.

4.2 Methodology

Obtaining information regarding construction industry is a challenging activity in Mongolia, mostly because construction materials producers are often conservative to share data about their production. Among the producers, there is a general tendency to avoid sharing data to reduce the amount of paid taxes.

The following activities were performed to obtain a sufficient amount of data about the main materials used in construction industry:

- **Literature review and interviews with construction materials producers**
  All the possible sources of information were translated and studied. These studies were obtained during interviews with third-party representative groups such as *Building Material Manufacturer's Association of Mongolia* and *Barilga Corporation.*

- **"Study on Construction Materials"**
  TU Delft prepared the ToR for the study and defined with CCR which material required detailed information. In particular, a list of different construction materials was created and the needed information specified.
  In the aforementioned document, to facilitate CCR in the research process, Table 8 was proposed to be filled out. Then, for each of the listed materials (Cement, PVC, Metal, Lime, Sand, Gravel, Ceramic Brick) the following points were asked:

  - **Total demand for the product:** gives information over general demand of that material during the year 2015 or the year before.
  - **Area of action of the producer:** shows the "Aimag" and the location of its customers.
  - **Location of the producer:** shows where the factory is located.
  - **Technology used:** a small description of the process used and number of people who work on the process.
  - **Type of equipment:** explains which equipment is used, years of usage, country of origins for the machines.
  - **Capacity:** capacity of the producer in terms of [tonnes / unit of time].
  - **Quantity produced over years:** actual production [tonnes/year] from 2000 – 2015.
  - **Prices 2015**
  - **Price change**
  - **How they deal with waste:** what is the policy regarding waste produced during the production process.

Materials	Cement, PVC, Metal, Lime, Lightweight Block, Concrete Mix Sand, Gravel Ceramic, Brick, Concrete		
Demand			
Producer	Small producer	Medium producer	Large producer
Area of action			
Location			
Tech. used			
Type of equipment			
Capacity			
Quantity produced over years	Quantity producer **2000** **2001** **2002** **2003**	**2004** **2005** **2006** **2007** **2008** **2009**	**2010** **2011** **2012** **2013** **2014** **2015**
Prices 2015			
Price change			
How they deal with waste			

Table 7 Information required for each of the selected construction material

4.3 Construction materials information

In the following sub-chapters, the information obtained for each of the material is presented:

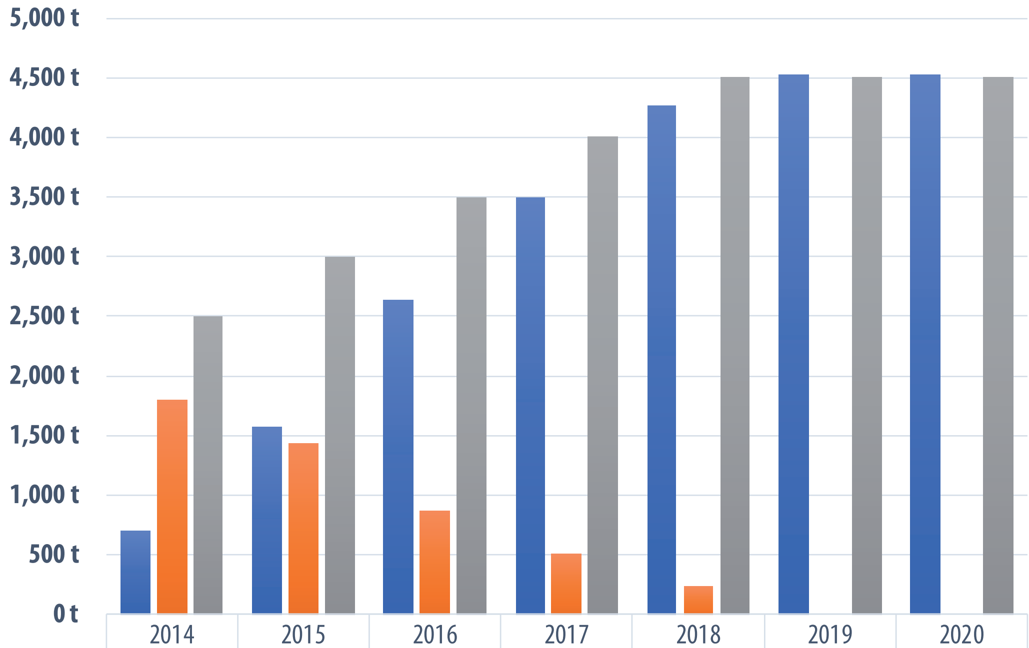
- Cement
- Concrete
- Sand, Gravel and Crushed stones
- Ceramic Brick
- Iron
- Plumbing plastic pipe, PVC and Window glass
- Asbestos

4.3.1 Cement

As already mentioned in Table 6, two factories satisfy 30% of the total demand of cement. Data collected shows that the amount of produced cement in 2014 was about 2,500,000 tonnes. Based on the available data and economic considerations local production is expected to increase while diminishing imported amount, as shown in Figure 5. This scenario is supported by the plan to build at least three new factories to produce cement.

Among all local producers, prices for one tonnes of cement packaged are around 72 €/tonnes.[2]

The main raw material for cement production in Mongolia is limestone and supplements are often gypsum, ash from power plants, volcano slag, steel manufacturers' slag.



	2014	2015	2016	2017	2018	2019	2020
Local production	700	1570	2630	3500	4265	4530	4530
Imported	1800	1430	870	500	235		
Total demand	2500	3000	3500	4000	4500	4500	4500

Figure 5 Total demand of cement, imported quantity and local production in millions of tonnes

4.3.2 Concrete

Concrete doesn't have a long history in Mongolia. Until 1940s, lime was the primary binder utilized for masonry and plaster mortars. However, from the late 1940s, Portland cement began to be imported from the Soviet Union. The industrialization of Mongolia was between 1965 and 1970, and the first Portland cement factory was constructed in 1967 with the support of Czechoslovakia.

Later two more plants were built, in 1984 and 1999, using Russian technology.

From 1990, Mongolia undertook the market economy, with the privatization of many state factories and companies. During the mentioned decade, there was a sharp downfall in the construction sector, but the industry began to grow again from 2005.

Concrete mix contains raw materials such as: sand, gravel and crushed stones.

Nowadays, 40 Ready-made Concrete mix manufacturers are operating and producing ready-made concrete mix. Demand is fully satisfied, especially for UB, but of course trend is increasing.

The price for 1m^3 is between range of 64-98€ depending on the quality of the materials and the producer. Table 9 presents the concrete production in Mongolia and in UB from 2012 to 2015.

[2]1 € is equal to 2166 MNT currently. And the following prices are relative to October 2015

	2012	2013	2014	2015
Concrete consumption in Mongolia (m^3)	450,525	548,621	586,603	786,603
Concrete consumption in Ulaanbaatar (m^3)	387,894	488,466	489,952	639,952

Table 8 Concrete Consumption in Mongolia and UB

The study conducted for Reinforced Concrete type shows that 37 factories out of a total of 67 are actually active. They are divided between different areas of Mongolia

- 27 in UB Area
- 3 Central area
- 4 Khangai area
- 3 Western area

These local producers satisfy 100% of the market demand, exact amounts can be seen in Table 9.

Areas	Demand, thousand m^3/ year	Capacity, thousand m^3/ year
Western area	49.80	10.26
Khangai area	53.14	74.64
Central area	75.84	27.00
Eastern area	31.84	0.00
Ulaanbaatar	365.92	774.95

Table 9 Demand of Reinforced Concrete in thousand tonnes and Capacity

4.3.3 Sand, Gravel and crushed stones

There are around 60 quarries operating in Mongolia and they have capacity to produce 1,200,000 m^3 concrete annually. The typical production process starts with full crushing and grading technology where mined mountain and river-basin sand and gravel mixture (raw gravel) pass through two crushing phases, through jaw-crusher and cone crusher with a belt conveyer connected to sieve with 3-4 circles. Then plant is equipped with drum washer for sand washing.

Gravel quarries are a major player in construction waste flow, as the extent of their operations is spread around the city, more densely in West-North area of the city. It was also observed that some gravel quarries allowed disposal of CDW nearby their extraction site for buyers.

In the Figure 6, a map of quarries in UB area is represented.

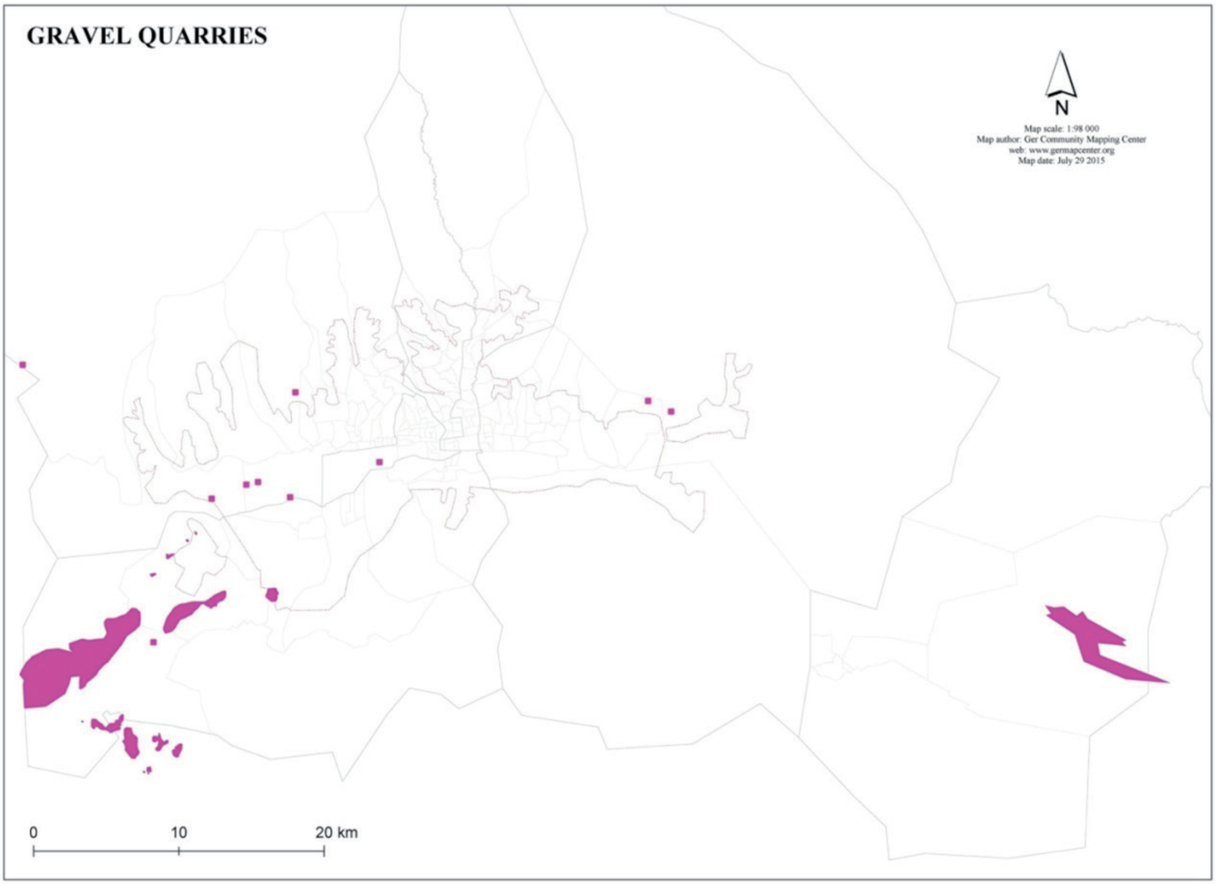


Figure 6 Gravel quarries location in UB area

Table 10 is presented to show the total number of factories producing lime, sand and gravel and their production.

Product	Number of Factories	Production
Lime	14	90 000 tonnes
Sand	84 (all located in UB)	2.2 million m^3 per year
Gravel	69	2 million m^3 per year

Table 10 Number of factories and production for lime, sand and gravel

4.3.4 Ceramic Brick

Total number of bricks manufactures in Mongolia is 68 and 34 of them are located and serve UB. Other Mongolian manufactures are located:

- 17 in the Western area
- 10 in the Khangai area
- 4 in the Central area
- 3 in the Eastern area

In the capital, there is the capacity to manufacture 176,0 million units of bricks while annual average consumption is around 300 million. Table 11 shows data relative to brick production in Mongolia.

	2012	2013	2014
Production (million pieces)	44.5	66.5	58.9
Importation (million pieces)	30	30.3	21.7
Importation (%)	40	31.3	27
Capacity (million pieces)	-	-	320

Table 11 Brick production and importation data from 2012 to 2014

Production process begins from crushed fallowed clay which is sized, then wet mixed in a double mixer, moulded in a vacuum press and cover dried in normal conditions and baked in a round kiln to manufacture regular or holed bricks.
It has to be noticed that statistical information relative to brick production is not accurate due to the following reasons:

- Insufficient registration of the factories.
- Insufficient information regarding construction materials procedures.
- Factories are not willing to provide reliable production reports.

4.3.5 Iron

Iron is mainly produced by one company which has a capacity of 79,000 tonnes of steel bar production and produced 74,400 tonnes in 2012. Some other smaller scale factories in Mongolia and China produce in total 39,100 tonnes of steel bar consumed inside of Mongolia.
Table 12 summaries the steel bar production from 2011 to 2014.

