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Dynamics of Carbon Stocks in Timber in Australian Residential Housing

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Dynamics of Carbon Stocks in Timber in Australian Residential Housing

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Executive Summary

The role of harvested wood products in the global carbon cycle has been considered in scientific analysis of greenhouse gas emissions for some time. Scientific evidence indicates that carbon in wood harvested from forests is stored in products for a period of time and then partially emitted as products decay in service or are disposed following their initial or subsequent usage. There have been some international and country level studies into storage and fate of carbon in wood products but there has been relatively little investigation of these processes in Australia. Housing and residential construction and renovation is a major use of wood in this country. Given the longevity of housing, this sector also has the greatest potential for long-term storage of carbon in harvested wood products. Other wood products such as plywood and panels, paper and packaging are also potentially important components of the carbon cycle.

From a climate mitigation perspective, one of the key advantages in using wood in construction is that carbon in wood is removed from the atmosphere as trees grow. However, a complete understanding of the carbon dynamics requires analysis of carbon in forests and the fate of wood after use. If the forest is sustainably managed and the carbon stock in a forest area is maintained, then the carbon removed from the forest in products or released during harvesting is replaced through new forest growth. Wood in house construction is derived from a range of forest types. Historically, most of the wood used in construction came from Australian native forests or was imported from North America or Europe. More recently, construction timber has largely been sourced from softwood plantations established from the 1950s to the 1990s to meet growing domestic demand. The historical carbon balance in Australian native forests is uncertain with factors such as fire, conversion to other land uses and the growth stage of the area harvested important influences on carbon dynamics. The area of softwood plantations in Australia is now relatively stable and they are currently in carbon balance over the longer term. A full life cycle analysis of the forest-product use-waste stream was beyond the scope of this study.

The aim of this study was to develop improved estimates of the dynamics of carbon stocks in timber in housing in Australia. Key variables in models to develop these estimates are the number and size of completed dwellings, the amount of wood products used per unit of floor area, the longevity of dwellings (and wood products), and the amount and fate of construction and demolition wood waste. The study was based on the analysis of the literature, published industry surveys, questionnaires sent to builders, architects and demolition companies across all States (except the Northern Territory) and interviews with estimators from large building companies. 442 survey responses were received representing 24% in response rate. The study did not attempt to determine the proportion of wood used from imported versus domestic sources.

Key findings

Carbon stock estimates

- An average of 2.05 Mt of carbon dioxide equivalents (CO_2-e) was added to carbon stocks each year in residential housing in Australia over the last 10 years. This was equivalent to about 0.4% of Australia's total greenhouse gas emissions in 2006. Additions to carbon stocks in residential housing have generally declined over the last 70 years, with some of the highest rates (over 10 Mt-CO_2-e per year) occurring in the 1930s and 1940s.

- New South Wales/ACT (37%), Victoria (26%) and Queensland (19%) account for the greatest proportion of carbon additions, with less in Western Australia, South Australia, and Tasmania.

- The extent of carbon storage in wood products is most sensitive to the number of dwellings, the average house area and estimates of wood volume per square metre of floor area. It is least sensitive to average wood basic density.

Wood products use in residential house construction

- There has been an upward trend in the average size of dwellings across Australia (from about 78 square metres in 1945 to about 250 square metres in 2008) but the average wood products usage per unit of floor area has decreased from about 0.29 m^3/m^2 to about 0.06 m^3/m^2 over the same period. The average volume of wood per dwelling has therefore decreased from about 24 m^3 to 14 m^3 over this time with relatively greater use of brick, concrete, steel, aluminium and plastics in house construction in Australia.

- The decline in wood usage per unit of floor area has been gradual in eastern States. In Western Australia there was a large decrease in wood use in the 1960s when there was a significant shift to double brick/concrete slab-on-ground construction.

- There has been increasing use of softwood rather than hardwood timbers in house construction. Currently, about 80% of the timber used in housing across the country is softwood. There is considerable variation across States and Territories. In South Australia, 98% of timber used in housing is softwood while Tasmania has a higher of proportion of hardwood use (56%).

Treated timber in structural applications

- Over 60% of architects in the surveyed States specified treated timber for structural uses except in Tasmania (33%).

- Usage of treated timber products was highest in Western Australia (97%), New South Wales (94%), Queensland (94%), Victoria (78%) and South Australia (74%). The lowest uptake of treated wood products was in Tasmania where only 18% of the builders surveyed used treated timber.

