Waste avoidance and reuse strategies for residential buildings in Australia

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Executive Summary

The Centre for Design and Society (CfD+S) at RMIT University partnered with Burbank Australia and the Housing Industry Association (HIA) to undertake a project aimed at developing and disseminating strategies and practices which minimise residential construction waste being sent to landfill.

As part of this project, Burbank Australia commissioned CfD+S to:

- develop a waste audit protocol to quantify and document residential construction waste
- facilitate design workshops to develop waste reduction strategies
- oversee two waste audits, conducted on two separate houses before and after the implementation of waste reduction strategies
- document and disseminate project outcomes

These activities were funded by Burbank Homes, through Sustainability Victoria’s Beyond Waste funding stream. This report details the findings of these activities.

The first house generated a total of 9,126.1 kg of waste. This waste generation was predominantly driven by off-cuts and excess bricks and mortar, concrete roof tiles and plasterboard. A suite of avoidance design strategies were developed by all stakeholders. Examples of these strategies include changing the type of bricks and roofing materials.

The implementation of these design strategies reduced waste generation by 6,603 kg, representing a 72.4% reduction. In addition to the design strategies, a number of waste management strategies were developed and implemented, including:

- Engagement and alignment with suppliers and contractors on waste minimisation and management
- Non-acceptance of over-deliveries (beyond the specified order)
- Delivery of sand in bulk-bags, which were later used for waste segregation purposes
- Take-back of recyclable waste by contractors
- On site-segregation of waste streams for recycling
- Manual sorting of comingled waste into recyclable and non-recyclables

The implementation of waste management strategies contributed to an additional 2,492.4 kg reduction in waste being sent to landfill.

The total amount of waste sent to landfill from the final house was quantified to be 30.8 kg, representing a 99% reduction.

The successful implementation and ongoing reduction in waste generation in the residential construction sector more broadly faces a number of challenges, including:

- Addressing the culture of over-supply
- Improvement in material quality systems (both at suppliers and customers)
- Adoption of on-site waste separation for recycling, which could be limited by
  - Waste management behaviours across the construction sector
  - Availability of area for on-site waste stream segregation
  - Economic viability of recyclate collection
- Consumer choices, which underpin materials selection. For example, a consumer choice for use of concrete roof tiles over Colourbond roofing will likely result in increased waste generation
1 Introduction

The Beyond Waste Fund is an initiative managed by Sustainability Victoria to help businesses avoid waste sent to landfill. The fund supports innovations that focus on waste avoidance, reduction and reuse, leading to improved resource management, and better environmental outcomes.

As part of the Beyond Waste Fund, a partnership between Burbank Australia, the Housing Industry Association (HIA), and the Centre for Design at RMIT University was established to conduct a research study aiming at reducing the waste generated in the construction phase of building by the volume residential building sector in Australia. The major steps in this project were to:

1. Establish a waste audit methodology
2. Undertake and assess an initial waste audit on a typical volume-built house
3. Develop waste avoidance strategies
4. Assess the efficacy of waste avoidance strategies by undertaking a final waste audit on a typical volume build-house, which utilises the identified strategies.

This report presents the final outcomes of this study, outlining the goal and scope of the study, the waste audit methodology and initial audit results, waste avoidance strategies, final audit results and an assessment on the efficacy and implementation of waste avoidance strategies.
2 Goal and scope

2.1 Aims

The aims of this research are to:

- Identify and quantify the main construction waste material types during the construction of a typical volume-built house
- Identify the main construction activities which contribute to waste generation
- Identify waste generation causalities
- Develop commercially viable strategies to avoid, reduce, reuse or recycle construction waste
- Quantify waste avoidance from the implementation of these strategies

2.2 Scope

The main objective of Sustainability Victoria’s Beyond Waste Fund, through which this project was funded, is to reduce the amount of waste sent to landfill through the avoidance of the generation of waste and/or reuse of waste. These waste management strategies cover the top-most approaches in the waste-hierarchy in Figure 2-1.

![Waste Management Hierarchy](image)

*Figure 2-1: Waste Management Hierarchy [ZeroWasteSA, 2013]*

This research focuses on developing and implementing waste minimisation strategies for the construction residential houses. The following waste generating activities are beyond the scope of this project:

- Cutting of site; the removal of earth prior to construction activities.
- Production waste; the generation of waste facilities within the upstream supply chain
- Landscaping waste; and
- Waste generated during the final site clean, after the landscaping phase.
2.3 Audience

The intended audience of the study includes Sustainability Victoria, the Housing Industry Association and Burbank Australia. Beyond this group, the audience may also include the decision-makers in the construction industry, the designers of the residential homes, the trade people who work in the construction industry, the research community, and the general public.
3 Literature review

Internationally, a number of guides have been developed for the construction industry. These guides include a ‘halving waste to landfill’ strategy document, developed by WRAP in the United Kingdom, [WRAP, 2011], and a ‘reducing waste for building owners’ developed by the United States’ Environmental Protection Agency [USEPA, 2000]. Within Australia, Curtin University developed the ‘Guidelines for minimising waste in residential construction’ [2001] and EcoRecycle (now known as Sustainability Victoria) developed the ‘Construction Waste Minimisation Strategy’ [EcoRecycle]. These publications had a number of common themes in order to minimise waste, including:

- A focus on waste avoidance, reduction, and reuse rather than treatment and disposal
- An emphasis on designing to minimise waste
- Supply-chain engagement.

Within the existing waste reduction guides there is also general acknowledgement of the causes for waste being generated in the first instance such as: poor design and specification, poor planning, poor jobsite layout, poor quality control on site and in the supply chain, and a lack of returnable packaging [Curtin, 2001].

Despite what appears to be consensus on the waste reduction hierarchy as the ideal approach to reducing construction waste, there is little empirical evidence documenting how design changes, and process improvements have been implemented to avoid waste in the first instance. Most waste reduction case studies presented are still end-of-pipe focused, reporting in terms of diverted waste for re-use or recycling. For example the UK case studies presented by WRAP [2011b]. The front-of-pipe solutions through design interventions are suggested to offer the greatest cost savings to a project, as waste avoidance offers greater savings than re-use or recycling. Potential win-win situations can occur through designing for standard sized dimensions, which also by default require less labour to install. BDAV’s ‘Designing in Waste Minimisation’ report suggests that ‘Consultants involved in the design and procurement process are often unaware of the waste implications of their design approaches. Similarly, they are often unaware of the environmental and cost implications of building waste’ [BDAV, 1998, p.8].

Consultants involved in the design and procurement process are often unaware of the waste implications of their design approaches. Similarly, they are often unaware of the environmental and cost implications of building waste. Relatively few designers adopt an identifiable design waste minimisation strategy, and waste reduction in the design stage is carried out as a by-product of total cost [BDAV, 1998, p.8].

Poor design and specifications cause types of waste such as waste of materials, over allocation of materials, rework, clarifications, and unnecessary handling of materials. It can be improved by designing homes with standard sized dimensions. Standard sizes reduce off-cut waste [BDAV, 1998].

The most commonly used housing constructs in Australia in 2008 were brick veneer (45%), double brick (24%), timber (13%) and fibro cement (8%) [ABS, 2008]. Insights into the fit-out materials and foundation types (e.g. concrete slab, elevated stumps) could not be garnered, including total and individual waste flows stemming from housing construction materials. Despite the lack of industry wide-statistics, other research indicates significant variations in the type and amount of waste generated during housing construction. A 2009 waste audit report by KESAB showed that for five types of houses, the mass of construction waste was between 3 and 9.5 tonne with an average of 5.4 tonne. Based on the density of the waste types, this equates to about 16.7 m$^3$ of demolition waste for an average 220m$^2$ house size. This estimation of demolition waste volume is in line with Burbank's own estimate of 16 m$^3$ of demolition waste for a house. Each year, the volume building industry builds approximately 150,000 houses in Australia. From these values, it is estimated that the total construction waste from the construction of volume-housing generates in excess of 2.5 million m$^3$ of waste or 815 thousand tonne.
From the construction waste management in the Australian context, landfill disposal is the default waste management practice for the majority of the construction waste materials including off-cuts plastic pipes, off-cuts carpets and off-cuts insolation materials. However, there are examples of waste reuse and recycling for some construction waste materials. These described below.

**Concrete and bricks:** Some waste recyclers including Alex Fraser (with sites in Victoria and Queensland) crush the concrete waste and use it in all-weather applications (e.g. low grade roads) and in pavement sub-bases (such as roads and non-structural applications) as a substitute for virgin crushed rock. Bricks are often presented as ‘mixed masonry’ or ‘builders rubble’ mixed with concrete and, like source-separated concrete, this waste is relatively simple to process, with similar end markets for concrete [DSEWPC, 2011].