Steel bar	2011	2012	2013	2014
Produced (thousand tonnes)	71.1	86.5	65.1	71.5
Capacity (thousand tonnes)	160.8	180.7	246.0	313.1

Table 12 Steel bar total production

4.3.6 Plumbing plastic pipe, PVC-plastic and Window Glass

In the following Table 13, data relative to plumbing plastic pipe, PVC-plastic used for windows and plastic doors and window glass are summarized.

	2008	2009	2010	2011	2012	2013	2014	2015
Production of Plastic pipe (million kg)	3.3	1.5	3.2	11.9	9.7	8.4	6.3	3.3
Importation of PVC-Window frames (m^3)	239.2	32.1	0.8	17.9	35.8	266.9	59	30
Importation of Window glass (million m^2)	1.44	0.96	0.92	0.82	1.85	2.73	2.65	1.92

Table 13 Production and Importation data for Plastic pipe, PVC frames and Glass

4.3.7 Asbestos in Mongolia

Mongolia has been using asbestos in thermal power plants, metal processing and construction industries as a component of thermal insulation and construction material since 1960.
Asbestos containing products have been widely used as powder asbestos, handle asbestos (asbestos treads), asbestos sheets, asbestos gaskets, asbestos cotton and asbestos carton for PP's thermal insulation system, steam and turbine system patching and replacement, imitation brick cladding, profiled sheets for outer engineering insulation, insulation for water pipe system and window insulation.
Renovation and installation workers, heat sealer, storage workers, driver, service technicians, shop assistants, plumbers, maintenance workers, carpenters and transporters have been exposed by asbestos and impacted.
Since 1995, the Mongolian Customs Organization has started to get declaration and forms, quantity and total value (in monetary terms) of imported asbestos and asbestos containing materials have been analysed, in the following Table can be seen total amount of imported asbestos and asbestos containing materials.

Year	China		Russia		Other countries	
	Quantity, kg	%	Quantity, kg	%	Quantity, kg	%
1995	-	0.00%	3,000	100.000%	-	0.000%
1996	-	0.00%	181,620	100.000%	-	0.000%
1997	-	0.00%	540,910	100.000%	-	0.000%
1998	15,200	4.04%	361,120	95.961%	-	0.000%
1999	25,200	37.00%	42,900	62.966%	-	0.000%
2000	175,300	31.75%	376,850	68.251%	-	0.000%
2001	15,830	3.11%	492,360	96.885%	-	0.000%
2002	47,010	10.27%	410,700	89.792%	-	0.000%
2003	311,636.24	55.52%	249,687.2	44.482%	1	0.000%
2004	311,636.24	55.52%	249,687.2	44.482%	1	0.000%
2005	1,610,640.5	78.15%	450,308.6	21.850%	-	0.000%
2006	3,315,939.2	88.41%	433,680.8	11.563%	1,000	0.027%
2007	4,968,425.5	97.64%	120,002.5	2.358%	25	0.000%
2008	7,726,147.2	98.40%	123,231.8	1.569%	2,500	0.032%
2009	7,554,744.2	99.84%	12,323	0.163%	-	0.000%
2010	5,099,852.49	96.95%	160,589.86	3.053%	37,4	0.001%
2011	38,009.99	38.78%	60,012	61.223%	-	0.000%
Total	**31,215,571.56**	87.96%	**4,268,982.96**	12.029%	**3,525**	0.010%

Table 14 Quantity and sources of imported asbestos and asbestos containing materials

During the period from 1995 to September, 2011, according to the data of General

Customs Authority, Mongolia has imported in total 35,484,554kg asbestos and asbestos containing materials from China and Russian Federation.

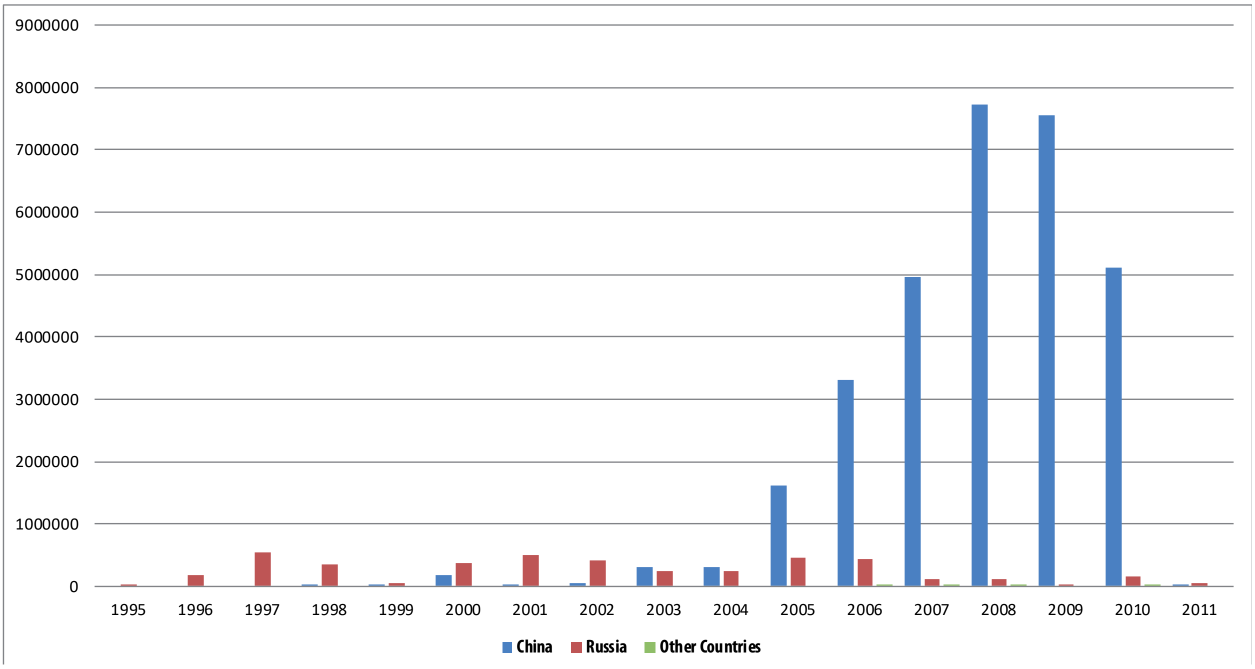


Figure 7 Importation of asbestos from major importers

Since 1960s, roof slates by asbestos and various pipes made by asbestos have been imported from the Soviet Union and widely used in construction sector.

Asbestos was extensively used in ceiling, roof, wall, wall coating and insulation of heat pipes and it is most likely that all buildings built before 1974 have contained asbestos in some way.

Due to the facts including the majority of building standards of the Soviet Union was used in Mongolia, many Russian experts worked in Mongolia and they made building architectures, it is very likely that asbestos containing materials used in waste pipes, insulation of heat pipes and asbestos roof ciphers.

Figure 8 shows some examples of the application of asbestos in the construction.

At present, there is no formal manufacturer of asbestos and asbestos containing materials in Mongolia and in construction sector. Asbestos waste pipes are being replaced by plastic pipes. Insulation of heat pipes are being replaced by printed materials and roof ciphers are being replaced by various metal and asphalt containing materials due to availability of different kinds of materials and market options.

In addition, asbestos containing materials are not used in construction framing, replenishment, plastering and external and internal plumbing of drinking water.

Few entities that have licenses from Ministry of Environment and Tourism to import and use asbestos for the energy production sectors such as power plant stations.

A. *Balcony of an apartment building was covered by asbestos panel*

B. *Storing old asbestos roof panels*

C. *Asbestos roof of an apartment building*

D. *Asbestos roof of an apartment buildi*

Figure 8 Asbestos roof panels which are used in construction

4.4 Conclusions and barriers

The study of the building materials industry in Mongolia leads to the following conclusions:

- Processing technology and equipment are often obsolete.
- There is no knowledge of recycling process technologies.
- Construction materials producers are not aware of the environmental problems related to CDW.

The main obstacle to the adoption of recycled materials remains the cultural attitude toward waste and the consequent lack of connections among MUST university, industries and Government agencies.
A scheme of the relations among different actors is proposed in Figure 9.

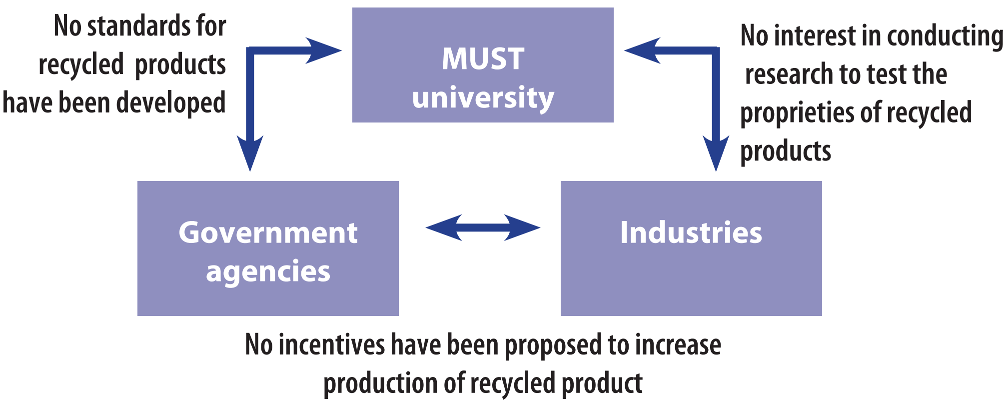


Figure 9 Relations among different actors in construction industry

5. RECYCLING SECTOR IN MONGOLIA

5.1 Introduction

Waste management regulations are in the early stage of development in Mongolia since its transition to market economy. Furthermore, stakeholders' coordination mechanism is not perfect, and some solid waste infrastructures are still under the state ownership. The Government has not fully reviewed and amended provisions to increase private sector participation in the relevant laws, regulations, and programs.

Along with the increase in the population of Mongolia in recent years, especially in Ulaanbaatar, 1.4 million tonnes of waste are received annually at centralized waste sites of Narangiin Enger, Moringiin Davaa and Tsagaan Davaa. In Ulaanbaatar, city waste maintenance organizations collect 75% of the total solid waste while 15% of the total solid waste is transported by the organizations with their trucks and 5-10% of solid waste is left without being transported.

Residents of the Ger district dispose of ashes and waste water directly in the streets, especially during winter time. Because of this improper action, 60% of the waste produced is spread in streets of the peri-urban area of Ulaanbaatar city. Statistics show that only one-third of the Ulaanbaatar population live in apartment buildings and two third are living in the house region or traditional dwelling Ger district where the illegal dumping has out of control and left without any charges

Waste collection is provided at district level by waste transportation organisations known as "TUK". TUK organisations provide collection services for both commercial and domestic premises. Construction waste is typically collected and disposed by construction companies or through direct contracting with waste collection companies or via private truck owners.

Recycling is mainly a back end process with recyclables of economic value targeted by groups of waste pickers operating at the city's landfills/dumpsites. There is limited source separation of recyclables from domestic or commercial sources.

Figure 10 provides a review of the waste flow in Ulaanbaatar, from waste production to reprocessing and landfills

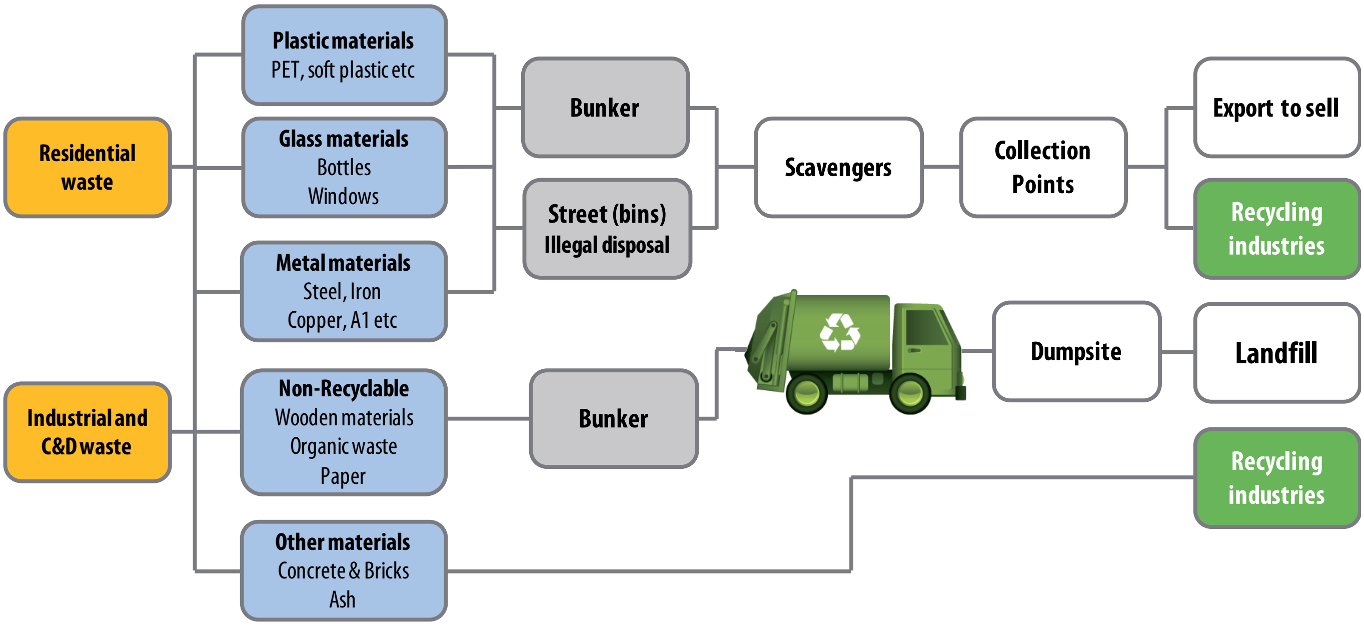


Figure 10 Waste flow in Ulaanbaatar

The following chapter will analyse in details the recycling industry in Mongolian to provide a comprehensive overview of the sector.