- Timber treatment may play a role in delaying the time to demolition, as onset of decay and/or termite attack can frequently occur much earlier than the service life (61 years) estimated in the survey. However, as noted below this product failure is not generally the main cause of demolition. Timber treatment can reduce the potential for carbon loss due to termite and/or fungal attack.

Longevity of dwellings and patterns of turnover

- The average lifespan of dwellings estimated by architects was 61 years. The majority of demolished dwellings were those built after World War II with 70% in use for between 25 years and 58 years. The remainder of demolished homes were constructed pre-World War II.

- Primary reasons for demolition included site redevelopment (58%), the building ceasing to suit owners' requirements (28%), the dwelling becomes unserviceable (8%), and for other reason like damage by fire, storm, etc (6%). Few dwellings were demolished due to the failure or decay of wood products. Most buildings were demolished for reasons other than the state of the structural systems.

Generation and fate of wood products waste during construction or demolition

- In construction, building practitioners allowed an average of 8% for construction wood waste when they ordered wood products, although some allowed slightly more (11%) for waste.

- Of the wood waste generated during construction, only 45% was utilised in some way either on the same site or offsite as noggings, packers and blocks, while the waste collected in skips to waste transfer stations was mainly indirectly recycled as mulch, animal bedding, or other products.

- Of the wood waste (55%) that was not utilised on site, 80% ended up in landfills. The remaining 20% was disposed by other methods, mostly by burning as firewood.

- A wide variety of wood materials are salvaged during demolition, including roof beams, ceiling battens, sub-floor timbers, interior wall framing timbers (if not contaminated with asbestos fibres), built-in robes, floor boards, skirting/architrave, window frames, external hard core doors and internal plywood doors. Most salvaged wood was taken to salvage/recycling yards or waste transfer facilities for further processing or sale.

- About 60% of wood products not salvaged from demolition sites were disposed of in landfills. The rest (about 40%) went to other uses such as firewood.

Timber recycling

- Timber recyclers sourced most of their wood products from either dwelling demolition (46%) or commercial building demolitions (31%). The remainder was sourced from dwelling construction and renovation sites.

- About 95% of wood products from recycling yards were sold or reused: about 77% of the wood sold or reused were utilised in new dwelling construction as flooring, internal wall paneling, ceiling, and in façades. Other reuses included outdoor furniture and children's playgrounds. About 18 % was indirectly recycled as mulch, animal bedding, etc.

- Wood products (about 5%) that were not used or sold were largely used for energy recovery, mostly collected by locals for firewood. Anecdotally, very little wood waste from recycling yards went to the landfill (not surprising because the primary objective of timber recyclers was to profitably divert all reusable timber from landfill).

Recommendations and policy options to increase timber usage

- Accounting for carbon stored in Australian housing stocks is most sensitive to assumptions of the wood used per square metre of housing. It is recommended that this survey is repeated periodically (e.g. 5 yearly) to detect trends in wood usage. This could also serve as a tool to measure the effectiveness of campaigns to increase wood usage.

- There is significant scope for greater carbon storage in houses by increasing use of wood products in applications such as sub-floor systems and wall cladding. As an example, doubling the volume of wood used in houses to 0.14 m^3 per m^2 of floor area, would result in additional annual C storage in houses in Australia from 1.6 Mt CO_2-e in 2008 to 4 Mt CO_2-e in 2050.

- When asked to rank (in terms of their potential) the policy options that governments or industry could adopt to increase the quantity of wood products used in residential dwelling construction,

    86% of building practitioners indicated that reduction in the relative price of wood products compared to competing products would increase wood products usage

    76% indicated that better training and education for builders, building surveyors, building designers, etc on the carbon storage benefits of wood products.

    62% indicated that changes to government building regulations or building codes, for example, to allow timber products to be used in a wider range of building applications than is currently allowed.