**Plasterboard:** Most plasterboard recovery often made through arrangements between the builder or construction company and the material manufacturer or supplier. Plasterboard manufacturers which supply construction sites regularly support the recovery of clean product from sites and support companies which purchase their materials [DSEWPC, 2011]. Plasterboard regarded as a contaminant when presented with other construction waste streams.

**Steel:** Steel waste can be easily recycled in Australia and there is a good market for the recycled steel locally and internationally. Even in a combined waste stream, steel can be easily recovered from the other waste materials using relatively inexpensive magnets.

**Timber:** There is a high-value market for the re-use of quality hardwood timber, with prices over $1000/m³ for some high-grade Australian timbers, although the volume of material recovered is relatively low. Nationally, the market for re-use of timber is estimated to be around 60,000 m³ [DSEWPC, 2011]. A significant source of salvageable hardwood is ‘infrastructure timber’, such as power poles and railway sleepers, for which there is strong demand in landscaping applications [DSEWPC, 2011].

The timber recycling rate varies nationally depending on the available recycling facilities on the different regions. The Hazelmere Timber Recycling Centre (Hazelmere) in Perth, Western Australia recovers and processes industrial timber waste so it can be diverted from landfill and recycled as a reusable woodchip. Hazelmere, operated by the Eastern Metropolitan Regional Council (EMRC), opened in 2008 and is the only one of its kind in Western Australia. Hazelmere aims to recycle at least 10,000 tonnes of timber waste per year. Previously the timber processed at Hazelmere was destined for landfill.

Uncontaminated timber waste is sorted and shredded into woodchip. The shredding process removes steel contaminants such nails, nuts and bolts. The recycled woodchip is then used as a raw material for identified end markets including particleboard, manufacture of compost and animal bedding, and as biofilter medium. Currently, untreated softwood or pine timbers in the form of pallets, packing materials, wooden crates, low-pressure laminated particleboard off-cuts (without plastic edging) and cable drums are accepted for recycling at Hazelmere [DSEWPC, 2011].

**Polystyrene waffle pods:** The introduction of the Pod Scrap Bag Program has been an industry initiative of Expanded Polystyrene Australia (EPSA) and its Pod Group members. Scrap bags are supplied with all pod deliveries to building sites to assist with the separation of EPS offcuts from the general waste stream. The filled scrap bags are then collected and taken back to the EPS manufacturer where it can be granulated and recycled in new waffle pods and other building and construction products [DSEWPC, 2011]. It is estimated that where the Pod Scrap Bag Program has been implemented, the collection and recycling rate of EPS pod offcuts is extremely effective—around 90 per cent [DSEWPC, 2011]. In Victoria, a waffle pod supplier, Unipod, has implemented such an approach, whereby EPS is accepted by Unipod for recycling back into new waffle pods.

**Plastics:** The Plastics and Chemicals Industries Association’s (PACIA) annual recycling survey highlights that very little material is recovered from the construction and demolition (C&D) sector, but acknowledges that there is growing activity around recycling of used plastics from the industry [DSEWPC, 2011].
3.1 Outline of the construction process

The construction stages as defined by Burbank are:

- Site cut (earthmoving)
- Laying of slab
- Framing (timber walls and roof framing)
- Roof and bricks
- Lockup (securing the site by installing doors and windows)
- Rough in (plumbing and electrical)
- Plasterwork
- Fix (fitting the internal cladding, skirting, cabinets)
- Internal tile and painting,
- Final fit off (interior works)
- Landscaping
- Final site clean (scrape)

It should be noted that the above classification may not be the same for other volume-built house developers. Some defined the stages in a more detailed approach [TSH, 2013].
4 Methodology

4.1 Assessment of current waste practices

To assess current waste practices within the residential housing construction sector, RMIT University undertook a number of preliminary interviews with Burbank Australia over the course of the project. A visit was conducted on 22 January 2013 to assess waste practices at least 10 of under-construction houses of different constructs. The visits were used to visually verify the different types of waste generated at different stages of construction. Waste samples were collected for measurements for use in data analysis.

4.2 Audit preparation

Burbank established a sorting and weighing area on site in order to quantify waste and briefed the project managers and the tradespeople on who will be working on the site and on the waste assessment protocol. Burbank also assigned project management responsibilities and provided them table and data collection sheets to record data.

4.3 Waste collection and measurement

All waste collection and measurement was undertaken by Burbank and overseen by RMIT University. Waste was placed in separate bins on site by tradespeople. The sorted waste was then measured by Burbank by mass or linear dimensions. The mass was measured to a nominal accuracy of ±0.1 kg, while the linear dimensions were measured to the nearest millimetre (mm) using a tape measure. The measurements were recorded on in project management diaries. In addition to these measurements, the following data was recorded:

- The type of building material (e.g. plasterboard, bricks)
- The construction activity type
- The date the activity was conducted
- The type of waste generated (e.g. empty paint container)
- The amount of waste generated per each waste type
- The casualty of the waste generated (e.g. off cuts)

Where possible, a photograph of the waste collected and the date related to each site activity was manually entered into a spread-sheet. The sorted waste materials were then disposed to the cage located at the site to be transported to a waste refuse centre. In total, the site cleaned four times during the course of construction when the following stages were completed:

- Framing
- Roof and bricks
- Plaster, and
- Final fit off

The completed data was provided to RMIT University at the end of the waste audit for analysis.
4.4 Audit houses

Waste audits were conducted on two houses of similar construct. The house design used on both sites is a Tierra 2300 design; a single-storey, 7-Star NatHERS energy rated house. This design was chosen by Burbank as it was considered to represent a build typical of volume housing in Australia, and was a popular house sold by Burbank in a median price category. The main features and options included in the Tierra design are:

- 4 bedrooms and 2 bathrooms
- Area:
  - Residential: 171.57 m²
  - Porch: 4.04 m²
  - Garage: 36.43 m²
  - Total: 212.04 m²
- Walk-in pantry
- Choice of options including theatre and workshop
- Separate living room
- Double garage
- Alfresco dining area

The initial waste audit was conducted by Burbank on a Tierra design house located at Lomandra Drive, Maddingley, Victoria. This initial waste audit house was constructed on a concrete slab, with timber frame and brick-veneer construct. The final waste audit was conducted Burbank on a similar Tierra design house located at 12 Ladborke Street, Melton South, Victoria. Photographs of these final houses are provided in Figure 4-1.
4.5 Data analysis

The total mass quantity (in kg) of each waste material, (e.g. timber) was calculated through summation of individual mass quantity of that waste material generated in the various construction activities (e.g. framing, cabinets).

4.5.1 Greenhouse gas emissions

The greenhouse gas emissions associated with the waste materials were estimated based on a life cycle approach, meaning that the emissions related to the all life cycle phases of the materials were considered. The life cycle phases of the materials under the study varied with the type of waste fate, as outlined below.

Included life cycle phases for materials sent to landfill:

- Virgin material production
- Distribution to site
- Distribution of waste to landfill site
- Management of waste in landfill

Included life cycle phases for materials reused:

- Virgin material production
- Distribution to site

Included life cycle phases for materials sent to recycling:

- Virgin material production
- Distribution to site
- Distribution of waste to recycling facility
- Reprocessing of waste
The intent of the greenhouse gas assessment is to quantify impacts, rather than environmental benefits. Because of this, no environmental credits were applied for either sequestration of carbon in landfill (e.g. from cardboard waste) nor recycling (for the avoidance of virgin production).

The greenhouse gas emissions profiles for the production of materials were calculated by applying the mass quantity of each material to emission factors for different material types. The background data required for this purpose acquired from the databases described in Table 4-2. When inventory data were not found in the Australasian dataset (e.g. insulation materials), inventory data from ecoinvent (a European life cycle inventory database, refer to Table 4-1) was adapted by modifying material and energy inputs. Distances to the construction site and landfill were assumed to be 20 km and 10 km, respectively.

Table 4-1: Background databases used for estimating the global warming potential of the waste materials

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<tr>
<td>Australasian Unit Process Life Cycle Inventory (AUPLCI) September 2010</td>
<td>Australian LCA database developed from 1998 up to 2008 by Centre for Design from data originally developed with the CRC for Waste Management and Pollution Control, as part of an Australian Inventory data project. The data from this project has been progressively updated, particularly the data for metals production, energy, transport and paper and board production.</td>
</tr>
<tr>
<td>ecoinvent 2.2 May 2010</td>
<td>Life Cycle Inventories compiled by the Swiss centre for Life Cycle Inventories. The ecoinvent database consists of approximately 4100 datasets covering a suite of industries in Switzerland and Western Europe.</td>
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Factors applied to convert emissions of greenhouse gas emissions into carbon dioxide (CO₂) equivalents emissions conform to IPCC 2007 factors for a 100 year time horizon. Carbon sequestrations of the waste materials were excluded.