5.2	**Methodology**
5.3	**Results and discussion**
5.4	**Recycling regulations and conclusion**

5.2 Methodology

Conditions in the Mongolian recycling sector were qualitatively investigated using a questionnaire survey and semi-structured interviews with main stakeholders in recycling sector, such as scavengers/collectors, collection points and recycling industries.

These semi-structured interviews followed a general outline but allowed for areas of interest to be explored in further detail (Punch, 2005). The interviews were intended for gathering further comments; elaboration and interpretation in the results obtained from the questionnaire.

The questionnaires were distributed to each target group and a response rate of 75% was considered satisfactory.

Collectors

The waste collectors are one of the most vulnerable groups in Mongolia's informal sector. The collectors are non-active group in society who are unemployed, poor, impaired, non educated and non-registered in civil registration.

A total of 30 survey questionnaires were distributed to collectors randomly selected from the target population. Collectors were invited to evaluate seven questions regarding their importance for waste collection.

The survey was important to clarify the information about

- Source of waste.
- Type of secondary materials collected included CDW.
- Taxation system, registration and challenges.

Collection Points

Collection points represent a major role in the waste chain in Ulaanbaatar. They represent an important source of information to clarify Recycling sector and create a list of Recycling Factories active in Ulaanbaatar.

To obtain a representative sample of collection points, it was decided to cover 30 collection points, five for each of the six district of UB. In total, 128 collection points are operating in UB city according to the 2015 statistics.

Collection points were invited to evaluate the 11 individual questions regarding their importance for waste collection.
This target group provided answers to the following questions:

- Exact location of the collection point.
- Total number of employees active in waste collection.
- The volume of secondary materials collected on a monthly base.
- Type of secondary materials collected included CDW.
- Price of the collected secondary materials.

Recycling industries

Obtaining information regarding recycling industry is a challenging activity in Mongolia, mostly because the sector is poorly regulated and informal. The first challenge of the research was to identify the exact number of recycling companies which are actively operating in UB.

To obtain a representative sample a total of 27 recycling industries was covered. In the questionnaire, recycling industries were invited to evaluate the 26 individual questions in terms of their importance for recycling.
The questionnaire provided the following information:

- Location of the company.
- Type of secondary materials recycled and their attitude toward CDW.
- Technology used in the recycling process. For each of different waste, a list of producers is created; technology, processing techniques and equipment are listed including suppliers and main customer types.

5.3 Results and discussion

5.3.1 Collectors

Currently there is no exact number of scavengers are working in the waste field. According to data from 2015 (ECO PARK project), around 20000 scavengers are currently active. Survey results show that scavengers are traveling on street, and collect secondary materials from street bins and apartment bunkers.

Collectors condition is vulnerable, they are not in possession of any tools to collect secondary materials, and also they do not follow any health and safety procedures. Often, collectors are active inside the main landfills sites and collect waste materials every time a truck arrives to dump its waste.

From the interviews it was possible to understand that each scavenger collects every day around 10-15 kg of secondary materials such as plastics, cans, glasses and small amount of metals and plastic bags.

Scavengers sell directly to domestic collection points who set the price for each secondary materials.

Price is not stable, price of secondary materials reaches lowest value during winter time, while price reaches its peak in the summer time.

Furthermore, there is no tax system set by government, and they represent an invisible part of the society. Notable examples of their activity are showed in Figure 11.

Figure 11 Examples of collectors in Ulaanbaatar

5.3.2 Collectors points

Collection points represent a part of the process of waste management, they are involved in the collection of recyclable materials. They purchase secondary materials from collectors, and then sell to recycling industries or to other countries, such as China and Russia.

Currently 128 collection points are operating. Most of collection points are located in SHD District and BZDs district. Table 116 shows the main information regarding the collection points in UB.

Districts	Average number of employee	Status of workplace		
		Own	Rent	Public
SHD	2-3	20	8	2
KHUD	2-3	5	4	1
BGD	2-3	-	4	8
CHD	2-3	-	2	1
BZD	2-3	35	4	-
SBD	2-3	1	23	-
Total	**479**	**61**	**55**	**12**

Table 15 Main information regarding Collection points

The following Figure 12 represents the number of collection points in each district.

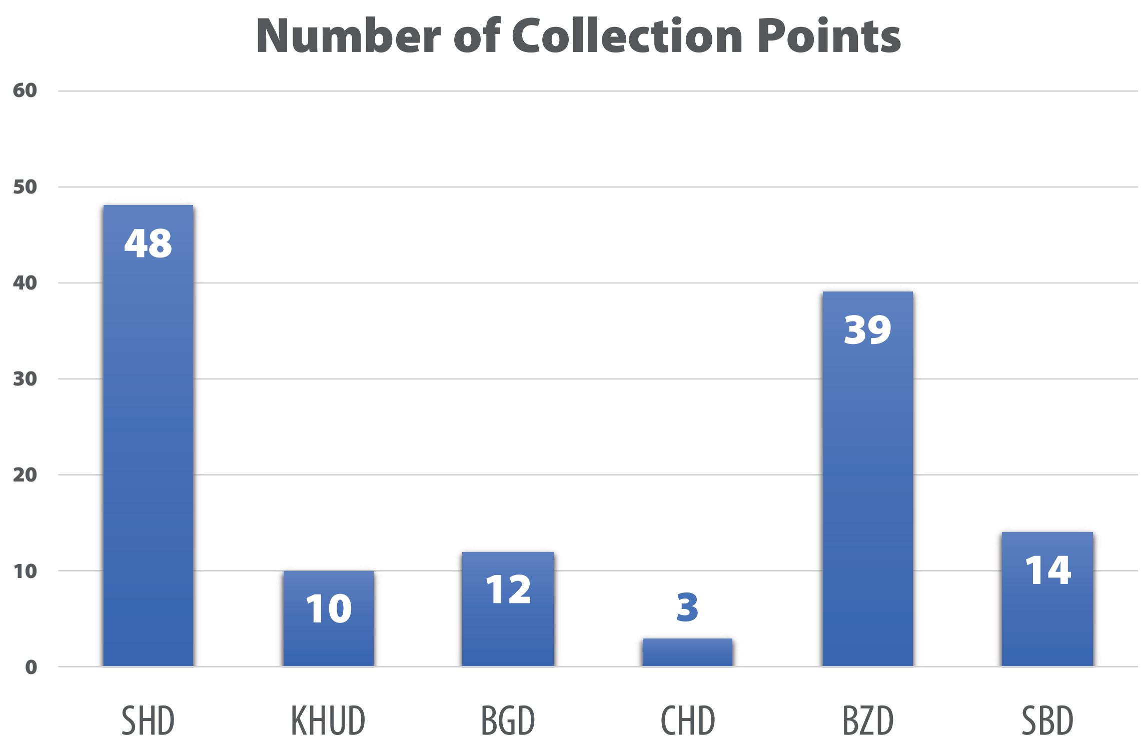


Figure 12 Number of Collection points in each district

The collection points involved in the survey currently purchases the following types of raw materials:

- Plastic
- Glass
- Metal
- Aluminium
- Copper
- Car batteries
- Can

On average of two people works in collection points, the workers do not have any protection for health and safety. The average monthly salary is around 192,000 tugrik which is the lowest salary in the labour wage. Figure 13 presents the exact number of employees working in the surveyed collection points.

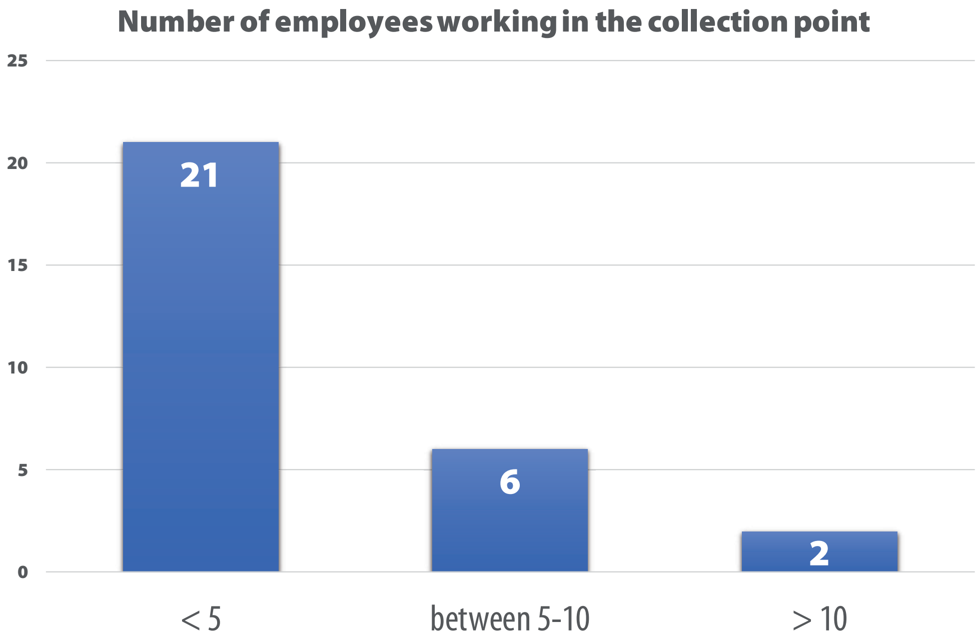


Figure 13 Employees working in the collection point

Collection points collect mainly valuable materials which can be easily sold to recycling industries such as metals, plastic and in a small quantity glass. Only metals (steel, armature, electric wire, water and heating tube) from CDW are collected.

The exact amount of the materials collected on a monthly base by collection points can be seen in Table 16.

Type of collected material	Volume [ton]
Plastic	1.1
Steel	20
Aluminium	1.3
Copper	0.6

Table 16 Exact amount collected by collection points in a monthly base

Table 17 shows the prices of secondary materials. Prices of secondary materials were found to be similar among the collection points.

Type of collected material	Price [MNT]
Glass [unit]	50
Car battery [unit]	5,000
Can [kg]	500
Plastic [kg]	225
Steel [kg]	77
Aluminium [kg]	771
Copper [kg]	5,481

Table 17 Prices of the secondary materials

5.3.3 Recycling Industries

Recycling is a new concept in Mongolia. The Mongolian recycling sector plays an important aspect of Mongolia's environment and society. A strong and sustainable recycling sector is essential for Mongolia to utilise resources more efficiently and maximise the full value of materials. At present there is limited information on the recycling sector and the potential for this sector to contribute to environmental, economic and social outcomes. The key reasons underlying this lack of information are the following:

- The recycling sector is often considered along with the waste sector and it is not always possible to isolate the data and information that relates to the recycling sector alone.
- The recycling sector is often highly integrated with other sectors, particularly transport, waste and manufacturing, and it is not always possible to, or there has been no attempt to, isolate the data and information that relates to recycling activity.
- Recycling sector is not clear belong to which government department collect data information, and strategy. There is no fixed law and regulation for recycling sector.

Recycling industries are most commonly concentrated in capital city along with Mongolia's population and industry. For reasons of efficiency, factories tend to locate themselves near the source of materials or end markets, or both.

A total of 21 recycling industries are currently operating in Mongolia and 20 industries are located in the seven districts of capital city UB. Namely the following entities are operating in cooperation and non-cooperation with the Mongolian National Recycling Association (MNRA). Figure 14 shows the number of recycling industries in Mongolia distinctly.