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INTRODUCTION

Carbon stored in harvested wood products has been the subject of considerable discussion in the development of climate change policy. For a range of reasons, inclusion of increased carbon stocks in harvested wood products as a contribution to country emission reduction targets has been contentious. Primary concerns included the measurement capacity and uncertainty associated with quantifying carbon stocks and dynamics in wood products, the attribution of internationally traded wood products to different countries and the interaction with carbon stocks in other pools, particularly in forests and the waste pools. Consequently, greenhouse gas emissions accounting rules for the Kyoto Protocol do not provide for the inclusion storage of carbon in harvested wood products and emissions associated with forest harvesting are assumed to occur at the time of harvest, unless countries can demonstrate that the stock of carbon in wood products is increasing. Garnaut (2008) observed that there is scope to reduce the carbon liability incurred when trees are harvested if inventories, and the proposed emissions trading scheme, recognise carbon stored in harvested wood products. In addition, the same review reported that the Australian Government believes that the Kyoto accounting rules are not an appropriate reflection of reality—carbon stored in wood products should be recognised in international agreements, and that Australia will increase its efforts to influence changes to the international climate change framework in ways that reflect Australia's particular circumstances, are based on science and provide appropriate incentives to reduce emissions.

The purpose of this project was to improve the estimates of carbon stocks in Australian housing where over 70% of harvested sawn wood products are used so that this pool of carbon can be properly accounted for in the national inventory.

Specific objectives of the project were to:

(a) estimate past and current timber products use in house construction;
(b) investigate the generation and the fate of construction and demolition wood waste, including salvaging/recycling rates, and disposal options;
(c) estimate the life span of residential dwellings and the factors influencing patterns and longevity of residential housing;
(d) to develop a method to estimate the level of carbon sequestered in Australian housing
(e) explore the opportunities to encourage greater use of timber in housing.

METHODS

Historical data on wood usage

To estimate past wood products usage in dwelling construction, we conducted an extensive search for published and unpublished material held by various organisations. While the initial plan was to get data from old bill of quantities from quantity surveyors, this proved unworkable because most of the firms we approached did not have the data or were not willing to share this information. We therefore used demolition and wood waste recycling data from the following organisations and sources to do the estimates:

- McGregor Environmental Services - *Predicting construction and demolition waste quantities - Inner Sydney Waste Board, 2000.*

- McGregor Environmental Services - *Study of demolition of houses for the Department of Housing and Waste Boards of NSW, 2000.*
- BIS Shrapnel - *Sawn timber in Australia 2000-2015*. BIS Shrapnel Forestry Group
- Jones & Juniper - *Analysis of timber volumes used in domestic construction, 1982*.
- Greve & Diem Queensland (*Timber volumes used in house construction,* Timber Trends, Queensland Department of Forestry *1984, 1985*.
- Sustainability Victoria (formerly EcoRecycle Victoria) – *Waste generation and recycling in the demolition sector, 1999.*
- Sustainability Victoria (formerly EcoRecycle Victoria) – *Ballarat construction and demolition waste market development, 2000.*
- Department of Housing and Works – *Housing Strategy WA, 2000*
- C&D Recycling (WA) – *Inquiry into waste generation and resource efficiency, 2006*.
- Peter Cuffley – *Australian Houses of the Forties & Fifties, 1993*
- Howard Turner – *Australian Housing in the Seventies, 1976*
- Robin Boyd – *Australia's Home*, 1987
- National Association of Steel-framed Housing Inc. – *General guide to steel-framed building; History of steel-framed housing in Australia*

Current data on wood usage

Face-to-face meetings, telephone interviews, mail and online surveys and in-depth analysis of selected dwelling designs were used to collect the following data:

- Wood products usage
- Generation and the fate of construction and demolition wood waste, including salvaging/recycling rates, and disposal options;
- Life span of residential dwellings and the factors influencing patterns and longevity of residential housing;
- Opportunities to encourage greater use of timber and to increased longevity of timber in housing.

Surveys

First, target populations were stratified on the basis of geographical location (States) – see Appendix 1. The second stratification was on the basis of type of respondent. The second stratum comprised architects, builders, frame and truss manufacturers, dwelling demolishers and timber recyclers: The geographical spread and sample sizes, including the response rates are shown in Appendix 2.

A comparison of early and late respondent answers to a subset of survey questions revealed no evidence of non-response bias.

Face-to-face and telephone interviews with large builders

In Victoria, one telephone interview was conducted with the Managing Director of Langford-Jones Homes. In addition, two face-to-face interviews were conducted: one with the Glenvill's General Manager Building Operations and the other with Metricon Homes Pty Ltd's Senior Estimating Administrator and the General Manager National Operations. Two builders and three architects completed the survey online.