4.6 Development of waste avoidance strategies

Following the release of audit results, a waste avoidance strategy workshop was held at Burbank’s head office on March 4, 2013. The following people were in attendance:

- Dr. Enda Crossin, RMIT University
- Mehdi Hedayti, RMIT University
- Max Hunter, Burbank Australia
- Andrew Mammarella, Burbank Australia
- Frank Perconte, Burbank
- Brent Yttrup, Burbank Australia

Kate Ellis (Burbank Australia) attended during the initial phase of the workshop. The aim of this workshop was for RMIT to facilitate the development of waste avoidance strategies by Burbank Australia, aimed at avoiding and reducing waste generation. The results of the initial waste audit were used to guide the strategy development.
5 Initial waste audit results

This section reports the results of the initial waste audit, which are used as the basis for ranking the waste materials, identifying the hot spots, and developing the waste management strategies.

5.1 Waste management practices

At the time of the construction of the initial audit house, construction waste generated on Burbank sites was disposed of in on-site cages. [Figure 5-1] These cages were then managed by contracted site cleaners. Site cleans were typically carried out four times during house construction. These four site cleans typically occur at the end of framing, roofing and brickling, plasterwork, and the final fit-out phases.

![Figure 5-1: Waste cages](image)

During these site cleans, the site cleaner would utilise a skid steer machine (bob-cat) to load the waste materials and unload them into a truck. The truck then transports the collected waste to a waste refuse centre; typically landfill.
5.2 Waste inventory and greenhouse gas impacts

Table 5-1 summarises the inventory of construction waste for the initial audit house, together with estimates of greenhouse gas emissions, stage of generation, waste causality and the final fate of the waste.

The total waste generated was 9,126.1 kg. The original land had a slope of approximately 1:10, which meant that extensive removal of earth was required to ensure level ground prior to construction. The inventory in Table 5-1 excludes this excavation waste (e.g. soil, rocks), which amounted to 349 m$^3$ or approximately 41,800 kg (assuming a waste density of 1200 kg/m$^3$). Brick waste dominates with 4,463.0 kg, or approximately 48% of the total mass of the waste materials, followed by roof tile waste (2,462.1 kg, 26%) and plasterboard waste (1,336.4 kg, 14%). The remaining waste materials individually contribute to less than 300 kg of total waste, with the individual materials contributing to between 0.1% and 3% of total waste mass. A schematic of the mass contributions for the individual waste materials is presented in Figure 5-2.

The total greenhouse gas emissions associated with the production and disposal of the material was estimated to be 5,534.3 kg CO$_2$-eq. The brick, plasterboard, roof tiles and polystyrene waste flows are the major contributors to the total greenhouse gas emissions, contributing to 1,738.2 kg CO$_2$-eq (32.5% of total greenhouse gas emissions), 992.4 kg CO$_2$-eq (18.6%), 873.3 kg CO$_2$-eq (16.3%) and 720.5 kg CO$_2$-eq (13.5%), respectively. All other waste materials individually contributed to less than 10% of the total greenhouse gas emissions profile. A schematic of the estimated greenhouse gas contributions for the individual waste materials is presented in Figure 5-3.

Approximately 77% of the 9,126.1 kg of waste was generated during the roof and brick construction phase. This 7,001.2 kg of waste was driven by the mass of brick and tile waste. The plasterwork phase generated 1,336.4 kg of waste. The remaining construction phases including slab pouring, framing, rough-in and fit-out accounted for a total of 788.5 kg of waste; less than 10% of the total. A schematic of the waste inventory by construction phase is presented in Figure 5-4.

The major causes for waste were off-cuts and excess supply, contributing to 4,789.6 kg and 4218.0 kg, respectively. Approximately 88% of total waste generated in off-cuts were associated with three main waste streams: roof tiles (1,735.1 kg), bricks (1,361.0 kg) and plasterboard (1,115.9). Similarly for the excess supply, bricks (3,100.0 kg), roof tiles (727.0 kg) and plasterboard (220.5 kg) contributed to over 95% of waste generated by excess supply.

The fate of all waste generated during the construction phase was landfill. Figure 5-5.
Table 5-1: Initial waste audit results and greenhouse gas emissions profile.

<table>
<thead>
<tr>
<th>Material</th>
<th>Waste quantity</th>
<th>Greenhouse gas emissions</th>
<th>Construction stage</th>
<th>Causality</th>
<th>Waste fate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mass (kg)</td>
<td>Volume (m³)</td>
<td>Slab (kg)</td>
<td>Framing (kg)</td>
<td>Roof and brick (kg)</td>
</tr>
<tr>
<td>Bricks and mortar</td>
<td>4463.0</td>
<td>5.39</td>
<td>1738.2</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Cardboard</td>
<td>27.6</td>
<td>0.50</td>
<td>77.4</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Carpet and underlay</td>
<td>8.9</td>
<td>0.11</td>
<td>73.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Cement sheet</td>
<td>54.4</td>
<td>0.07</td>
<td>59.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Concrete</td>
<td>31.0</td>
<td>0.03</td>
<td>8.1</td>
<td>31.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Illegal dumping and mixed waste</td>
<td>51.6</td>
<td>0.13</td>
<td>50.8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Isolation &amp; Sarking</td>
<td>9.6</td>
<td>0.10</td>
<td>19.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Metals</td>
<td>34.5</td>
<td>0.00</td>
<td>80.0</td>
<td>24.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Plasterboard</td>
<td>1336.4</td>
<td>5.89</td>
<td>992.4</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Plastics (PVC pipes and packaging)</td>
<td>51.1</td>
<td>0.71</td>
<td>101.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Polystyrene (Waffle Pod)</td>
<td>139.2</td>
<td>6.63</td>
<td>720.5</td>
<td>139.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Tiles (interior)</td>
<td>189.5</td>
<td>0.23</td>
<td>205.8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Tiles (roof)</td>
<td>2462.1</td>
<td>1.64</td>
<td>873.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Timber</td>
<td>257.2</td>
<td>1.71</td>
<td>344.6</td>
<td>0.0</td>
<td>252.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9126.1</strong></td>
<td><strong>23.1</strong></td>
<td><strong>5343.4</strong></td>
<td><strong>194.7</strong></td>
<td><strong>252.2</strong></td>
</tr>
</tbody>
</table>

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Figure 5-2: Initial audit results. Contributions of waste materials.

Figure 5-3: Initial audit results. Greenhouse gas contributions of waste materials (kg CO$_2$-eq)
Waste avoid ance and reuse strategies for residential buildings in Australia

Figure 5-4: Initial audit results. Waste by construction phase.

Figure 5-5: Initial audit results. Waste by fate.
5.3 Material flows

5.3.1 Bricks

Of the 4,463 kg of brick waste, 3,100 kg was from oversupply and the remaining 1,363 kg were from off-cuts. The ‘roof and brick’ stage is the only construction activity in which the waste bricks were generated. Photographs of excess and off-cut brick waste are provided in Figure 5-6.

![Excess](image1.png) ![Off-cuts and rejects](image2.png)

*Figure 5-6: Brick waste*
5.3.2 Cardboard

The cardboard waste generated at the site mainly sourced from the packaging materials for internal tiling, fixtures and fittings. The total amount of the cardboard waste generated at the site was 27.6 kg. A photograph of the cardboard waste is provided in Figure 5-7.

![Cardboard waste](image)

**Figure 5-7: Cardboard waste**

5.3.3 Carpet and underlay

The carpet and underlay waste of 8.9 kg was from off-cuts generated during fit-out.

5.3.4 Cement sheet

The cement sheet waste was mainly generated in the roof and brick phase and was generated from the construction of roof eves. The 54 kg of cement sheet waste was off-cuts.

5.3.5 Concrete

The only source of concrete waste was the excess concrete supply during the slab stage. Approximately 31 kg waste concrete was generated at the site.

5.3.6 Illegal dumping

In total, the illegal dumping accounted for a total of 51.6 kg. A photograph of some of this waste is shown in Figure 5-8.

![Illegal dumping](image)

**Figure 5-8: Illegal dumping (the blue child table)**
5.3.7 Isolation and sarking

Approximately 9.6 kg of isolation and sarking off-cut wastes during the roof and brick stage. A photograph showing some of this waste is provided in Figure 5-9.

Figure 5-9: Isolation materials (left) and packaging strapping (right).

5.3.8 Metals

All metal waste was steel. Of the 34.5 kg waste generated, 24.5 kg was generated during the slab pour, with the remaining 10 kg generated from off-cut down pipes. Figure 5-10.

Figure 5-10: Steel off-cut waste

5.3.9 Plasterboard

Plasterboard waste was generated during the house construction in the ‘plasterwork’ stage. A total of 1,336.4 kg was generated, of which 220.5 kg was excess supply with the remaining 1,115.9 kg being from off-cuts. Photographs of these waste streams are provided in Figure 5-11. Activities generating off-cuts include the cutting-out of plaster from doorways and the installation of cornice. Figure 5-12.