Number of recycling factories in Mongolia

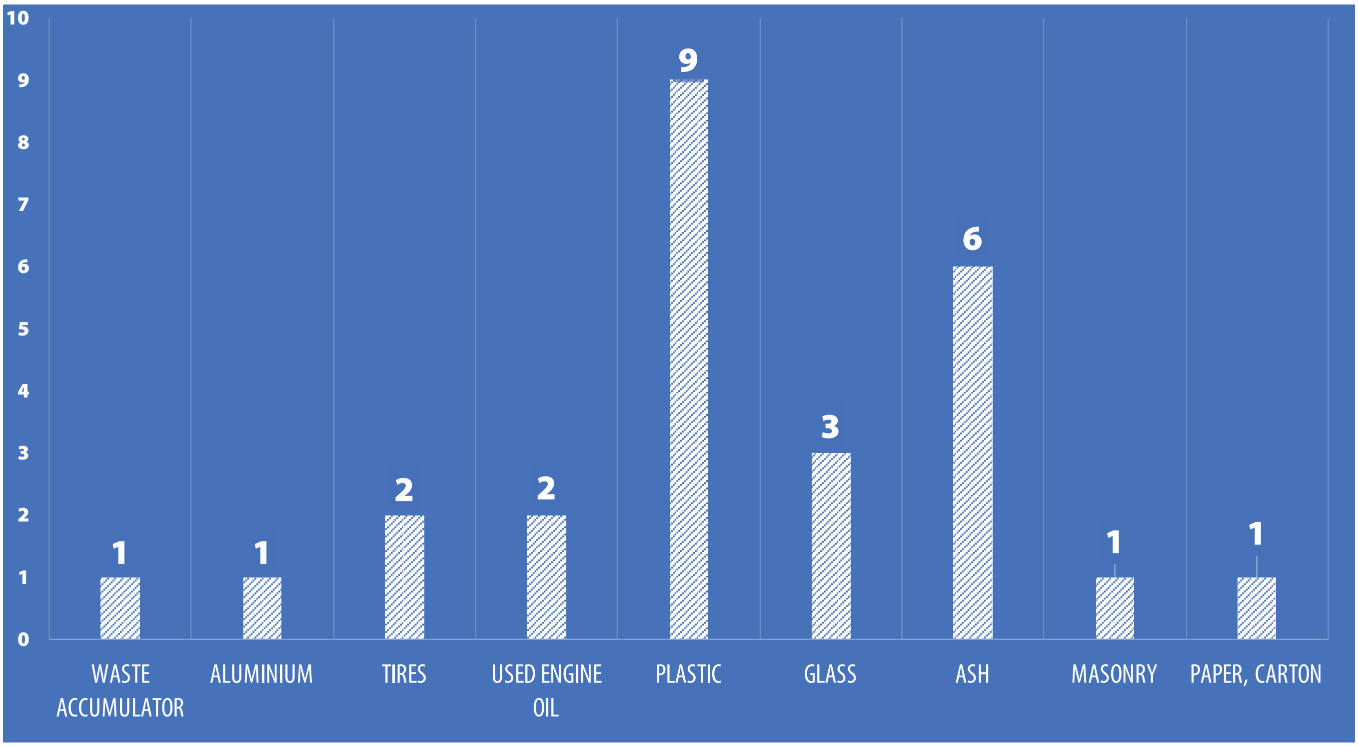


Figure 14 Number of recycling companies in Mongolia

The surveyed factories present different sizes depending on their market, technology, volume of production, sales of production in market, organizational structure, and human resources. The majority of the industries are medium size industries, except for ash and masonry recycling factories. Depend on industry size, volume of secondary materials and production is varying, such as in the case of plastic recycling where an average of 30-35 tonnes are recycled monthly. On the other hand, large size industries are present such as ash recycle industries with a recycling rate of 100-150 tonnes monthly. These ashes recycle industries able to recycle more than 300 tonnes.

All of industries pay for their raw materials (secondary materials), and purchase them from collection points, collectors or other entities.

In the following sub-chapters, the information obtained for each of the material is presented:

- Plastic
- Glass
- Metal
- Tire
- Ash
- Masonry materials
- Used oil and car battery

5.3.3.1 Plastic

Plastics and polymer products are significant contributors to overall Mongolian waste generation, as they are incorporated into a wide variety of materials across all industries. Each category of plastics has different properties which make it suitable for various applications.

The price of secondary materials is related to the quality of materials and plastic bottles and bags are primary sources of productions. The major applications are tubes, plastic bags, bottles and others (chair, cage, bin). There is no standardization implemented into industries. Most of the industries have been operating since the 2010 year and all the surveyed factories funded by their money and loan.

Table 18 presents all the information relative to the plastic recycling in Mongolia.

		Total volume input	[unit]	Total volume output	[unit]	Product	Average price MNT
Type of waste: Plastic	Number of companies: 9	35	tons	30	tons	Plastic bag tube	400-600kg
		7	tons	6	tons	Granulated recycled plastics	300kg
		30	tons	22,5	tons	Chairs, fences, floor	400-500kg
		130	tons	60	tons	Export	300-500kg
		42	tons	42	tons	Spacer	200kg
		8	tons	5	tons	Package	150-600kg
		45	tons	35	tons	Package for bottle	300-1000kg
		10	tons	10	tons	Chair	280kg
		12,5	tons	1400	tons	Tube for electric wire	400-1000kg

Table 18 Relevant information for plastic recycling in Mongolia

An overview of the production process of plastics from generation through to the manufacture of products using recycled material is provided in Figure 15 and further discussed below.

Figure 15 Overview of the reprocessing plastic flow

There are around 20 employees work 160 hours monthly in the factories. Average salary is 600,000-1,000,000 tugrik per month. Employees receive health and safety instructions before start operation.

Industries receive only sorted materials from collection points and scavengers but other types of industries produce plastic waste such as mining and agricultural companies. The main problem is a lack of awareness of the potential waste suppliers, and the absence of collaboration with other sectors. Only a few manufacturers collaborate with mining companies and receive plastic waste from them.

One of the most significant problems is the size of the market, because of small market manufacturers work with full capacity and they found difficulties in selling products.

The following photos were taken during the interviews. Different factories involved in the plastic recycling can be seen in Figure 16.

Figure 16 Plastic recycling

5.3.3.2 Glass

Glass is a material that can be reprocessed indefinitely and manufacturers benefit from recycling in several ways: recycled glass reduces emissions and consumption of raw materials, extends the life of plant equipment, such as furnaces, and saves energy.

The complete information relative to volume of secondary materials, amount of monthly production and average price of the secondary material can be found in Table 19.

Type of waste: Glass	Number of companies: 3	Total volume input	[unit]	Total volume output	[unit]	Product	Average price MNT
		20	tons	1000	tons	Road	40-50kg
		5	tons	60	pieces	Exterior statue	40-50kg
		20	tons	5	tons	Bottle for flower, exterior	40kg

Table 19 Relevant information for glass recycling in Mongolia

Glass collected for recycling in Mongolia primarily comes from food or drink containers, and includes clear, green and amber glass. Cookware glass, light globes, drinking glasses and window glass are examples of common glass types that will contaminate the recycling process for glass containers due to different melting points compared to that of recyclable glass. Plate glass, or window glass, may be reprocessed in Mongolia into products. However, this is not widespread, and a significant quantity goes to landfill. Nowadays, industries purchase only sorted glass such as bottles.

Industries receive only sorted materials from dumpsites, collection points, and scavengers. There is no standardization implemented to industries.

Glass bottles and jars are separated by colour either by hand sorting. The sorted glass is transferred to a beneficiation plant where contaminants are removed. Here, the raw material is loaded into a vibratory feed hopper, and the material is broken down and fed into shearer units which crush the glass. The crushed glass is referred to as cullet. The cullet is sorted by size and undergoes a visual inspection to remove visible contamination. An overview of the flow of glass from waste generation through to the manufacture of products using recycled glass is provided in Figure 17.

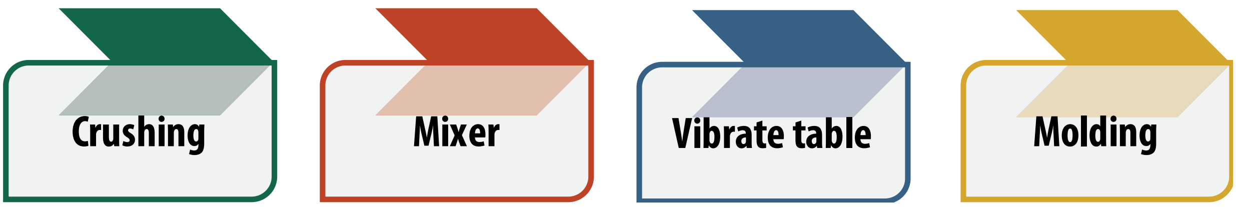


Figure 17 Overview of the flow of reprocessing glass

The main problem is given by the lack of market and investment, currently there is only one industry work. Furthermore, industries use obsolete technology, which results in low capacity.

5.3.3.3 Metal

The primary inputs for metals reprocessing fall into three material streams: steel, aluminium and other non-ferrous materials. Metal waste is predominantly sourced through commercial and industrial (C&I) activities, with contributions from municipal and CDW streams varying slightly by state/territory.

Steel scrap is 100% recyclable, having a potentially continuous lifecycle with the exception of some applications which render the steel unrecyclable. Recyclable scrap steel comes from a wide range of sources including packaging cans from municipal waste sources, automobile parts, large equipment and machinery, manufacturing off-cuts and building and construction materials.

Aluminium is also 100% recyclable, with infinite reprocessing resulting in no loss of properties. Common municipal aluminium waste comes from aluminium beverage cans. Inputs from C&I and CDW sources include automobile parts, machinery, electrical and electronic equipment, cables and foil.

Aluminium waste is shredded at steel shredding facilities and reprocessed through the melting of the scrap streams. Any coated aluminium is stripped of its coating prior to melting. Once the aluminium metal is in a molten state, its alloy levels are tested and adjusted before casting into aluminium ingots for further processing.

Figure 18 below shows the flow for reprocessing metals.

Figure 18 Overview of the flow of reprocessing metals

Industry receives and purchases wasted metal from scavengers, collection points and other industries.

5.3.3.4 Tire

In the following Table 20 data relative to tire recycling are summarized.

Type of waste: Tire	Number of companies: 2	Total volume input	[unit]	Total volume output	[unit]	Product	Average price MNT
		3000	pieces	30000	m^2	Surface	300-400kg
		7,5	tons	4	tons	Rubber surface (road)	3-5 tons

Table 20 Data relative to recycling tires in Mongolia

5.3.3.5 Ash

Coal ash also referred to as coal combustion residuals or CCRs, is produced primarily from the burning of coal in coal-fired power plants. Coal is the primary source of energy to generate electricity. Currently, four coal-fired power plants are located in Ulaanbaatar. Coal-fired power plants may dispose of it in surface impoundments or landfills. And also Ger districts are one of the major producers of ash. Residents of the Ger districts may discharge it into a nearby illegal dumpsite for landfill.

Ash blocks are used for construction in application such as filling material and coal ash may also be recycled into products like concrete or wallboard, such as fly ash brick.

Table 21 is presented to show the complete information regarding ash recycling in Mongolia.

Type of waste: Ash	Number of companies: 6	Total volume input	[unit]	Total volume output	[unit]	Product	Average price MNT
		100	tons	1500	m^3	Filling for construction	6000 ton
		30	tons	3000	m^3	Filling for construction	3300-5500 ton
		1350	tons	8000	m^3	Filling for construction	10000 ton
		600	tons	2800	m^3	Block construction	4000 ton
		500	tons	2750	m^3	Block construction	4000-5500 ton
		30	tons	600	m^3	Roof filling materials	4000 ton

Table 21 Data regarding ash recycling in Mongolia

Each industry implanted standardization such as construction materials standard and the majority of the factories were established within 2008-2014. The industry follows a seasonal trend from April to November because of the Mongolian climate conditions. Industries use modern technology, and present high production capacity. Following Figure 19 shows the overall process of reprocessing ash block.

Figure 19 Overall process of reprocessing ash block

Figure 20 Ash recycling

5.3.3.6 Masonry materials

Masonry materials are generated by building, construction and demolition activity. The largest proportion of masonry materials are generated by the construction and demolition industry. An overview of the flow of reprocessing masonry materials from generation through to the manufacture of products using recycled masonry materials is provided in Figure 21.

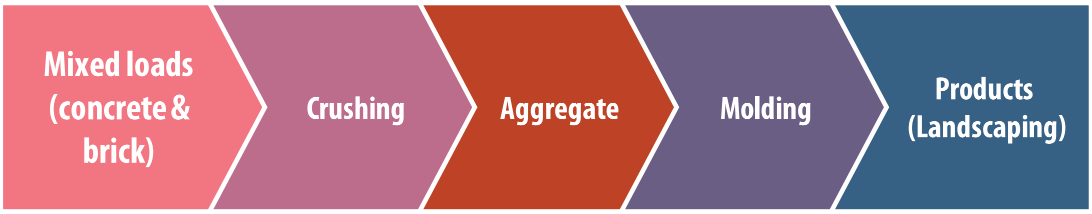


Figure 21 Overall flow of reprocessing masonry materials

Mixed materials currently represent the majority of CDW that is disposed to landfill. In general, materials tend to be transported to the closest site due to the expense of material cartage and the relatively low value per tonne of the recovered product. Masonry materials include asphalt, bricks, concrete, clay, fines, sand and rubble and plasterboard and cement sheeting.
The following Table 22 presents the data relative the masonry recycling in Mongolia.

Type of waste: Masonry	Number of companies: 1	Total volume input	[unit]	Total volume output	[unit]	Product	Average price MNT
		40	tons	5000	m^2	Landscaping	5000 m^2

Table 22 Data relative to the masonry recycling in Mongolia

Reprocessing techniques for masonry materials are generally relatively uncomplicated. Concrete, bricks and asphalt are crushed, either as mixed loads or in source separated streams. Once crushed, concrete is generally to test the physical properties of the mix.

Concrete is crushed and then reused as an aggregate with fresh cement. Aggregate products are screened to divide crushed materials into different sizes for different applications. The final application of recycled masonry aggregate may depend on:

- The size of the crushed, screened masonry.
- The composition of recycled materials (brick, rock, sand, crushed asphalt) and the resulting physical strength of the blended product.