For New South Wales, six (6) interviews were conducted face-to-face. Subject to their willingness to participate in the survey, the companies chosen to be interviewed were selected from the Housing Industry Association (HIA)'s *Housing 100: Australia's Largest Home Builders and Residential Developers*. It should be noted that many of the builders and developers in the above publication concentrate solely on medium to high density multi-units where there is minimal usage in timber and other wood-based products during construction. For all interviews, location and availability of the interviewees were the determining factors in all successfully completed interviews.

Three major residential developers based in Queensland were selected from the same HIA publication. Due to distance, they completed the surveys sent to them via fax and email.

Due to the initial poor response from dwelling demolishers and timber waste recyclers from both NSW and Queensland, telephone interviews were conducted to instigate some more responses. From Queensland, four (4) dwelling demolishers and four (4) timber waste recyclers completed the survey online.

In-depth analysis of Bill of Quantities

In Victoria, Metricon Homes Pty Ltd agreed to provide bills of quantities for eleven (11) dwelling designs for in-depth analysis. The company also facilitated the provision of bills of quantities from Timbertruss Geelong Pty Ltd for timber roof trusses for the 11 dwelling designs. Data from this analysis was used to compare and cross-check wood product usage estimates from the survey and other sources. The bill of quantities for two of the more popular house designs (single-storey and double-storey) were provided by one of the major home building companies in NSW. Detailed volumes of timber used in the wall frames were provided by their timber wall and truss supplier.

Profile of survey respondents

Respondents for the large builders were general managers/managing directors, construction managers, estimating administrators, project managers, or building managers. The average number of employees for the large builders was 55 and more while the average annual turnover was more that AU$15 million. On average large builders built more than 200 dwellings per year.

For other builders, titles of respondents included owners, designers, estimators, and tradesmen. Respondents for frame and truss manufacturers included CEOs, owners, engineers and State managers. Their average number of employees was less than 55 and their average annual turnover was less than AU$15 million. The average number of projects by this category of builders was less than 100.

Respondents for architects included principals, partners, associates, directors and owners. Over 80% of the respondent firms had 5 employees or less and their average annual turnover was AU$1 million or less.

From residential dwelling demolishers, respondents were mainly owners or managing directors. The average number of their employees was less than 25 and average annual turnover of AU$1 million or less. The titles for respondents from timber recyclers included owners, directors and coordinators. Most timber recyclers had less than 10 employees with average income between AU$1 million to AU$5 million.

7.1 Carbon Estimation Model

Carbon is stored in wood in a variety of complex organic molecules. Carbon generally constitutes about 50% of the total oven-dry mass of wood. In this section, 'carbon' refers to the stock or change in stock (emissions or removals) of carbon or carbon dioxide. Consistent with national and international reporting of greenhouse gas emissions, all quantitative figures are referred to in terms of carbon dioxide equivalents

The key parameters for carbon estimation model were

- Number of dwellings (completed annually and estimates from the National Census)
- Average wood usage per square metre of floor area over time
- Weighted wood basic density
- Average size of dwellings
- Estimated longevity of dwellings

Other variables needed included

- Wood carbon content
- Conversion factor to convert carbon to dry mass
- Conversion factor to convert carbon to carbon dioxide equivalent
- Rate of loss of carbon from the wood product pool in housing

The estimates for the above parameters used in the model are presented in the attached Excel file (*Carbon estimation model*).

7.1.1 Approach to carbon stock estimation

Carbon stocks were estimated by integrating the number of dwelling completions, average dwelling size, average wood volume per square metre of floor area, average wood density, and then applying conversion factors for carbon content, ratio of atomic weight of carbon to oxygen and moisture content.

Separate carbon stock estimates were undertaken using:

(a) estimates for each State (excluding Northern Territory) to determine annual carbon additions to housing based on completed dwellings from 1945 to 2007.

(b) estimates based on reported housing stocks in each National Census year from 1911 to 2006. These estimates were compared with the carbon stock estimates for Pool 5 (very long- term products such as those used in structural members in houses as described by Richards *et al* (2007).

The method used to estimate carbon losses from the pool is given in Appendix 7.

Delimitation

We should point out that this study did not attempt to compare carbon storage in residential dwellings to carbon emissions during their life cycle. What the study did was to assess the dynamics of carbon stocks in wood products in residential housing, which is one of the reservoirs in the carbon pathways from the forest. Also, the study did not extend to carbon stocks in wood products waste (from dwelling construction and demolition) disposed in landfills. Furthermore, Northern Territory (NT) was not included in the study while the Australian Capital Territory (ACT) was included as part of NSW when estimating carbon stocks. This was due to the small population compared to all other states and the comparatively lower usage of timber in the NT (according to advice from the NT Department of Lands). NT was not included in previous similar national surveys (e.g. CRC for Greenhouse Accounting survey). The results of this study should therefore be understood within the above constraints.