Figure 5-11: Plasterboard waste
Waste avoidance and reuse strategies for residential buildings in Australia

5.3.10 Plastics

The construction-related plastic waste is off-cuts of PVC pipes, which amounted to 11.7 kg waste. The packaging waste, Figure 5-13, was generated from different sources, including for packaging for tiles, fixtures and fittings. The packaging plastic was generated during various stages and was 39.4 kg.

5.3.11 Polystyrene (waffle pods)

All polystyrene waste was generated during the slab stage, in which the polystyrene waffle pods are used. Approximately 139.2 kg of polystyrene waste was generated, with 64.2 kg being excess, Figure 5-14(a) and 75 kg from off-cuts, Figure 5-14(b).
5.3.12 Tiles (roof)

As with the brick waste, the waste roof tiles were generated at the ‘roof and brick’ construction stage. The total waste roof tiles amounted to 2,462.1 kg, of which 727.0 kg was excess tiles and the remaining 1,735.1 kg being off-cuts. Photographs of excess and off-cut roof tiles are reported in Figure 5-15.

5.3.13 Tiles (interior)

Interior tile waste was generated during the fit-out stage, with a total mass of 189.5 kg from off-cuts. Two photographs showing drivers of some of these off-cuts are reported in Figure 5-16 and Figure 5-17.
5.3.14 Timber

The main source of the timber waste is ‘framing’ stage, generating 252.2 kg of the 267.2 kg total. The remaining 15.0 kg was generated during rough-in and fit-out activities, including from the installation of kitchen cabinets. Of the 267.2 kg of waste, approximately, 66.5 kg was excess and the remaining 200.8 kg was from off-cuts. A photograph of off-cuts from the framing stage is provided in Figure 5-18.
Figure 5-18: Timber waste

(a) Excess

(b) Off-cuts
6 Waste avoidance strategies – design

This section outlines the outcomes of the waste avoidance strategy workshop, held at Burbank’s head office on March 04 2013. The workshop was focussed on addressing each waste stream, by order of total waste flow generated during the construction of the initial audit house. These streams and waste flows were:

1. Brick waste: 4,463.0 kg
2. Roofing waste (tiles): 2,462.1 kg
3. Plasterboard: 1,336.4 kg
4. Timber: 267.2 kg
5. Internal tiles: 189.5 kg
6. Polystyrene: 139.2 kg
7. Cement sheet: 54.4 kg
8. Illegal dumping: 51.6 kg
9. Plastics: 51.1 kg
10. Metals: 34.5 kg
11. Concrete: 31.0 kg
12. Cardboard: 27.6 kg
13. Isolation and sarking: 9.6 kg
14. Carpet and underlay: 8.9 kg

Under each material sub-heading, the identified issue has been documented, together with a summary of the suggested strategies. The agreed strategy(s) are then reported.

6.1 Brick waste

The main issue with brick waste generation was from excess supply and off cuts.

6.1.1 Suggested strategies

In order to address the main waste generation issue, the following strategies were discussed:

- Bricks for garden beds - reuse? Reuse not an option in this project
- Sandwich panels an option - but start to lose flexibility in design
- Number of cladding materials, as mandated by councils - must have a different finish. The more the colours the more the waste
- Brick variations are as much as +/- 15 mm on a 230 mm brick
- Dominated by two market players, who are not willing to introduce better controls on dimensions on product
- Second-hand bricks were more likely to have people accept this. BCA compliance standard tolerance guide for brickwork. Unlikely to get over the line because of the BCA brick code.
- Compressed bricks industry currently don’t have capacity to keep up with demand

Approach 1

- More quality assurance enforcement on brick suppliers
- Mandatory saw-cutting and retention
- Cement-based bricks – different colours, more reproducible → could seal in colours. Don’t chip as easily, don’t have sharp edges. Coloured through
- On-site brick count. Using existing house for prototyping
- Manual handling → manually blending
- Reduce the contrast → Back and paint (not allowed), seconds and off-cut bricks for feature walls, with coloured/rendering
Approach 2

- Hebelcrete (no warranty on ground?)
- Polystyrene + render (detailed with or without a rebate)
- Cavity needed for polystyrene? Dulux want packers (cavity) off the all. BCA doesn’t stipulate, foam companies don’t want
- Vents not needed for polystyrene
- Weepholes needed?
- Rebate? Needed for termites?
- Brickwork from ground level, then other materials from ground up

6.1.2 Agreed strategy

On-site brick count (using existing house for prototyping), then switching to either cement-based bricks or polystyrene and possible render finish (depending on aesthetic of cement-based bricks).
6.2 Roofing

The main issue with roofing waste generation was from off-cuts and over-supply.

6.2.1 Suggested strategies

In order to address the main waste generation issue, the following strategies were discussed:

- Colour-bond roofing
- Pre-cut off site or on site? Needs to be fudged on site.
- Skillion design ' adjustment in pitch points and trusses?
- Gable-ends + outriggers ' will results in large eves?
- Max ' not possible without compromising garage height ' Brent ' as we do in Qld
- Max ' split the roof (double gables, which will only be seen from the back)
- Cement sheet waste ' select materials specifically for this
- Drop down garage to 2 bricks, rather than 1?
- Gables also gets rid of height on boundary rules issues
- Change of pitch down to 18 degrees
- Crush waste tiles on site and use as back fill ' no, avoid it
- Outcome ' gable ends with steel flashing (e.g. colourbond)
- Will people want gables?

6.2.2 Agreed strategy

Burbank design team to investigate angle-cut skillet roof design (usually a $25 k premium), and potentially a gable option.

6.3 Plasterboard – entrance doors

The main issue with plasterboard waste generation in entrance doors was from off-cuts

6.3.1 Suggested strategies

In order to address the main waste generation issue, the following strategies were discussed:

- Very difficult to avoid
- Full length doors a possibility, but would require custom framing
- Smaller sized plaster for placement above door frames not an option. Can’t plaster between above door and adjoining sheet (cracking and BCA compliance issue)
- Medium-density fibreboard boxing

6.3.2 Agreed strategy

Burbank to investigate use MDF boxing.
6.4 Plasterboard – bulk heads

The main issue with plasterboard waste generation in bulk heads was from off-cuts.

6.4.1 Suggested strategies

In order to address the main waste generation issue, the following strategies were discussed:

- No bulk heads in design.
- Bulk heads are no longer standard practice across the sector

6.4.2 Agreed strategy

Remove bulk heads from design.

6.5 Plasterboard – internal wardrobes

The main issue with plasterboard waste generation in internal wardrobes was from off-cuts.

6.5.1 Suggested strategies

In order to address the main waste generation issue, the following strategies were discussed:

- Add sliding drawer to bottom, then push existing standard size doors up
- Use MDF of standard size → likely to create off cuts
- Full height doors (can be a premium feature)

6.5.2 Agreed strategy

Redesign with full height internal wardrobes.
6.6 Plasterboard – internal walls

The main issue with plasterboard waste generation, pertaining to room size, was that sheets come in a standard 6 m length.

6.6.1 Suggested strategies

In order to address the main waste generation issue, the following strategies were discussed:

- Discounts given for standard (6 m lengths) → saves on labour and handling, but encourages waste generation
- Issue with transport of custom-size plaster. Machine cutting to custom size, automatic packing and designated order of plastering work. Industry not at this stage yet. Plastering sequence not yet viable.
- Vertical rather than horizontal installation? Labour, aesthetic and possible thermal expansion issues
- Multi-component system has designed-in wastage in all components so that it works
- Limited by standard lengths, on 300 mm increments, order to size based on room

6.6.2 Agreed strategy

Measure and order plasterboard to room size.

6.7 Plasterboard – cornice

The main issue with plasterboard waste generation from cornice was from off-cuts.

6.7.1 Suggested strategies

In order to address the main waste generation issue, the following strategies were discussed:

- Cornice hiding expansion joint
- Could use square set → would minimise off-cuts

6.7.2 Agreed strategy

Burbank to investigate use of square set
6.8  Structural timber
The main issue with structural timber waste was from excess battens and temporary bracing.

6.8.1  Suggested strategies
Batten waste would largely be eliminated by using alternative roof design (as reported previously). Utilise temporary bracing strategy for noggins, ensuring that permanent bracing is in place before noggins are required.

6.8.2  Agreed strategy
Burbank to plan/oversee use of temporary bracing for noggins

6.9  Internal tiles (vertical, in kitchen)
The main issue with internal tiles (vertical, in kitchen) was off-cuts.

6.9.1  Agreed strategy
Change to glass splash back of standard size.

6.10  Internal tiles (vertical, in showers)
The main issue with internal tiles (vertical, in showers) was off-cuts. In addition, the current labour practice is to start tiling at edge of shower screen, then work back to corner.