Bricks may be reused completely intact in housing and construction, or in less structural applications if the collected bricks are excessively damaged, although technically these uses for intact bricks may constitute "reusing" rather than "recycling".

Industry receive and purchase from scavengers, collection points and other industries. The only industry in Mongolia was established in 2001 year and is implementing standards and codes for its products. The actual capacity of industry can provide 40% of market but actual production provides 26% of total demand.

Figure 22 Concrete a brick recycling in Mongolia

5.3.3.7 Used oil

Used oil is a valuable resource for diesel production. According to official records, the volume of used motor oil at dumpsites currently equals to 489 tonnes. However, based on the actual volume of import data of used motor oil, it was estimated that a total of 700 tonnes of used motor oil are generated.

Actually, only two companies reprocess used engine oil into diesel fuel as can be seen in Table 23.

Type of waste: Used engine oil	Number of companies: 2	Total volume input	[unit]	Total volume output	[unit]	Product	Average price MNT
		90	tons	60	tons	Diesel fuel	150-250kg
		250	tons	225	tons	Oil (New)	200-300l

Table 23 Data relative to used oil recycling in Mongolia

5.4 Recycling regulations and conclusion

One of the purposes of the in-depth interviews conducted for the research was to arrive at an understanding of the effectiveness of current waste management policies and regulations. Waste management reform is in its early stage of development since Mongolia's transition to market economy. The relevant legislative acts for this sector were started to be developed from 2000.

The waste issue is dealt by different ministries and there is not a clear distribution of responsibilities related to waste management and to reduction of waste disposal. Most current policies are not detailed enough for guiding and enforcing waste management. Furthermore, interviewees expressed the view that the government should implement an operable waste management policy to actually guide waste sorting, reduction, reuse, recycling, and disposal. More specific policies should be adopted to explicitly specify the responsibilities of concerned stakeholders and prevent illegal dumping in street and open space. Also it is required to continue establishing landfill sites in urban areas in connection with a policy which creates a waste classification system.

Comparing to other countries, recycling sector in Mongolia is an informal sector and a limited amount of data, and information are registered. The industry should be regulated by the government both at municipality and districts levels.

Furthermore, the lack of investment constitutes a major problem, most of actual recycling plant's equipment is obsolete and a strong renovation is needed.

The Municipal Governor's Office is in charge of waste treatment along with its executive agencies including environmental protection authority and district maintenance companies. Furthermore, there is a lack of potential policies, techniques, financial resources and human resources

6. RECOMMENDATION BASED ON EU BEST PRACTICES

6.1 Introduction

Waste arising from construction and demolition activities in both structural and civil engineering, as well as from earthworks, is referred to as CDW. Like its sources, CDW is a mixture of different components such as concrete, wood, bricks, glass, metals and asphalt as defined in the European list of wastes (EC, 2000).

Mongolia is facing problems similar to what happened in Europe in former times when CDW was dumped together with municipal solid waste or was used due to its mainly inert character directly for landfilling.

Nowadays, in Europe, the waste hierarchy (3Rs) orders the waste management options: prevention or reduction as the most preferable, preparing for reuse, recycling, other recovery, and disposal (JRC-IES, 2011). To meet these requirements, generated CDW needs to be separately collected and processed in waste management plants to allow recycling of the materials.

CDW recycling rates vary strongly between EU member countries and range from, for example, around 14% in Spain to 98% in the Netherlands (Tojo and Fischer, 2011). This variation can be partially attributed to differences in reporting between countries.

According to calculations of this report, Ulaanbaatar will experience a large amount of CDW in the following years, mostly due to extensive plans for demolition of old buildings and newly gained economic prosperity.

The large majority of the total amount of CDW will be constituted by stony materials, in particular, brick and concrete and if the present situation will persist all this waste will go to disposal sites, probably to illegal landfills.

To avoid this situation is necessary to find main problems and firstly tackle only important ones, following the 20-80 rule whereby focusing on 20% of total problems it will achieve 80% of the goal.

The following chapter aims to highlight the major barriers in CDW recycling in Mongolia and to present the possibilities for using recovered C&D waste, in accordance with European applications and standards.

The focus was made on different fractions that are most likely found in the CDW stream in Mongolia. The aim here was to describe for each identified fraction the EU applications that are made in the construction sector (buildings and civil engineering), the current reuse and recycling rates already achieved, and the emerging techniques.

6.2	Mongolian gaps in CDW sector
6.3	Recommendation based on EU best practices
6.3.1	"3R"
6.3.2	Legislation recommendations
6.3.3	Asbestor-related problems and regulations
6.3.4	Selective Demolition
6.4	Conclusions

6.2 Mongolian gaps in CDW sector

In Mongolia, during 2006 to 2014 the amount of CDW has increased by a factor of six. Therefore, CDW is a critical concern and requires better management. In this report it is calculated that CDW represents about 10-15% of the total waste generated in UB.

In Mongolia, CDW management represents a significant challenge because the performance of SMEs in this field is still poor. There are difficulties which keep SMEs away from proper CDW management practices. In addition, CDW Recycling SMEs in Mongolia face a lack of knowledge and the technical capability to deal with negative environmental impacts.

Based on the results of the study, it is concluded that the technical and non-technical limitations in the existing CDW management system include mainly:

By the extend of this baseline study it is sufficient to present information about the number of buildings for each districts by year built in Table 20.

- Lack of awareness and culture regarding waste management by Government agencies.
- Lack of support and human resources from key stakeholders such as Inspection Agency.
- Lack of incentives from construction regulatory authorities and low costs of sending materials to landfill.
- Lack of community attention on CDW management.
- In the building materials and in recycling industry in Mongolia processing technology and equipment are often obsolete.
- Demolition activity is not followed by the separation of CDW because companies have no incentives to perform this task.
- Construction companies do not collaborate with recycling companies, most of the time they are not aware of the existence of recycling sector in Mongolia.
- Lack of a database for the buildings of UB create a big obstacle to a clear understanding of the quantities of CDW produced after a demolition.

- Recycling companies do not have sufficient knowledge and technical capability to recycled CDW effectively.
- Recycling companies lack access to finance and face difficulties in marketing their products.

The aforementioned constrains have roots in existing cultural, environmental, economic and politic constraints.

The main obstacles are the lack of political will, the clients interest for wastes recycling and the lack of trust in recycled materials, the lack of treatment facilities in some areas and the importance given to storage facilities which seem neither expensive nor selective enough. From a general view the first thing to notice is the lack of specific regulation related to CDW management in Mongolia, until now there is not any planning or regulation for proper way of dismantling and demolition of End-of-Life buildings.

In the regulation it is written, only in general terms, that wastes like brick, concrete, wood, insulation materials, nails, electrical materials, plumbing equipment, reinforcing armatures, tiles and wall paper wastes which cannot be used again is called construction waste. On the other hand, most of the articles of the regulation are about roles of different organizations and citizens. Very little has been written about the fining system if the regulation is not followed and also there is a gap about the incentive part, or rather if organizations and citizens adopts separating the waste constantly for certain period of time they can be allowed to not pay the waste fee.

Furthermore, the rule for demolition, approved in 2012, is about the demolishing process of the old buildings and buildings that cannot be used again because of the damages they have.

The rule is mainly about the reason to demolish a building, separation of the different demolish able buildings, methodologies of demolition but presented only in a very general way, the preparation of demolition work, management and safety issues, and at the end prohibited activities during the process of demolition.

It is also difficult to adapt the on-site waste management practices to ensure waste sorting (appropriate containers are not always implemented). However, many drivers can be used to address these obstacles, such as a binding regulation encouraging recycling facilities development as well as high recovery rates, a deterrent storage taxation system, the generalisation of the practice of allotment in call for tenders highlighting the costs of waste management and the necessity for waste tracking.

It is also important to mention that wastes treatment is an economic and social issue for all the stakeholders: CDW management represents important costs for the construction and demolition companies. Even though improving on-site CDW sorting is costly, it potentially enables to reduce the overall costs by improving recycling rates.

6.3 Recommendations

To solve CDW in Mongolia, it is required a multidisciplinary effort needing coordinated inputs from different stakeholders. Any waste management strategy should be considered in the framework of administrative, financial, legal, planning and engineering functions. This is in line with the trend that CDW management is becoming an important issue of sustainable development, which concerns environmental, social, and economic development as a whole.

The importance of multidisciplinary efforts has been increasingly acknowledged in both waste management research and practice. The report is providing solution mainly focused on the "hard" technologies while a dedicated part to the "soft" measures will be presented.

The criteria for the choice of the recycling technologies to be further studied in details depended either on the importance of the fraction in the total CDW stream and therefore on the potential contribution the material could bring to sustainable improvements in Mongolian construction sector.

The identified fractions are the following:

- Bricks, tiles and ceramic
- Concrete
- Gypsum
- Wood
- Glass

6.3.1 "3R"

CDW practices in Mongolia have to be guided by "3Rs" principle, which is also known as the hierarchy of CDW.

The principle refers to the 3Rs of reduce, reuse, and recycle, which classify waste management strategies according to their desirability (Peng et al., 1997).

The 3Rs is meant to be a hierarchy, arranged in ascending order of their adverse impacts to the environment from low to high.

Reduction is considered as the most effective and efficient method for managing CDW. It can not only minimize the generation of CDW, but also reduce the cost for waste transporting, disposal and recycling (Poon, 2007; Esin and Cosgun, 2007). The important solutions for reducing CDW in Mongolia can be generally summarized into five categories:

- Reducing waste through government legislation.
- Reducing waste by design.
- Developing an effective waste management system (WMS).
- Use of low waste technologies.

- Improving practitioners' attitudes toward waste reduction.

Reuse means using the same material in construction more than once, including using the material again for the same function (e.g. formwork in construction) (Ling and Leo, 2000) and new-life reuse for a new function (e.g. using the cut-corner steel bar for shelves; using the stony fraction for road base material) (Duran et al., 2006). It is the most desirable option after reduction because a minimum processing and energy use is achieved (Peng et al., 1997).

When reduction and reuse become difficult, recycling is desired. Tam (2008) summarized that recycling can offer three benefits:

- Reducing the demand for new resources.
- Cutting down transport and production energy cost
- Utilizing waste which would otherwise be lost to landfill sites.

Two major concerns on recycling in Mongolia are the economic viability and acceptability of recycled materials. Typically, from a purely economic point of view, recycled materials are only attractive when they are competitive with virgin materials in terms of cost and quality. Besides, the general public often worries about the quality of reused or recycled materials.

6.3.2 Legislation recommendations

The European Union, in the early nineties, created a strategy that can guide and harmonize the waste management policies of construction and demolition in the different member states. The EU plan presents the following principles:

Prevention: In addition to education/information campaigns, involving the development of design in a material once the reuse and waste reduction, in conjunction with the production of environmentally friendly materials.

Separation: means the spread of selective demolition oriented to material recovery, encouragement of recycling and discouraging landfilling.

Treatment: It proposes to introduce a system of permits and licenses issued to companies involved in activities related to the production of construction & demolition waste. CDW consists of the debris generated during the construction, renovation, and demolition of buildings, roads, and other engineering works. The large amounts of those wastes that are generated annually can be recycled and reused because of the high potential for reuse and recycling embodied in these materials.

Directive 2008/98/EC sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling, recovery. It explains when a waste ceases to be waste and become a secondary raw material (so called end-of-waste criteria), and how to distinguish between waste and by-products.

The Directive includes two new recycling and recovery targets to be achieved by 2020:

50% preparing for reuse and recycling of certain waste materials from households and other origins similar to families, and 70% preparing for reuse , recycling and another recovery of C&D debris.

The Directive requires that Member States adopt waste management plans and waste prevention programs.

Mongolia has to look at countries which have dealt with those problems and have achieved high recovery levels like Germany or Netherlands.

In Netherlands, over 93% of the CDW is recovered (recycling, energy recovery and other recovery) of which 95% is recycled while the amount of landfilled CDW is dropping.

In the Netherlands, the legal framework regarding waste management and CDW management in particular, is extensively set up. The most important decisions and legislations are:

- It is compulsory that a National Waste Plan is established
- For the majority of the waste, a landfill ban exists. The tax for landfilling is €13 per tonne.
- Import and export of wastes are highly restricted.
- Currently, also an incineration tax in introduced, in order to decrease the amounts of burned waste.

In the Netherlands, waste management and more specific CDW management are mature. Both an advanced waste management plan and waste prevention plan exist. As mentioned before, over 93% of the CDW is recovered and landfilling CDW is almost non-existent.

Many governmental entities, building designers, clients, contractors and recyclers are involved in sustainable CDW management. The most important best practices are:

- Led by the government and in collaboration of various industry organisations and sector associations, so called Greendeals are brought to live. Among others, Greendeal cirkel city, Greendeal circular buildings, Greendeal sustainable ground, roads and water construction and Greendeal sustainable concrete exist.
- Many industry initiatives exist in which buildings or entire districts are built with the use of CDW.
- Different R&D programs on recycling mono streams from CDW exist.
- Finding and implementing circular economy solutions is on the rise in for different waste types, among which concrete.
- More and more CDW prevention initiatives start to arise.

An important recommendation for Mongolia is the enforcement of the landfilling bans.