RESULTS

Part 1: Wood products use in housing

1.1 Changes of timber use in housing over time

Timber has been an important building material in Australia since the arrival of white settlers and since then, the association of timber as an established part of the Australian building culture has led to its public acceptance as a building material, especially in private residential buildings (Nolan, 1994).

Timber and brick have been the dominant materials for outer walls of Australian dwellings. However, there has been a long-term shift from timber to brick as the most popular outer wall material. In 1911, 55% of dwellings had timber outer walls and 25% had brick outer walls, while in 1999, 71% of new dwellings had brick outer walls (ABS, 2001).

In 2001, about 74 % of dwellings had timber wall framing, with Queensland, Tasmania, South Australia and Victoria had the highest percentage of dwellings with timber wall framing and Western Australia the lowest proportions (36%). At the same time, about 89% of dwellings had timber roof framing, with a notable increase in usage in Queensland, Victoria, and Tasmania (CRC Greenhouse Accounting, 2001).

Suspended floors were dominant until approximately 40 years ago, when there was a sharp increase in the use of concrete slabs, and concrete slab is now the flooring system used in over 80% of new dwellings built (Department of Housing and Works, 2000; Kapambwe *et al. Wood utilisation trends in residential dwellings in Victoria, Australia*, in press; CRC for Greenhouse Accounting, 2001.

1.1.1 Trend in dwelling size

The estimated size of dwellings constructed in the early to late 1940s ranged between 80 m^2 to 116 m^2. This is because of war time government restrictions limiting the size of a new house to 111.48 $m^2$for a timber house and 116.12 m^2 for one in brick (Cuffley, 1993). After government restrictions were lifted in 1952, there had been a slow but steady increase in the size of Australian dwellings, as demonstrated by the rises in the average floor area and in the average number of bedrooms.

While the average size of the block of land on which separate houses are built has been declining, the estimated average floor size of new houses increased from 80 m^2 during 1940s to 258 m^2 in 2006, while estimated the average floor size of medium and higher density dwellings increased from 61 m^2 to 149 m^2 over the same period (Australian Greenhouse Office, 2006). Overall there has been an upward trend in dwelling size across all States and Territories (Figure 1.1)