6.10.1  Suggested strategies
In order to address the waste generation issues, the following strategies were discussed:
- Change tiling size, start tiling in corner, then tile past edge of shower screen.

6.10.2  Agreed strategy
Burbank to change tile sizing, then oversee labour practice
6.11 Internal tiles (floors, wet areas)

The main issue with internal tiles (floors, wet areas) was off-cuts.

6.11.1 Suggested strategies

In order to address the main waste generation issue, the following strategies were discussed for wet areas:

- Polished concrete. Issues with availability of skilled labour, potential defects after handover and ongoing maintenance (i.e. defects liability)
- Lino/vinyl flooring. Likely to generate waste, as only available in rolls of pre-determined length
- Floorboards likely to peel up/warp ➔ also wouldn’t meet BCA
- Run smaller tiles, designed to fit wet areas
- Change dimensions not house ➔ not possible as limited by brick size

6.11.2 Agreed strategy

Smaller tiles, designed to fit wet areas. Burbank to determine better tile sizing, based on wet area dimensions.

6.12 Internal tiles (floors, living areas)

Floor tiling starts in one corner of entrance way, then propagates down a line in the hallway, then propagates either side of this centre line. Sideways propagation leads to off-cut tiles on both sides of the house, as well as one side of the hall-way

6.12.1 Agreed strategy

Burbank to select floor board system/sizing which will minimise off-cuts/waste

6.13 Polystyrene (waffle pods)

The main issue with polystyrene waste was from over-orders and damage to waffle pods.

6.13.1 Agreed strategy

Better handling and delivery of waffle pods, use initial order and initial audit results to determine exact number of waffle pods required. Return off-cuts and excess for recycling.

6.14 Cement sheet for eves

The main issue with cement sheets is off-cuts generated for the installation of eves and infill across windows.

6.14.1 Suggested strategies

In order to address the main waste generation issue, the following strategies were discussed:

- Eliminate eves (standard feature, client requested eves for the initial audited house)
- Polystyrene + render to replace infill across windows.
6.14.2 Agreed strategy
Burbank to redesign, based on no eves and polystyrene infill.

6.15 Illegal dumping and mixed waste
Not a major issue for the initial audited house.

6.15.1 Agreed strategy
Continue with current practice of regular site cleans, secured cages etc.

6.16 Plastic
Packaging waste was a minor issue (less than 1% of waste generated) and was considered beyond the scope/control of Burbank.

6.16.1 Agreed strategy
Separate waste, recycle.

6.17 Metals – steel reinforcement
Steel reinforcement waste was a minor issue (less than 1% of waste generated). Waste generation was driven by off-cuts

6.17.1 Agreed strategy
Reuse back in slab. Separate for recycling if required.

6.18 Concrete
Concrete waste was a minor issue (less than 1% of waste generated). Waste generation was driven by excess supply.

6.18.1 Agreed strategy
Control amount used in pour. Excess to be reused.

6.19 Cardboard
Packaging waste was a minor issue (less than 1% of waste generated) and was considered beyond the scope/control of Burbank.

6.19.1 Agreed strategy
Separate waste, recycle.
6.20  **Isolation and sarking**

Isolation and sarking was a minor issue (less than 1% of waste generated).

6.20.1  **Agreed strategy**

Continue with existing practices to minimise, in addition, separate and recycle whenever possible.

6.21  **Carpet and underlay**

Carpet and underlay was a minor issue (less than 1% of waste generated).

6.21.1  **Agreed strategy**

Continue with existing practices to minimise.
7 Waste avoidance strategies – waste management and supply chain engagement

The design strategies outlined in the previous section were targeted at the first three elements of the waste hierarchy: avoid, reduce and reuse. To target the next element of the waste hierarchy, recycle, Burbank examined its on-site waste management practices to identify potential strategies to maximise recycling. The initial waste audit found that waste management was handled by landfill of comingled waste. To address this, Burbank firstly engaged a recycling company (Jumbobag) who was able to divert waste from landfill towards recycling pathways. In order to maximise the likelihood of recycling, it was identified that recyclable waste should be separated from other waste into individual streams. To enable individual waste streams, Burbank identified that it would firstly need to provide on-site facilities for individual waste collation, and secondly, engage its suppliers and tradespeople to promote separation of recyclables on-site. To enable this second issue, Burbank engaged its suppliers to brief them on the new waste avoidance strategies.

During these supplier briefing sessions, two additional recycling strategies were identified. The first of these recycling strategies was for, whenever possible, for tradespeople to take-back recyclables. A number of Burbank contractors were able to return their waste back to their central businesses for bulk recycling. Examples of these take-backs include: electrical, plumbing, air-conditioning, solar panel installation packaging. It was identified that these central businesses often engage in on-site recyclate collection and that this collation imposed no additional cost on construction. For example, a plumbing central business can have facilities to for the collection of recyclable off-cuts. The take-back of recyclable waste by tradespeople was identified as an additional on-site waste avoidance strategy.

The second additional recycling strategy was the identification of material suppliers who take full responsibility of their materials from supply through to recycling waste management. For example, one plasterboard supplier collects waste plasterboard for recycling into gypsum.
8 Implementation of waste avoidance strategies

8.1 Design

8.1.1 Bricks

Using the findings of the initial house build, Burbank counted the total individual bricks, and ordered cement-based bricks (in place of clay-fired bricks) based on this quantity. Despite this specific-order and engagement with the supplier on the aims of this project, the brick supplier over-supplied the final site with four extra pallets of bricks. Burbank did not accept the delivery of these extra bricks. The bricks were returned to the supplier for restocking. During the construct, half-bricks were used for sill construction. Although brick-counts were used, some excess bricks remained following construction due to bricks being supplied by pallet (the minimum supply quantity is a pallet), rather than by count. Photographs of bricks used in the final house are provided in Figure 8-1.

(a) Over-supply bricks returned to supplier
(b) Half-bricks used in sill
(c) Stacked waste full-bricks
(d) Brick waste in Jumbo Bag

Figure 8-1: Bricks and brick waste at the final house
8.1.2 Roofing

The design of the roof was changed from concrete tiles to pre-cut Colourbond (corrugated) steel, Figure 8-2. The implementation of Colourbond roofing proved no major hindrance to Burbank, as their designs (including the house design assessed in this study) can have the option of Colourbond roofing. The additional pre-cut requirement was implemented well by the supplier. Burbank indicated that the time to complete the construction roof was reduced (relative to non-pre-cut roofing), due to reduced labour requirements from the elimination of on-site cutting. Some waste was generated from off-cuts of valley-iron, which need to be cut to size on-site.

![Figure 8-2: Pre-cut sheeting used in final house.](image)

8.1.3 Plasterboard

The strategies to minimise plasterboard waste focussed on five strategies:

1. The removal of box-heads above cabinetry
2. Design and construction of full-length wardrobes
3. The order of plasterboard to suit individual room sizes
4. Replacement of cornice with square-set finishing

The implementation of each of these strategies is reported below.

Box-heads above kitchen cabinetry were easily eliminated from the design and were not installed in the final, as per the agreed strategy.

Internal wardrobes were designed by the Burbank design team to be full-length, as per the agreed strategy. However, the design plans were not followed by the supplier, hence the standard design layout was provided to site, meaning that standard length wardrobes and doors (with infills above) were installed. Rectification of this was considered likely to generate waste, as such, the installation was left as-is.

All plasterboard was ordered to suit individual room sizes, as per the agreed design strategy. However, a breakdown in communication between the plasterboard supplier and installer meant that the plasterers did not install the plasterboard designed for each room. All plasterboard waste generated was collected by the plasterboard supplier for recycling into gypsum.

The higher technical requirements for square-set finishes compared with installation of cornice meant that the plasterboard supplier had to pre-select the plasterboard contractor for this work, based on the contract’s technical ability. The square-set finish was implemented with no major challenges faced.

Photographs of the plasterboard installation and waste are provided in Figure 8-3.
Elimination of bulk-heads from cabinetry (a)

Installation of standard height robe in lieu of full-length wardrobes. (b)

Square-set finishing (c)

Plasterboard waste (d)

Figure 8-3: Plasterboard
8.1.4 Structural timber

The strategy for reducing structural timber waste focused on using temporary bracing timber within the structure. Minor timber elements, such as noggins and bulkheads, are normally supplied as extras with major structural elements, such as walls and trusses. Like the issue which occurred with the delivery of bricks, despite Burbank specifically requesting that these minor timber elements not be supplied, extra materials were supplied and accepted on-site. Despite this, the implementation of using the temporary bracing timber was successful, with almost the entire frame bracing materials used for noggins, spacers or bracing in the final structure. The major challenge faced on-site were the additional time required to cut the bracing timber to suit sizes required within the frame, and the choice of which temporary structures could be used without compromising the integrity of the structure during the assembly phase. Photographs of the timber framing, including reuse of temporary bracing, are provided in Figure 8-4.