Mongolia can follow the EU approach where the most drastic measures to prevent landfilling of CDW were adopted in Flanders, with straightforward landfill bans for recyclable fractions of CDW. However, its applicability might depend on the local context: in Flanders, low historical landfill rates of CDW, high density of population and scarcity of landfill space available may have contributed to the efficiency of this measure.

In Mongolia, a stricter control of landfilling for CDW is needed. Setting proper landfilling regulations will be a major driver towards better CDW management. For example, in Denmark, Netherlands and Germany it is forbidden to landfill waste materials which can be recycled or incinerated. In addition, the landfill disposal fees and taxes, governmental encouragement for environmental friendly practices and granting the related activities and management of demolition waste are key factors.

The responsibility of each stakeholder must be clearly defined and could be as follow:

- The client is responsible for the waste and takes into account waste management costs and tools in its specifications and budget.
- The project management company identifies the different materials and waste streams, assess the potential for recovery identifying clearly the potential waste treatment options and ensures waste tracking during the project.
- The demolition company takes into account the assessed waste generation in the organization of its work, knows the chosen recovery options, tracks the waste.

Once, legal framework is set up, it is necessary to create standards for recycled products to ensure quality and ease market tendency to buy those products.

Looking at concrete as the main waste flow estimated in Ulaanbaatar, EU standards can be applied and adapted.

In EU, recycled concrete aggregates can be used as the substituent of the natural coarse aggregates for new concrete production. Use of up to 20% concrete aggregates as substitute of natural coarse aggregate is a common practice in the mortar and concrete production facilities. There are specified EU standards related to the concrete properties. In the Netherlands, concrete with or without recycled aggregate content should comply to NEN-EN 206-1 and NEN 8005. Aggregates that are included in the concrete, for example, sand, gravel or concrete aggregates, need to comply with the NEN-EN 12620 and NEN 5905. In case the portion of added recycled aggregate is 21% or higher, the concrete should comply with the CUR-recommendation 112. Use of more than 50% of recycled aggregate into the new concrete, requires adjusted calculation methods for the use of the concrete.

6.3.3 Asbestos-related problems and regulations

Asbestos-related diseases kill more people than any other single work-related cause. All types of asbestos can be dangerous if disturbed. The danger arises when asbestos fibres become airborne. They form a very fine dust which is often invisible. Breathing asbestos dust can cause serious damage to the lungs and cause cancer. There is no known cure for asbestos-related disease.

The more asbestos dust inhaled, the greater the risk to health. Until recently it was thought that those dying from the asbestos-related diseases were regularly exposed to large amounts of asbestos. It is now thought that repeated low exposures or occasional high exposures to asbestos can lead to asbestos-induced cancers, although the exact scale of risk at lower levels of exposure is unknown. Therefore, precautions should always be taken to prevent exposure, or where this is not practicable, to keep it to a minimum. Workers such as plumbers, electricians, and heating engineers may not consider that they work with asbestos, but they might regularly drill, cut and handle materials containing asbestos and need to be protected.

Asbestos is a very durable fibre. It was widely used in materials where resistance to heat or chemical attack was important and to give strength to cement products such as insulation boards, corrugated roof sheets and cement guttering and pipework. Sprayed asbestos coatings have also been used to reduce noise.

In May 2004, regulation 4 of the Control of Asbestos at Work Regulations 2002 came into force. Since then, anyone responsible for maintenance and repair of a commercial or industrial property has an explicit duty to identify asbestos in the premises and manage the risk.

In summary, this means they must:

- Check whether there is any asbestos present.
- Check on its condition.
- Assume the material contains asbestos unless there is strong evidence to the contrary.
- Assess the risks from any asbestos-containing material.
- Take action to manage the risk so that no one will unknowingly disturb asbestos.
- Provide information about the material to anyone likely to disturb it.

Building and maintenance contractors should no longer be unsure about when they will come across asbestos in commercial buildings as, under the duty to manage asbestos in non-domestic premises, the building owner/occupier is required to provide information about the presence of asbestos on their premises. Often the presence of asbestos will not be obvious, and it is not always easy to identify asbestos from its appearance. Unless the building owner can produce clear records to show that the area where work is to be done is free from asbestos, it is sensible to assume that any buildings constructed or refurbished before the 1990s are likely to contain asbestos-based materials.

Directive 2009/148/EC

The Directive applies to activities in which workers are or may be exposed to dust arising from asbestos or materials containing asbestos in the course of their work. If any activity is likely to involve such risk of exposure, a risk assessment must be carried out including consultation with the workers.

The risk assessment has to determine the nature and degree of the workers' exposure to dust arising from asbestos or materials containing asbestos and it must be revised if circumstances change significantly. If the exposure of the worker is sporadic and of low intensity with exposure limit not exceeded, the activity need not to be notified, health assessment of workers and clinical surveillance are not obligatory and workers need not be registered.

Activities with exposure to asbestos dust are to be notified by the employer to the responsible authority of the Member State, and re-submitted if a change in working conditions result in higher asbestos exposure. The minimum content of such notification is set. Workers or their representatives are entitled to see the notification.

Any activity exposing workers to intentionally added asbestos fibres shall be prohibited, with the exception of the treatment and disposal of products resulting from demolition and asbestos removal.

Exposure to asbestos during demolition and asbestos removal must be reduced to a minimum, including: minimising the number of persons exposed, prioritising dust-free work processes, cleaning buildings and ensuring that materials are properly stored, transported and labelled.

In order to ensure compliance with the limit values, qualified personnel shall regularly measure asbestos-in-air concentrations, in an appropriate way.

The single maximum limit value for airborne concentration of asbestos is 0.1 fibres per cm^3 as an eight-hour time-weighted average (TWA).

If the limit value is exceeded, the reasons must be identified and appropriate measures taken to remedy the situation. Work may not continue before measures are taken. Effectiveness of measures shall be verified. In case limit values cannot be observed by other means, employers shall provide proper protective equipment. The use of the equipment may not be permanent and appropriate break periods shall be set.

Before beginning demolition or maintenance work, employers shall take all necessary steps to identify presumed asbestos-containing materials. This may include obtaining information from the owners of the premises.

If it is foreseeable that limit values cannot be kept by technical measures, following consultation with workers, the employer shall ensure protection, including: providing proper personal protective equipment, putting up warning signs and preventing the spread of asbestos dust.

A plan of work, specifying health and safety measures shall be drawn up before start of work. Competent authorities have a right to require detailed information.

Employers shall provide appropriate training for workers on:

- Properties of asbestos and health effects.
- Products/materials that may contain asbestos.
- Operations that could result in asbestos exposure and the importance of preventive controls.
- Safe work practices, controls and protective equipment.
- The appropriate role, choice, selection, limitations and proper use of respiratory equipment.
- Emergency procedures.
- Decontamination procedures.
- Waste disposal.
- Medical examination requirements.

Asbestos removal/demolition can be done by firms that have provided evidence of their ability.

Workplaces with exposure risks shall be demarcated and indicated by warning sign. Access shall be forbidden to others than those who by reason of their work or duties are required to enter. Smoking shall be prohibited. Areas are to be set aside where workers can eat and drink without any risk of asbestos contamination. Working/ protective clothing/equipment shall stay at the place of work, always separated from street clothes, and be cleaned/maintained accordingly at no cost to the workers.

Employer shall inform workers on every aspects of work in asbestos exposures (risks, binding limit value, obligatory atmosphere monitoring, hygiene requirements and specific precautions). If the limit value is exceeded, workers concerned shall be informed and consulted.

Each worker's state of health must be assessed, including a specific chest examination, prior to exposure asbestos, and subsequently at least once every three years during exposure. Physician shall inform worker if ongoing surveillance might be recommended even after exposure.

Employers must keep a register indicating the nature and duration of the activity and the exposure. Worker and physician shall have access to information concerned. Data shall be kept for 40 years and transferred to the authority concerned if the firm ceased to exist. Member States must keep a register of cases of asbestosis and mesothelioma.

6.3.4 Selective demolition

One of the main objective of the CDW project in Mongolia is to transfer the knowledge of an optimum demolition strategy (for example process, costs, logistics, procedures, timing) and select the best tools for dismantling and demolition that will maximize the high quality reuse of valuable components and materials, minimize contamination mixed with recycled products, and minimizing time, the safety risk and the impact of demolition process on the environment. An End-of-life (EoL) building may be conventionally or selectively demolished. In the Netherlands, selective dismantling and demolition of EoL buildings is one of the common practices in CDW management projects.

The difference between conventional and complete selective demolition is that in selective demolition the workers use light mechanical tools in order to recover the highest percentage of materials that can be reused, whereas in conventional demolition the workers use heavy equipment (explosives, wrecking balls, bulldozers) and, as a result, the generated waste is mixed and the recovery of materials is difficult.

This technique requires more working hours and a longer time period, as the removal of various materials is carried out manually. However, the generated waste is clean from dangerous contaminants and materials that cannot be recycled, thus at the end the process is economically beneficial as well. The complete selective demolition is separated into various phases, so in each phase a different material is removed and collected (Nakajima 2000). Consequently, the recovery and recycling rates of materials are increased substantially.

The Selective Demolition, as presented in Figure 23, is divided in four main phases:

- Tendering Stage
- Dismantling Stage
- Demolition Stage
- Post-Demolition Phase

Figure 23 Overview of the Selective Demolition process

Below, each of the stage is summarized into the main parts.

Tendering Stage

The demolition process starts when the client makes a decision to demolish a structure. The demolition contractors are then invited to bid for the job. The contractor has to go on site for study it and choose the best technology and methods for demolish the building.

In practice, demolition contractors do not have a structured framework for selecting the demolition technique. They make judgments based on their skills, relevant knowledge on the techniques, and past experience. This has resulted in the need to conduct a selection process for any specific project in a structured and systematic manner. At the same time the contractor has to calculate the waste produced and produce an inventory of the elements to be reused or recycled.

In the tendering stage the companies have to:

- Measure the duration and the costs of demolition.
- Create satisfactory working conditions.
- Ensure the safety of staff at site.
- Increase the quantity and improve the quality of materials intended for enhancement.

To achieve this goal, the companies can use an integrated approach by comparing the costs of different techniques to use and enhancing a maximum transformation of the constructive elements in reusable or recyclable materials.

The following phase is to produce a method statement. The method statement addresses the site's particular needs, and details the planned sequences and techniques of demolition selected in the previous process.

The tender document together with the method statement will then be submitted to the client for the contractor evaluation purpose.

Dismantling Stage

If the contractor is selected the first process in the pre-demolition stage is the site preparation. The phase may include the erection of security fencing, and the setting-up of welfare facilities (e.g., site office, washing facilities and toilet).

Subsequently, decommissioning can be defined as a "process whereby an area is brought from its fully operational status to one where all live or charged systems are rendered dead or inert and reduced to the lowest possible hazard level". The decommissioning activities include, for example, removal of all asbestos and chemicals (e.g., battery acids and oils), and controlled release of stored energy in strong springs or suspended counterweights.

In 1970s and 80s, the Dutch construction sector used asbestos in the buildings. Therefore, prior to the dismantling, asbestos should be removed (see Figure 24). Mongolia has been utilizing asbestos for 42-48 years for the different purposes such as thermal pipe system insulation, water supply pipe system insulation, gasket that can function as a sealing or isolation. Therefore, also in Mongolia prior to demolition of EoL buildings, it is essential to detect and remove asbestos.

Figure 24 Asbestos sanitation in Netherlands

The process followed after decommissioning is soft stripping. The soft stripping is the removal of non-structural items such as fixtures and fittings, windows, doors, frames, suspended ceilings, and partitions (see Figure 25). Some of the product from the soft stripping process can be reused and recycled. Materials, such as wood from windows or door panels, can be reused as building lumber, landscape mulch, pulp chip, and fuel. The bricks can be cleaned and reused, but this is rarely done. Aluminium, stainless steel panels, and copper are the typical recycled metals. Architectural artefacts, such as sinks, doors, bathtubs, and used building materials, are almost always resold. Even the industrial process equipment can be marketed both domestically and internationally.

Figure 25 CDW recovered from dismantling phase of the selective demolition

Dismantling Stage

There are three main types of structural demolitions:

- Top-down demolition
- High-reach demolition
- Demolition by explosives

These are alternative techniques that can be selected by the contractor in the selection process, conducted in the tendering stage.

The reuse and recycling process of concrete can be performed after or concurrently with the structural demolition process.

Post Demolition Stage

The final process is the site clearance, in which the site should be left in a safe and secure condition. Any pits, sump, trenches, or voids must be left filled and securely covered, and the site drainage system must be thoroughly cleaned and tested to ensure that it continues to operate. All contaminants must be left or removed in a manner such that they demonstrate no hazard to health or the environment. Finally, the planning supervisor should ensure that the Health and Safety File has been compiled and handed to the client upon completion of the work.

Figure 26 gives the overall picture for dismantling and demolition of an EoL building in the Netherlands.

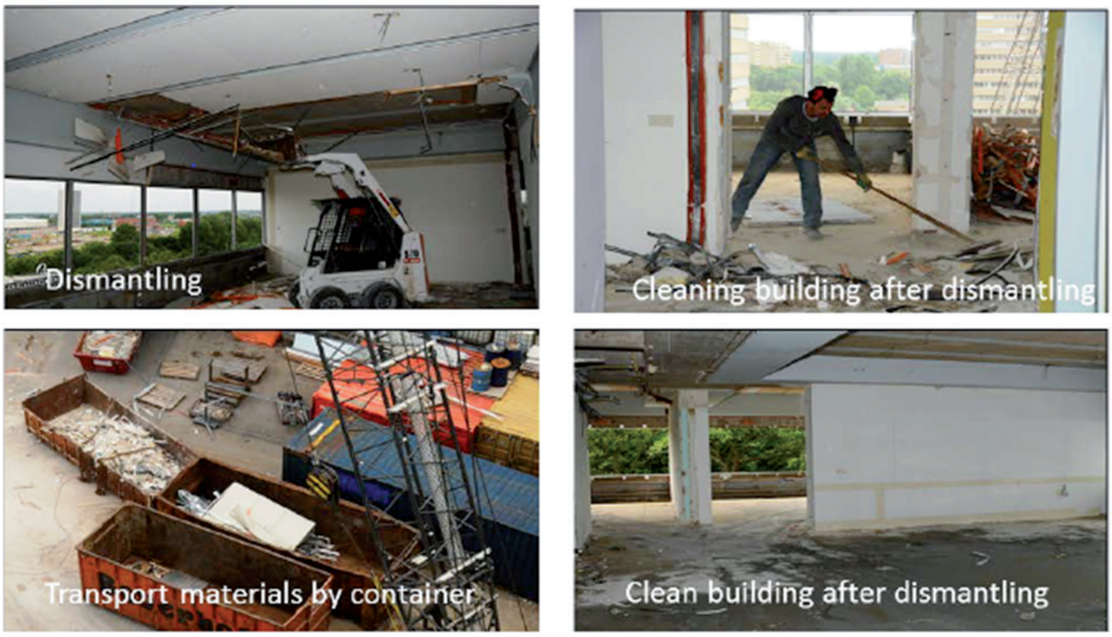


Figure 26 Overview of the selective demolition process

6.3.5 Recycling technologies

When analysing the scope of CDW recycling, a system's perspective on the entire waste chain and the primary aggregate supply chain is necessary to better understand the system's behaviour and assess future developments and possible consequences of interventions.

The CDW recycling methods are grouped according to the Ladder of Lansink (see Figure 27). The upper step is the preferred waste treatment option, rather preventing the waste to arise. Second, it is preferable to reuse the material as a whole, for example reuse of a window frame in a new or renovated house. Third, recycling of the material into other purposes is preferred. Next is energy recovery, burning the material and extracting energy from this process. The following step downwards is incineration without energy recovery. The lowest step of the Ladder is landfill, which should be avoided if possible. In the Netherlands, this last option has already been forbidden for a long time to stimulate recycling and incineration of materials (VROM, 2010a).

Figure 27 Ladder Van Lansink

6.3.5.1 Bricks

Bricks can be reused in their original purpose, use in the masonry of a construction. In order to prepare the brick for reuse a temperature treatment can be practised or the mortar can be manually removed from the brick. Treatment of bricks at a high temperature leads to strains built up in the brick and mortar. This causes shear stress on the mortar, since the mortar is on the interface of the brick (Mulder et al., 2007). As a result, crack formation on the interface sets the brick free.

The recovered bricks are of the same quality as before heating, complying to the Dutch standard NEN 2489 and the Dutch Building Materials Decree. Van Dijk (2004) shows that cement dominated mortar requires a temperature of 540°C for separation of the mortar and the brick. Higher temperatures are required for separating brick and mortar containing lime. A higher temperature results in more cracks in the bricks. This will especially be the case if the masonry debris is presented in large lumps. The critical quartz solid phase transition temperature of the ceramic clay brick is 573°C, in case a higher temperature is required for mortar separation the chance of fractures in the bricks increases.

In order to lower the cracking percentage, the bricks can be separated mechanically before heating. For the cement based mortar, Mulder et al. (2007) found that the recovery rate was 36% of the total mass of masonry input. In the test for the other mortar, containing lime, 2200 kg of bricks where mechanically separated before heating at 650°C. The recovery rate was 41%. The latter is higher, but the treatment is more labour-intensive, due to pre-treatment.

Masonry can be recycled with or without mortar separation. If the brick and mortar are not separated, the masonry is crushed to a fine grain size smaller than 0.5 mm. The aggregates are mixed with clay and fired in a kiln in order to make clay bricks. Since the mortar is still present in the added aggregates, the strength of the clay bricks will be affected (van Dijk, 2004). Van Dijk (2004), recommends based on empirical results is to use no more than 25% share of recycled masonry aggregates in brick production.

It is preferred to separate the clay bricks from the mortar in the masonry rubble, since the cement fraction will affect the strength of the brick when it is included in production of new bricks. By thermal treatment, the masonry is separated in cement and sand (ibid.; Tam and Tam, 2006). For different types of bricks, the added brick aggregates in production should be analysed on strength and quality. In the experiment of van Dijk (2004) where brick aggregates were added to bronze firing clay, from a Dutch river, was shown that from 70% brick aggregates with 30% bronze firing clay, a good quality clay brick can be produced.

In Spain, masonry aggregates are used as a substitute for virgin aggregates for different types of stones (Del Río Merino et al., 2010). In order to separate the masonry with contamination, all small particles were eliminated from the waste stream. The material stream remaining is crushed to the desired size while impurities are removed by the most common used method in Spain, the dry method: large size impurities are manually removed in an early phase of crushing.

The different recycling options promoted by the European Tiles and Bricks Association are described below:

- To fill and stabilise minor roads, especially in wet areas such as woods and fields. The practice is common in countries that lack adequate stone supplies such as Denmark. The material is generally used uncrushed.
- Crushed clay bricks, roof tiles and other masonry can be used on larger road building projects, especially as unbound base material. It is used to build roads in countries such as Germany, Denmark, the Netherlands, Switzerland and UK. In Germany, the maximum brick content for such use is 30%, due to quality requirements for frost attacks and impact resistance. The material replaces natural materials, such as sand and gravel, which are normally used in large amounts for this purpose.
- Aggregates for in-situ. Crushed clay bricks and other masonry can also be used to level and fill pipe trenches. The fine crushed material will replace natural materials such as sand.

- Crushed clay bricks, tiles and other masonry can also be used as aggregate in concrete. The crushed material replaces other raw materials such as sand. This is commonly practiced in Austria, Denmark, Switzerland and especially the Netherlands.

6.3.5.2 Concrete

Concrete can be reprocessed into coarse or fine aggregates. The first step is to remove all impurities such as insulation and steel reinforcement before crushing and grading. As a consequence, an effective sorting out at the construction site or at the treatment facility is essential to maximise the recycling potential. Mobile sorters and crushers are often installed on construction sites to allow on-site processing. In other situations, specific processing sites are established. Sometimes machines incorporate air knives to remove lighter materials such as wood, joint sealants and plastics. Magnet and mechanical processes are used to extract steel, which is then recycled.

Once sorted and processed, these aggregates can be used as such in road works, or reintroduced into the manufacturing of concrete. These different possible applications are described below.

Coarse aggregates can be used for road base, sub-base and civil engineering applications. The road construction sector still represents one of the main applications for recycled concrete aggregates in Europe and can significantly contribute to decrease Mongolian CDW flow.

Furthermore, coarse aggregates can also be used as a filling material in quarries (referred to as backfilling) which is in practice especially in Eastern Europe whereas in Western Europe quarries are rehabilitated into leisure spaces. Crushed concrete can also be used in earthwork constructions, to build streets, yards and parking areas, as backfilling for pipe excavations, environmental construction, foundations for buildings, etc.

Fine aggregates can also be obtained from concrete waste and used in place of natural sand in mortars. However, the use of recycled concrete fine aggregates could affect directly the mortar content and therefore its workability, strength and can cause shrinkage due to high water absorption. This could increase the risk of settlement and dry shrinkage cracking. For these reasons, recycled fine aggregates are not used in the production of structural concrete. Moreover, the contamination of concrete with gypsum may hinder the recyclability of the material, as cleaning represents important additional costs, both economic and environmental.

The above applications are often referred to as "down-cycling" as opposed to reintroducing recycled concrete directly into concrete production, where it can be used as a substitute to natural aggregates.

Focusing attention on concrete, a good starting point for Mongolia to pass from a linear economy to a circular economy prospective is concrete recycling regulatory framework in the Netherlands as shown in Figure 28.

As it can be seen, a lot of elements are involved to make a successful process and eliminating even one element could lead the process to a failure. This framework is developed during years in the Netherlands and can be successfully transferred and adapted to the Mongolian condition.

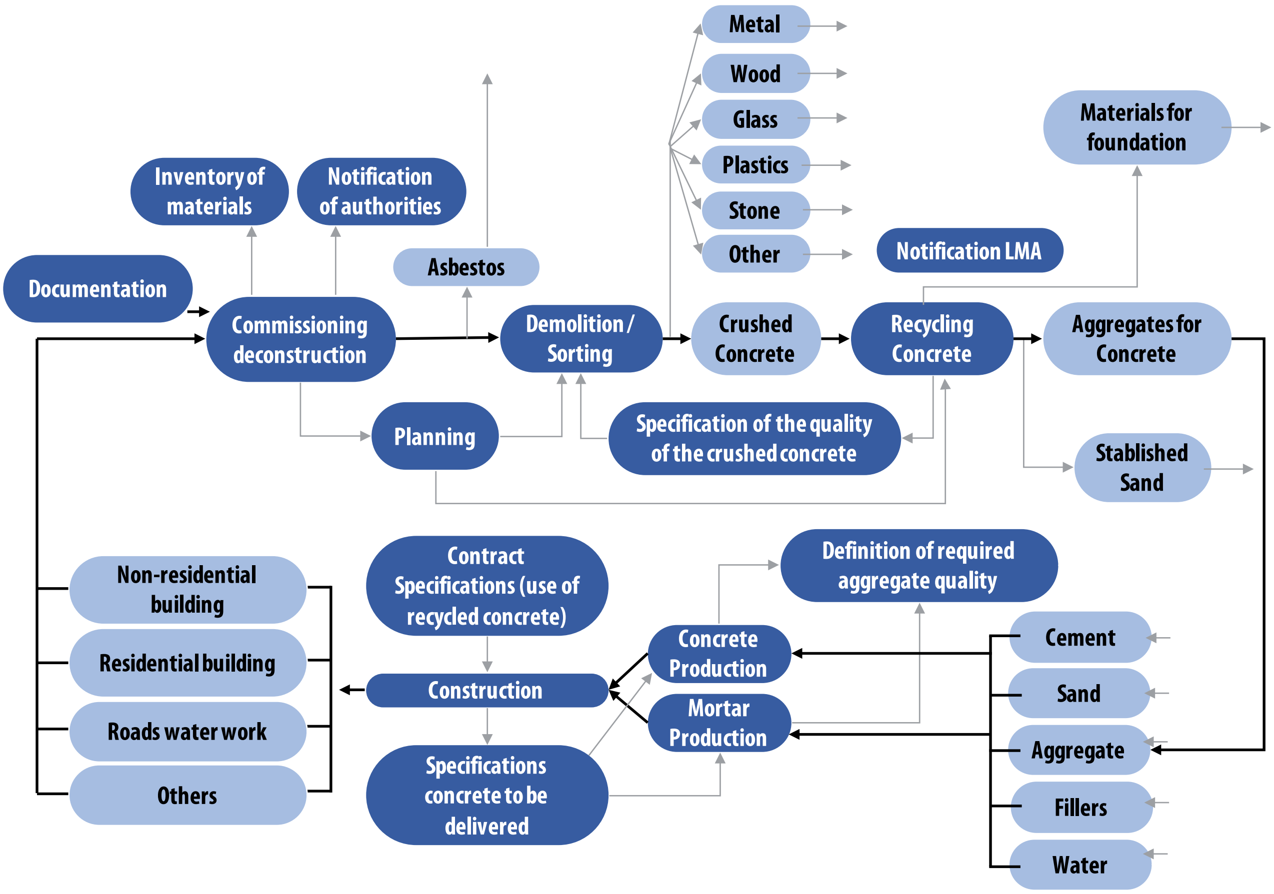


Figure 28 Concrete cycle developed in Netherlands

This framework signs the passage from a perspective where a linear process is followed, so as happens in Mongolia: "mineral - raw material - use of product – waste", to a circular process.

In the new chain by using waste as raw material, the surplus can be used to satisfy the demand for minerals, this produces the circular economy. For the concrete chain means that concrete rubble, the 'waste' of the demolition, is used in new concrete. Concrete aggregate is crushed from concrete rubble because the properties of this material make that it can be used as a gravel substitute in concrete.

6.3.5.3 Gypsum

Gypsum products are mainly composed of calcium sulphate dihydrate (CaSO4 2H2O). Examples include gypsum plasterboard and gypsum blocks. The hydration reaction of the CaSO4 2H2O is reversible (from stucco powder to gypsum products and vice versa) and because of this, the material can repeatedly change its properties, which enables closing the material loop. Once gypsum products reach their end-of-life (EoL) they become EoL gypsum, which is mainly composed of $CaSO_4 \cdot 2H_2O$, lining paper (from plasterboard) and impurities.