Figure 8-4: Timber framing and reuse of bracing timber in structure
8.1.5 Internal tiles

The strategies for reducing tile waste were two-fold. Firstly, kitchen tiles above base cabinets were to be replaced with a glass splash-back. This strategy was implemented well, with no major challenges faced. The second strategy was to select and install tiles (including for floors and vertical areas) to minimise off-cuts. The installation of tiles could be guided by pre-selecting starting points for installation. This second strategy was also successfully implemented, with no major challenges faced. Photographs of the tile installation are provided in Figure 8-5.

(a) Example of guidance on starting point
(b) Example of guidance on starting point
(c) Vertical tiling, with tiles commencing at inside corner
(d) Example of tiling commenced from a pre-determined commencement point with optimised tile size.

Figure 8-5: Installation of internal tiles
8.1.6 Polystyrene (waffle pods)

The ordering of exact numbers of polystyrene waffle pods was well-implemented, with only one pod remaining and two bags of off-cuts. Photographs of the installed and excess waffle pods are reported in Figure 8-6.

![Installed waffle pods](image1)
![Excess waffle pods](image2)

Figure 8-6: Polystyrene waffle pod installation and waste

8.1.7 Cement sheet for eves

Eves were a requirement for the demonstration home, a cutting plan was developed with no off-cuts remaining.

8.1.8 Illegal dumping and mixed waste

No additional strategies were identified to minimise illegal dumping and mixed waste. Burbank’s existing strategies were implemented successfully; however some illegal dumping still occurred, Figure 8-7. Wherever possible, illegal dumping waste was diverted to recycling streams.

![Illegal dumping](image3)

Figure 8-7: Illegal dumping recovered for recycling; steel range hood, wire frame and paint roller.

8.1.9 Plastic

The separation of plastic waste from other waste streams was implemented successfully.

8.1.10 Metals

Left-over reinforcement steel was successfully installed into the concrete slab of an adjacent Burbank construction. All other metal waste was successfully separated on-site.
8.1.11 Concrete

The control over the amount of concrete used in the slab pour was successfully implemented, with no waste concrete being generated.

8.1.12 Cardboard

All cardboard waste was successfully collected and separated for recycling, as per the agreed strategy.

8.1.13 Isolation and sarking

All isolation and sarking cut-offs were successfully collected and separated for recycling, as per the agreed strategy.

8.1.14 Carpet and underlay

No additional strategies were identified to minimise carpet and underlay waste.
8.2 Waste management activities

During the slab pour and site backfill stages, the construction waste was managed by suppliers and through the onsite general waste cage. Polystyrene waste from waffle pods was picked up by supplier for recycling. Similarly, Burbank has an agreement with its steel reinforcement supplier to pickup all slab steel waste for recycling. In this final house, however, all excess steel was used in the adjacent site’s slab.

Following the slab pouring stage, waste was managed by the used of bulk bags as segregation receptacles, which were located at the front of the construction site, behind the site’s hoarding. Recycling waste streams were divided into:

- Bricks & Mortar
- Timber
- Plastic
- Cardboard
- Ceramic Tiles
- Metal

The onsite general waste cage was used for non-recyclable materials eg:

- Cement bags (due to internal plastic lining)
- Silicon and adhesive tubes
- Adhesive buckets

Photographs of individual waste collation areas are provided in Figure 8-8(a).

The first bulk bag was introduced at the framing stage to collect timber waste. This was then collected immediately following the delivery sand for brickwork, which was also supplied in bulk bags. The removal of the timber waste provided onsite space establish the next phase of material separation for recycling. Waste generated between the end of the framing and start of the brick stage was placed in the onsite cage for later separation. Heavy materials, such as metal or timber, were placed into a segregated allocated area for transfer into bulk bags when one became available. As the bulk bags used for sand were emptied, these same bags were then used for waste segregation collection.

Periodically the onsite general waste cage was required to be manually resorted into waste streams across the bulk bags. This was generally due to contractor habits of using the onsite cage on all other construction jobs they were involved with, rather than practicing on-site segregation.
(a) Separation area behind hoarding

(b) Empty Jumbo Bag, for recyclable cardboard/paper waste. General Cardboard waste cage in background waiting to be separated.

(c) Jumbo Bag with wood waste

(d) Jumbo Bag with metal waste

(e) Jumbo Bag with plastic waste

(f) Jumbo Bag with brick waste

Figure 8-8: On-site waste separation
Although not included in the scope of this assessment, the site required levelling prior to construction. All of the earth removed during site levelling was retained for use in parkland elsewhere in the housing estate.

With respect to the management of waste by tradespeople, most tradespeople segregated materials well. Burbank noted that smaller contracting companies and their tradespeople were more willing to actively participate in waste separation. Non-conformance by some tradespeople meant additional manual waste separation was required by others on site.

The area available for on-site waste management is generally very limited, meaning that waste separation and continued segregation of waste can be problematic. On the final audit house site, segregation of waste was managed with minimal inconvenience, due to the availability of space on that particular site. The applicability of similar waste separation and segregation practices on smaller sites and/or larger dwellings could make segregation to the same level problematic.

No cage cleans or site cleans were required during the construction, with only one cage clean required at the end of construction. Similarly, only one site-clean was required at the end of the construction.
9 Final waste audit results

9.1 Waste inventory and greenhouse gas impacts

Table 9-1 summarises the inventory of construction waste for the final audit house, together with estimates of greenhouse gas emissions, stage of generation, waste causality and the final fate of the waste.

The total waste generated was 2,523.2 kg. The inventory in Table 9-1 excludes this excavation waste (site cut waste, e.g. soil, rocks). All excavation waste was used within the residential estate for other developments. As for the initial audit, brick waste dominates the waste total of the final audit house, with 837.6 kg, or 33% of the total mass of the waste materials, followed by plasterboard waste (766.9 kg, 30%). Internal tile waste contributed to a total of 213.7 kg (15%) of waste. The remaining waste materials individually contribute to less than 70 kg of total waste, with these remaining individual materials contributing up to 7% of total waste mass. A schematic of the mass contributions for the individual waste materials is presented in Figure 9-1.

The total greenhouse gas emissions associated with the production and disposal of the material was estimated to be 1,775.7 kg CO₂-eq. The plasterboard, metals, and internal tiles are the major contributors to the total greenhouse gas emissions, contributing to 468.8 kg CO₂-eq (26% of total greenhouse gas emissions), 397.6 kg CO₂-eq (22%) and 204.3 kg CO₂-eq (12%), respectively. All other waste materials individually contributed to less than 10% of the total greenhouse gas emissions profile. A schematic of the estimated greenhouse gas contributions for the individual waste materials is presented in Figure 9-2.

Of the 2,523.2 kg of waste, 867.3 (34%) was generated during the roof and brick construction phase, driven by the mass of brick and tile waste. The plasterwork phase generated 778.9 kg of waste. Framing accounted for 315.2 kg (12%) of waste, largely driven by timber waste. The rough-in and fit-out stages contributed to a total of 302.8 kg (12%) of waste. The slab and remaining construction activities accounted for the remaining 259.0 kg of waste. A schematic of the waste inventory by construction phase is presented in Figure 9-3.

The waste generation causality was dominated by off-cuts, contributing to 1,625.8 kg (64%) of waste generated. This off-cut waste was dominated by plasterboard (766.9 kg), bricks (280.2 kg), timber (266.8 kg) and interior tiles (13.7 kg). A total of 787.0 kg (31%) of waste was due to over-supply or excess materials, driven by excess bricks and mortar (577.4 kg), timber (112.2 kg) and metals (112.0 kg). Illegal dumping and packaging waste contributed to 16.4 kg and 93.9 kg. A schematic of the waste generation by causality is reported in Figure 9-3.

The majority (2,347.9 kg, 93%) of waste was sent to recycling, with 144.5 kg being reused on-site or at an adjacent site. A total of 30.8 kg of waste was sent to landfill, accounting for less than 2% of the waste generated. A schematic of waste by fate is reported in Figure 9-4. Materials which were not recycled included:

- Empty Silicon and corking tubes
- Empty cement and lime bags
- PVC bucket with remnants of tile adhesive or grout
- Contaminated packaging eg cardboard
- Carpet and underlay off cuts
Table 9-1: Final waste audit results and greenhouse gas emissions profile.