According to the Council Directive 1999/31/EC gypsum based waste must be sent to "Non Inert Non Hazardous Waste landfill" and any load of gypsum-based waste must be only landfilled in cells with no biodegradable material to avoid any risks of sulphate leaks and H_2S release.

To be considered recyclable gypsum, impurities should be kept as low as possible, usually below 2%. Impurities include metal or insulation, which are common construction materials part of the gypsum systems. The current main destination of EoL gypsum is landfill, which poses a risk of higher landfill emissions. In particular, higher hydrogen sulphide (H_2S) and methane (CH_4) are estimated to be released when plasterboard is deposited in mixed waste landfills. Alternatives to gypsum landfilling are those options higher in the waste hierarchy, including open loop recycling (e.g. cement manufacture, agriculture) and closed loop recycling (i.e. production of new gypsum products).

Gypsum waste is processed into recycled gypsum through a series of mechanical steps such as crushing (i.e. to convert different sizes of waste into gypsum powder) and sieving (i.e. to separate paper waste or potential impurities from the recycled gypsum).

As an example, in Figure 29, it is shown the recycling process used by a specialized company in recycling of gypsum plasterboard: GRI (Gypsum Recycling International).

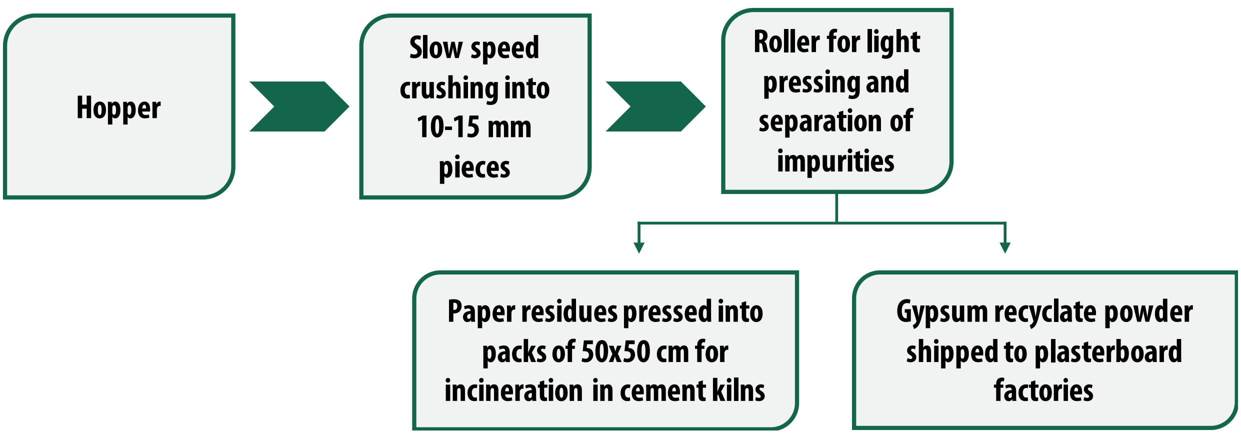


Figure 29 GRI gypsum recycling method

6.3.5.4 Wood

Wood material is typically used in Nordic countries as construction material due to its availability.

Wood waste from construction activity may be handled so that contamination is avoided while, recycled wood from demolition site, will probably be contaminated in different ways.

Recycling of wood would, in the optimal situation, follow a cascade of use applications as depicted in Figure 30 (Goverse et al., 2001). Wooden material, can next to or after being reused, recycled. The wood can be recycled into another high quality wood product. If, for instance, the wood starts as a beam, after its useful life as a beam it can be used for floor board. After its life as a floor board it can be made into a window frame. Each extra step, extra life form of the wood before incineration, is enlarging its useful lifetime and therefore saving newly produced wood.

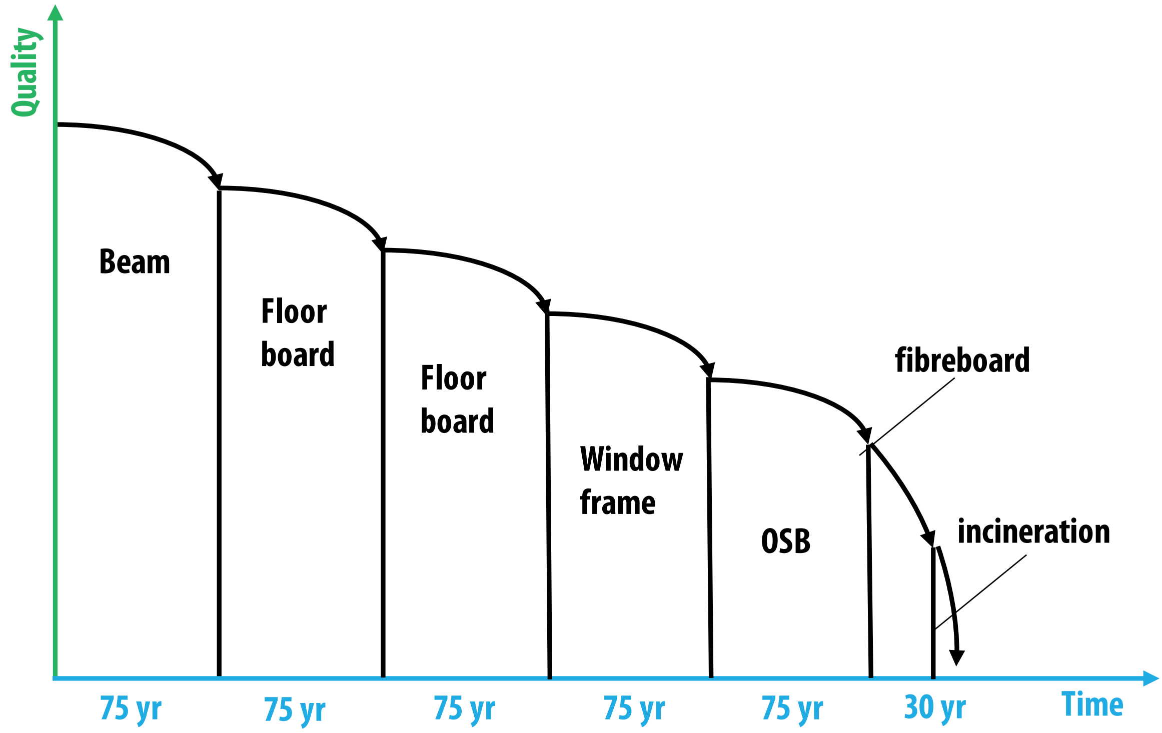


Figure 30 Wood cascade of use applications (Goverse et al., 2001)

In Finland and Sweden, wood waste is recycled or reused if the recycling infrastructure and re-manufacturing is present. However, an efficient energy recovery replacing the use of fossil fuels, biomass and wood chips, is often the best economically and environmentally option also with the climatic conditions taken into account.

During the use phase, the quality of wood may under certain condition deteriorate and the wood waste is not always suitable for recycling or reuse. Also the pre-treatment of wood materials containing nails and paint is labour intensive. To a minor extent, timber structures (e.g. beams) and interiors (doors, windows) are reused today.

6.3.5.5 Glass

Glass product is formed by melting raw materials and/or cullet (recycled glass) in a furnace with temperature higher than 1200°C. The molten glass is then formed into the desired shape by a variety of techniques. In the context of FISSAC the processing of post-consumer glass for re-melting will be included in the glass melting process to prevent good cullet being considered as a waste product.

Glass amounts up to 0.5% in total European CDW flow. Glass waste from CDW sources is generally broken up and mixed with recycled aggregate on site or collected separately in a skip and sent to landfill or to glass recycling company for sorting and cleaning. Depending on the level of contamination with non-glass materials the recycled glass can be returned to glass manufacturers to make new glass (glazing, bottles or fibreglass insulation).

Glass removed from construction and demolition sites will always require some form of further processing before recycling. The low economic value of recycled glass and the difficulty in avoiding contamination when removing from buildings has traditionally discouraged recycling of glass products from demolition sites as removing glazing units as a whole is labour intensive.

Refurbishment projects where windows are taken out with more care and replaced with a new unit offer a more likely source of uncontaminated glass if glass is separated from other materials carefully.

The recycling technologies of the glass in CDW are to reuse directly, grinding to powder, polishing, crushing into aggregate.

- Glazing units installed in building (for new builds waste will only be from breakages, for renovations will be a supply of glass in the old glazing units).
- Demolition of buildings glass is often just smashed as the building is demolished when it becomes mixed and crushed with the recycled aggregate. If the glassing is removed separately from the building it is removed and placed in skips as part of the whole unit for later separation or separated on site into a separate skip.
- Irrespective of whether the glass is separated onsite or the whole units are separated later the waste glass will almost certainly be sold to a glass processor who will carry out sorting and cleaning of the glass prior to selling it on to an end user either for re-melting into glass, use an aggregate or another alternative end use.

6.4 Conclusions

CDW represents around the largest amount of the total solid waste generation in Mongolia. When landfill fees will be high, there will be an incentive encouraging extensive material recovery through a strategy of selective demolition followed by recycling. According to some European estimates, with this strategy, most (around 80%) of the material from End-of-Life (EOL) construction is recovered and only 20% ends up as mixed demolition waste that has to be treated in specialized waste treatment facilities. Landfill tax, which is raised in most EU member countries (Fischer et al., 2012) is considered as a strong driver to tackle Mongolian CDW problem.

Furthermore, imposing a landfill tax needs further analysis of the Mongolian future legislation and needs to be complemented by a package of policy instruments such as source separation mandate, a landfill ban or recycling targets. As the example of

Germany shows, where there is only a source separation mandate, landfill taxes are not necessary to achieve high recycling rates.

In addition, in order to create a market for recycled materials, it is necessary to encourage the adoption of those recycled materials. A possibility could be to impose minimum contents of recycled material in a construction material product. The Netherlands, with more than 98% is the country with the highest recycling rate in the EU, imposes a minimum of 10% recycled material in cement and asphalt.

Equally important is the demand for recycled aggregate materials. Consumer acceptance and trust in recycled products needs further improvement. Waste-based products can only be sold if the general public, construction companies and authorities gain confidence in the quality of these products.

The majority of SMEs lack data on market size and the attitudes of different groups of consumers to recycled products. They also do not have marketing plans and do not know how to promote waste-based products. To improve perceptions of waste-based products, it is important to raise public awareness of the advantages of products made of CDW and to assist SMEs to promote these waste-based products. Greater sales of such products will enable recycling SMEs to expand their operations and employ more staff, thus contributing to reducing poverty in the targeted areas.

7. CONCLUSIONS

In Mongolia, during 2006 to 2014 the amount of CDW has increased by a factor of six but estimating the exact quantities remains highly challenging. Therefore, CDW is a critical concern and requires better management.

The European project SWITCH – Asia II "Improving resource efficiency and cleaner production in the Mongolian construction sector through materials recovery" aims to promote sustainable production and consumption in the construction sector, through supporting SMEs to switch to more resource-efficient practices.

TU Delft, in cooperation with the Mongolian partners (CCR, MUST and MNRA), conducted a study to identify the most relevant local CDW materials for successful reuse and recycling. This involved conducting a Material Flow Analysis (MFA) of CDW in Mongolia. In cooperation with MUST and the MNRA, TU Delft prepared the MFA and presented the possibilities for using recovered C&D waste, in accordance with European applications and standards.

To solve CDW in Mongolia it is required a multidisciplinary effort needing coordinated inputs from different stakeholders. Any waste management strategy should be considered in the framework of administrative, financial, legal, planning and engineering functions. This is in line with the trend that CDW management is becoming an important issue of sustainable development, which concerns environmental, social, and economic development as a whole.

The importance of multidisciplinary efforts has been increasingly acknowledged in both waste management research and practice. The report provided solution mainly focused on selective demolition and methods to recycle CDW materials.

Based on the results of the study, it is concluded that the technical and non-technical solution in the CDW management system include mainly:

- Creation of a dedicated regulatory framework specific to CDW in Mongolia based on the existing regulations adopted in Europe.
- A stricter control of landfilling for CDW and the enforcement of landfills bans.
- Promotion of incentive to recycling companies to stimulate production of recycled materials and ease the access to finance green production.
- Application of selective demolition technique to obtain a separated flow for each of the CDW in Mongolia.
- Increase the awareness regarding CDW and the risks associated to hazardous materials such as asbestos.

In the medium term, it is important to focus on the main wasted materials represented by bricks and concrete. The technological solutions to recycle them have to be tailored to Mongolian needs and to Mongolian capabilities. In particular, a large amount of bricks can be used for road filling and satisfy Mongolian necessity for new roads and infrastructures.

On the other hand, concrete and mixed CDW can be recycle in new tiles for pavement usage as an outdoor floor. Specific tests have to be conducted at MUST laboratory to understand characteristics of the materials and to find the optimal solution. In addition, MUST university has to collaborate both with recycling industries and Government agencies to create new standards.

In the long term, TU Delft considers important to invest on education of new engineers and to eradicate the cultural bias towards waste. To reach this goal, a new curriculum will be created in collaboration with MUST university and an online course will be delivered to all the stakeholders in the CDW sector.

The online course will represent a unique opportunity to show to Mongolian students and industry workers the application of selective demolition technique and the recycling technologies adopted in Europe for the main wasted materials.

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