<table>
<thead>
<tr>
<th>Material</th>
<th>Waste quantity (kg)</th>
<th>Greenhouse gas emissions (kg CO\textsubscript{2}-eq)</th>
<th>Construction stage (kg)</th>
<th>Causality (kg)</th>
<th>Waste fate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mass (kg)</td>
<td>Volume (m\textsuperscript{3})</td>
<td>Slab Framing</td>
<td>Roof and brick</td>
<td>Various</td>
</tr>
<tr>
<td>Bricks and mortar</td>
<td>637.6</td>
<td>124.2</td>
<td>0.0 0.0 837.6 0.0 0.0 0.0 557.4</td>
<td>837.6</td>
<td></td>
</tr>
<tr>
<td>Cardboard</td>
<td>68.4</td>
<td>141.6</td>
<td>0.0 0.0 0.0 0.0 0.0 0.0 68.4</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Carpet and underlay</td>
<td>8.4</td>
<td>68.9</td>
<td>0.0 0.0 0.0 0.0 6.4 0.0 8.4</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Cement sheet</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0 0.0 0.0 0.0 0.0 0.0 0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0 0.0 0.0 0.0 0.0 0.0 0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Illegal dumping and mixed waste</td>
<td>38.1</td>
<td>62.9</td>
<td>0.0 0.0 0.0 0.0 0.0 36.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Isolation &amp; Sarking</td>
<td>0.3</td>
<td>0.6</td>
<td>0.0 0.0 0.0 0.0 0.0 0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Metals</td>
<td>172.3</td>
<td>397.6</td>
<td>114.1 0.2 29.4 12.0 16.6</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Plasterboard</td>
<td>766.9</td>
<td>468.8</td>
<td>0.0 0.0 0.0 0.0 766.9</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Plastics (PVC pipes and packaging)</td>
<td>32.3</td>
<td>98.7</td>
<td>0.0 0.0 0.0 0.0 32.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Polystyrene (Waffle Pod)</td>
<td>9.1</td>
<td>42.1</td>
<td>9.1 0.0 0.0 0.0 0.0 0.0 5.3</td>
<td>3.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Tiles (interior)</td>
<td>213.7</td>
<td>204.3</td>
<td>0.0 0.0 0.0 0.0 213.7</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Tiles (roof)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0 0.0 0.0 0.0 64.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Timber</td>
<td>379.1</td>
<td>166.0</td>
<td>0.0 315.0 0.0 0.0 64.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>2523.2</td>
<td>1775.7</td>
<td>123.2 315.2 867.3 778.9</td>
<td>302.8</td>
<td>135.8</td>
</tr>
</tbody>
</table>
Waste avoidance and reuse strategies for residential buildings in Australia

Figure 9-1: Final audit results. Contributions of waste materials.

Figure 9-2: Final audit results. Greenhouse gas contributions of waste materials (kg CO₂-eq)

Waste avoidance and reuse strategies for residential buildings in Australia
Figure 9-3: Final audit results. Waste by construction phase.

Figure 9-4: Final audit results. Waste by fate.

Waste avoidance and reuse strategies for residential buildings in Australia
10 Comparative assessment

Total waste generation reduced by 6,602.9 kg, from 9,126.1 kg in the initial build to 2,523.2 kg in the final build, representing 72.4% of the initial waste mass. A comparison of the material waste streams is provided in Figure 10-1. The majority of this reduction was achieved through reducing brick and roof waste by 3,625.4 kg and 2,462.1 kg, respectively. Other minor waste reductions were achieved in plasterboard (569.5 kg), polystyrene (130.1 kg), cement sheets (31.0 kg), plastic (18.9 kg), illegal waste (13.4 kg), isolation and sarking (9.3 kg) and carpet/underlay (0.5 kg). Some increased packaging generation occurred, with metal waste increasing by 137.7 kg, timber by 111.9 kg, cardboard by 37.8 kg and internal tiles by 24.2 kg.

The estimated greenhouse gas emissions reduced by 3,567.7 kg CO$_2$-eq from the initial house to the final house. This 67% reduction was largely driven by the reduction greenhouse gas emissions associated with avoiding brick and roof waste, Figure 10-2.

In both the initial and final houses, the roof and bricking and plastering were the top-two activities contributing to waste generation, Figure 10-3. In both cases, off-cuts still dominated the causality. The relative contribution from excess material reduced from 46% in the initial home to 31% in the final home. The contribution of illegal dumping was similar, contributing to approximately 1% in both cases.

Overall, the waste generation was reduced in the final house by 6,603.0 kg; 72.4% lower than for the initial house. Although 2,523.2 kg of waste was generated in the final house, approximately 99% of this waste was managed through reuse and recycling, Figure 10-4. The design and implementation of the design strategies contributed to a 99.7% reduction in waste sent to landfill, reducing landfill waste from 9,126.1 kg to 30.8 kg.
Figure 10-1: Comparison of waste generation by material.
Waste avoidance and reuse strategies for residential buildings in Australia

Figure 10.2: Comparison of greenhouse gas contributions (kg CO\textsubscript{2}-eq).

Figure 10.3: Comparison of waste generation by construction activity.
Figure 10-4: Comparison of waste fate.
11 Discussion

11.1 Efficacy of waste management strategies

A qualitative assessment on the efficacy of the material-specific design strategies are reported in Table 11-1. All strategies achieved either or both waste reduction and landfill avoidance.

The implementation of the design strategies were implemented well within Burbank’s design team. The implementation of the design strategies through the material was largely successful. The brick and timber suppliers delivered an excess of material, but both of these were managed by Burbank by refusing to accept the delivery of excess materials (bricks) or by utilising the excess materials within the construction (timber). These materials were over-supplied despite Burbank both requesting specific amounts and requesting for no excess supply. The supply chain and the construction industry tends adjust material quantities up rather than rely on exact quantities. This behaviour of excess material supply is largely driven by costs; the marginal costs associated with supply and delivery of excess material is lower than if a separate supply and delivery was to occur (e.g. make-up orders to account for potential material shortage during construction). In addition, time delays can result in additional incurred costs. This study found no evidence for the need for delivery of make-up materials during either house construct but this cannot be discounted for other builds by others.

The implementation of the design strategies during construction was largely successful. The incorrect installation of wardrobes (standard height rather than specified full-length) was adjusted onsite due to the supply of door frames over all internal doors. Rectification will have generated extra waste. Plasterboard off-cuts were used in the infill area. The use of temporary bracing as for additional noggins, spacers and bracing was a technique used for some time by the construction industry. At some time (not determined in this study), suppliers began supplying pre-cut noggin packs, potentially as an added value feature of their products. The added value of this would be the elimination of on-site cutting of bracing to suit noggins, and speed of frame completion. The use of pre-manufactured wall and truss components provides a positive result in onsite waste minimisation it also provides increased lean, re-use and recycling opportunities at the manufacturing site.
<table>
<thead>
<tr>
<th>Material / application</th>
<th>Strategies</th>
<th>Implementation (pass / fail)</th>
<th>Waste generation reduction</th>
<th>Landfill avoidance</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bricks</td>
<td>Individual count and supply minimum, cement-based bricks</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Roofing</td>
<td>Angle-cut skilet roof design</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Plasterboard – bulk heads</td>
<td>Eliminate</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>N/A</td>
</tr>
<tr>
<td>Plasterboard – internal wardrobes</td>
<td>Full-length wardrobes</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Plasterboard – internal walls</td>
<td>Cut to room size</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Plasterboard – cornice</td>
<td>Square-set</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Structural timber</td>
<td>Utilise temporary bracing</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Internal tiles</td>
<td>Change to glass splash back of standard size</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Polystyrene (waffle pods)</td>
<td>Better handling, determine minimum order</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Cement sheet for eves</td>
<td>Eliminate</td>
<td>✓</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Illegal dumping and mixed waste</td>
<td>Existing strategy to control. Separate, recycle</td>
<td>✓</td>
<td>N/A</td>
<td>N/A</td>
<td>✓</td>
</tr>
<tr>
<td>Plastic</td>
<td>Separate waste, recycle.</td>
<td>N/A</td>
<td>N/A</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Metal</td>
<td>Reuse back in slab. Separate for recycling if required.</td>
<td>✓</td>
<td>N/A</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Concrete</td>
<td>Control amount used in pour. Excess to be reused.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>N/A</td>
</tr>
<tr>
<td>Cardboard</td>
<td>Separate waste, recycle</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>✓</td>
</tr>
<tr>
<td>Isolation and sarking</td>
<td>Minimise. Separate waste, recycle</td>
<td>N/A</td>
<td>N/A</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Carpet and underlay</td>
<td>Minimise</td>
<td>N/A</td>
<td>N/A</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
11.2 Additional causalities

Burbank highlighted a number of other reasons for potential waste generation, which were not found during the course of this project. The first of these reasons is the tendency by suppliers to leave erroneous material deliveries on site for builder disposal. Outside of this project, specific instances of this practice (cited by Burbank) have included:

- Non acceptance of return by the supplier of incorrectly delivered truck load of bricks to site;
- Non acceptance of return by supplier of oversupply of brick and roof tiles;
- Non acceptance of return by supplier of imperfect build materials;

Additional reasons for potential waste generation include:

- Oversupply of fix materials by suppliers;
- Different design and/or manufacturing processes in the supply chain, resulting in variations in onsite practice and resultant differences in onsite construction waste, e.g. timber framing.

11.3 Adoption of processes by Burbank

By the time of the publication of this report, Burbank had already implemented strategies and learnings garnered through the project. These implementations and expected benefits include:

- Extended trial of use of bulk bags for sand delivery and using the same for the recycling of bricks, roof tiles and mortar.
  - Expected benefits include:
    - Diversion of waste to landfill
    - Reduction of sand loss from site, (on paths, roads and drains)
    - Reduction in product loss to ground, compared to standard tip truck delivery
    - Reduction in sand contamination, meaning that ordered sand quantities can be reduced
    - Improved site access, as the sand is no longer piled in areas which can cause site access problems (e.g. in driveways) and potential safety hazards

- Extended trial of use of bulk bags for disposal of timber frame offcuts.
  - Expected benefits include:
    - Diversion to landfill,
    - Improved housekeeping,
    - Reduction of waste stored on site,

Most of the strategies used in the project will be available as a standard item or an optional upgrade in Burbank’s current range of homes available to clients. These features include:

- Pre-cut metal roofing
- Removal of eves
- Cement-based bricks in lieu of clay bricks
- Square set plaster in lieu of cornice,
- Full height robes
- Deletion of plaster hob above cupboards
- Optimisation of tiles to wet areas,
- Glass splashbacks in lieu of tiles,

Burbank has implemented supply agreements with material supplier to pick up and reuse/recycle
oversupply or waste material. These agreements apply to a number of materials, including:

- Slab metal
- Polystyrene pods
- Electrical packaging
- Plumbing packaging
- Insulation packaging
- Solar panel installation packaging,
- Air-conditioning/heating packaging,

These agreements are expected to deliver a suite of benefits, including bulk returns overs several sites provide default sorting of materials into streams at supplier sites for recycling opportunities.

11.4 Comparison to KESAB study

The available literature which examines the waste flows from residential home construction in Australia is limited. The most comparable study to this study was undertaken by KESAB [Olesinski, 2009]. In the KESAB study, the waste generated from a number of different houses were assessed, including two single-storey brick veneer homes with timber frame and steel roofing and one single-storey brick veneer home with timber frame and tile roofing. KESAB measured the total mass of waste disposal and estimated the volume contribution from the different construction materials [Olesinski, 2012]. Individual mass flows were not reported and as such, a direct comparison between findings is not possible. Uncompacted densities can be used to estimate the mass contribution from the volume contribution [EPA Victoria]. When these uncompacted densities were applied to the KESAB volumes, the total mass was higher than what was recorded, indicating that the cited uncompacted densities were not reflective of actual uncompacted densities. To account for this discrepancy, the ratio of the actual mass to calculated mass was applied to each individual mass flow. This approach resulted in an estimate of individual waste mass flows for each of the KESAB houses.

The timber-framed brick-veneer house with concrete tiling audited by KESAB was closest in size and construct to the initial house, with an area of 238 m², compared with 212 m² for the initial house. KESAB determined a total of 4.95 tonne of waste [Olesinski, 2009, Olesinski, 2012]. Tile waste was the main contributor, with an estimated 3.40 tonne of waste. The next biggest contributor was brick waste, with 0.72 tonne. The dominance of brick and tile waste is consistent with the findings of this study, however the order and magnitudes of this are different to the KESAB findings. KESAB audited two brick veneer houses with wooden frames and steel roofing; one with a footprint of 200 m² and another with 215 m². These houses generated 6.50 tonne and 3.32 tonne of waste, respectively. The steel-roofed house generating 3.32 tonne is lower than the roof-tile house (4.95 tonne), and is consistent with the finding in this study. However, this consistency is contradicted by the other steel-roofed house, which generated more waste than the roof-tiled house. The reasons for these discrepancies are not clear but reinforce the significant differences in waste generation that can occur between similar house constructs.

11.5 Challenges and opportunities

Foreseeable challenges in the domestic construction industry include:

- Improvement in quality systems (both at suppliers and customers) to minimise the need for additional material to be supplied to site to compensate products which do not meet specification or expectations
- Culture change in suppliers and contractor base to segregate waste streams on site
- Construction build footprints are increasing in proportion to land allotments, due to smaller land sizes, this significantly reduces the opportunity for waste stream segregation onsite
- Small and remote builders will find some aspects of diversion strategies due to economies of scale, it needs to be service driven to make it available to everyone
- A successful waste avoidance strategy will be influenced by the consumer as most options are
driven by choice in the design phase and materials selection. For example, a consumer choice for use of concrete roof tiles over Colourbond roofing will likely result in increased waste generation.

A number of opportunities exist to promote and further reduce waste generation across the residential construction industry, including:

- Developing and implementing supplier packaging/waste return programs, which increase the opportunity for reused or more effective recycling.
- Increased use of bulk bags for sand and reuse of the same for waste collection and recycling.
- Increased off-site manufacturing of construction components, which:
  - increases the likelihood for reuse of off cuts into other components
  - increases the opportunity of bulk recycling
  - reduces waste on site
  - eliminates the need for onsite waste stream segregation.
- Promotion of waste minimisation materials and processes via an education campaign.
- A reconsideration of the general requirement to provide clean cover on allotments, with preference given to native soil for levelling.

Even though outside the scope of this project, the use of the site cut material on site into parkland is worth consideration. It is not unusual for developers to import clean fill to top-dress allotments only to have it scaped off and disposed to landfill as part of the site cut. Clean fill and rock processing plant could be staged onsite, with all clean fill site cut material used on site in the development in landscaping or parkland development.
12 Conclusions

The aims of this report were to:

- Identify and quantify the main construction waste material types during the construction of a typical volume-built house
- Identify the main construction activities which contribute to waste generation
- Identify waste generation causalities
- Develop commercially viable strategies to avoid, reduce, reuse or recycle construction waste
- Quantify waste avoidance from the implementation of these strategies

A typical volume-built brick veneer house generated a total of 9,126.1 kg of waste. The main drivers, causalities and construction stages for this waste were:

- Bricks and mortar: 4,463.0 kg
  - driven by excess (3,100.0 kg) and off-cuts (1,363.0 kg)
  - during the roof and brick stage
- Concrete roof tiles: 2,462.1 kg
  - driven by off-cuts (1699.2 kg) and excess (762.9 kg)
  - during the roof and brick stage
- Plasterboard: 1,336.4 kg, driven by
  - Drive by off-cuts (1,115.9 kg) and excess (220.5 kg)
  - During the plasterwork stage

A suite of avoidance design strategies were developed and implemented, including:

- Changing the type of bricks from clay fired to cement-based
- Changing roofing material from concrete tile to Colourbond
- Eliminate plasterboard bulk heads from the kitchen
- Utilise square set in place of cornice
- Reuse temporary bracing timber as noggins
- Order waffle-pods to the exact number needed
- Change floor tile sizes to better suit room sizes
- Change labour practices for installation of internal tiles
- Replace vertical internal tiles in kitchens with splash-backs

By implementing these design strategies, a total of 6,603 kg of waste was avoided during the construction of the final house. This reduction represents 72.4% of the mass of waste generated in the initial house. Additional design strategies were developed but were not well-implemented during the construction of the final house, including the installation of full-length wardrobes and plasterboard cut to suit specific rooms. The lack of implementation of these strategies was driven by insufficient communication through the supply chain. Successful implementation of these additional strategies may have resulted in further reductions in waste generation.

In addition to the design strategies, a number of waste management strategies were developed and implemented, including:

- Engagement and alignment with suppliers and contractors on waste minimisation and...
The implementation of waste management strategies contributed to an additional 2,492.4 kg reduction in waste being sent to landfill. The total amount of waste sent to landfill from the final house was quantified to be 30.8 kg, representing a reduction of over 99% relative to the initial house.

At the time of publication, Burbank had already implemented a number of the design and waste management strategies, with a view to implementing more. The successful implementation and ongoing reduction in waste generation in the residential construction sector more broadly faces a number of challenges, including:

- Addressing the culture of over-supply
- Improvement in material quality systems (both at suppliers and customers)
- Adoption of on-site waste separation for recycling, which could be limited by
  - Waste management behaviours across the construction sector
  - Availability of area for on-site waste stream segregation
  - Economic viability of recycleate collection
- Consumer choices, which underpin materials selection. For example, a consumer choice for use of concrete roof tiles over Colourbond roofing will likely result in increased waste generation. Planning overlays could also influence materials selection.
13 References


ECORECYCLE Construction Waste Minimisation Strategy.