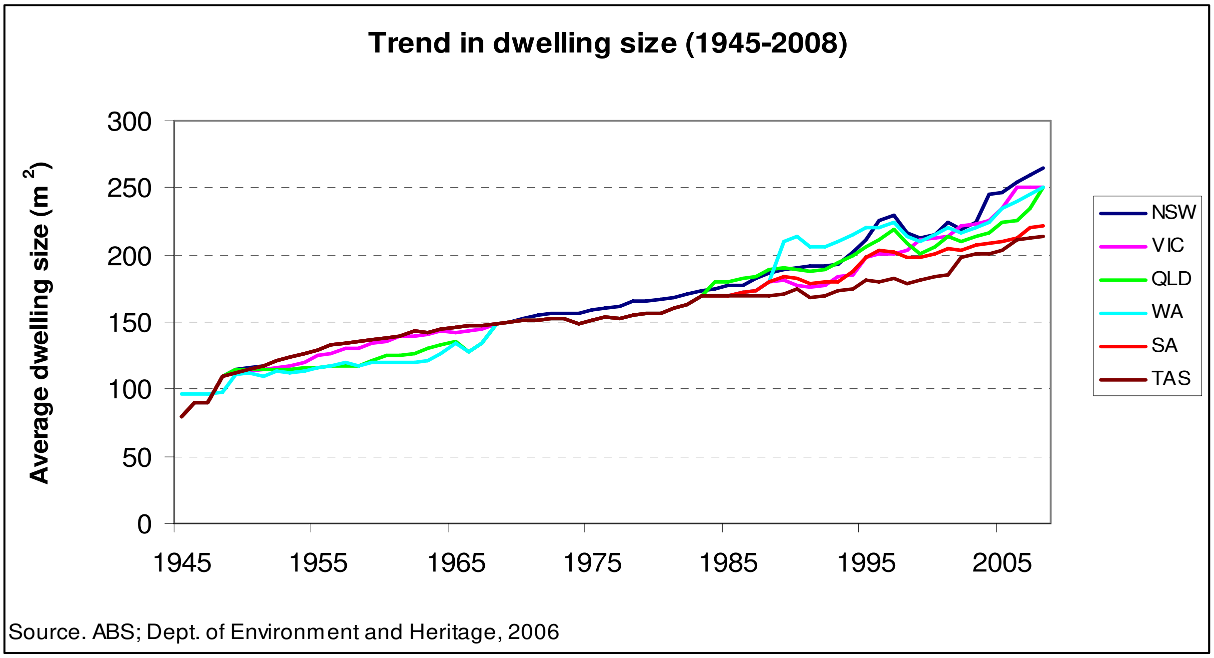

Figure 1.1 Trend in dwelling size across Australia

1.1.2 Trend in wood usage per house and per unit of floor area

Most ordinary houses built between 1940 and 1945 were built of basic materials from a standard range available. Dwellings of all kinds, in all types of materials and built by either the owner-builder or various professional contractors, shared basic characteristics due to regulation and prevailing ideals before and during the two wars. This is evidenced by the similarity in the estimates of the quantities of timber from demolished dwellings built during that period assessed in this study. For example, while there is some variability in construction materials, an average of 18 tonnes of timber (0.16 tons or 0.23m^3) of timber per square metre of demolished house floor area (an average floor area of 110 m^2 per dwelling) has been estimated for Victoria and Western Australia, using house demolition data from Nolan-ITU (1999) and C&D Recycling (2006): The age of demolished dwellings ranged from 25 years to 110 years, with the average floor area of 110 m^2.

Similarly, an average of 0.15 tons (or 0.2 m^3) of timber per square metre of demolished house floor area was estimated for New South Wales using data from McGregor Environmental Services (2000): The age of demolished dwellings ranged from 40 years to 80 years, with the average floor area of 116 m^2. Although McGregor Environmental Services used an average density of 800kg/m^3 (i.e. 900 kg/ m^3 for hardwoods and 700 kg/ m^3 for Cypress pine) to estimate the volume of timber from demolished houses, this study used a density of 700 kg/ m^3 for timber in predominantly hardwood construction (pre- 1945), reducing to 500 kg/ m^3 after 2000 (see carbon stock estimation model). Thus, estimates of wood usage per dwelling indicated that average wood volume per dwelling decreased from about 24m^3 to about 14m^3 between 1945 and

2008 (Figure 1.2). During this period, the following factors could have contributed to the reduction of wood usage:

(a) the architectural changes such as the increased use of dwellings built with concrete slab foundations rather than conventional basement or crawl space foundations. This could have reduced wood usage by about 12-14% (Greve and Diehm, 1985; Jones and Juniper, 1982)

(b) structural building changes such as increased use of roof trusses (less wood used in trusses than stick-built (B. Stevens 2008, pers. comm.)

(c) a large scale substitution of non-wood products for timber. Often recognised as a time when the range of building and associated materials expanded rapidly, the post-war years brought about fierce competition in products such as wall cladding, roof materials, flooring materials, plastic laminates, etc. For example, while variations of the weatherboard suburban house continued to be a standard type, the cost and scarcity of some materials drove substitution of materials. For instance, a scarcity of timber resources in South Australia had led to a tradition of building in brick and stone, with a subsequent shortage of bricks caused South Australian builders to gradually adopt brick veneer, yet many low-cost timber-framed houses were given asbestos-cement cladding (Cuffley, 1993). Loss of external cladding, wall framing, and timber floors could reduce wood volume by about 18%, 45%, and 17% respectively (estimates based on Greve and Diehm, 1985; Jones and Juniper, 1982; our survey).

(d) More open planning (less internal walls) and more efficient timber usage with smaller members

From 1970s to 1990s, the volume of wood products per square metre of floor area declined from an estimated 0.24 to 0.07 m^3/m^2 in South Australia (TDA SA/ South Australia Housing Trust), from estimated 0.28 to 0.12 m^3/m^2 in Victoria, New South Wales and Queensland (Jones and Juniper, 1982; BIS Shrapnel, 2000; Greve and Diehm, 1985). In 2008, average wood products use in dwellings declined further to 0.06 m^3/m^2 across the eastern State and to less than 0.05 m^3/m^2 in Western Australia.

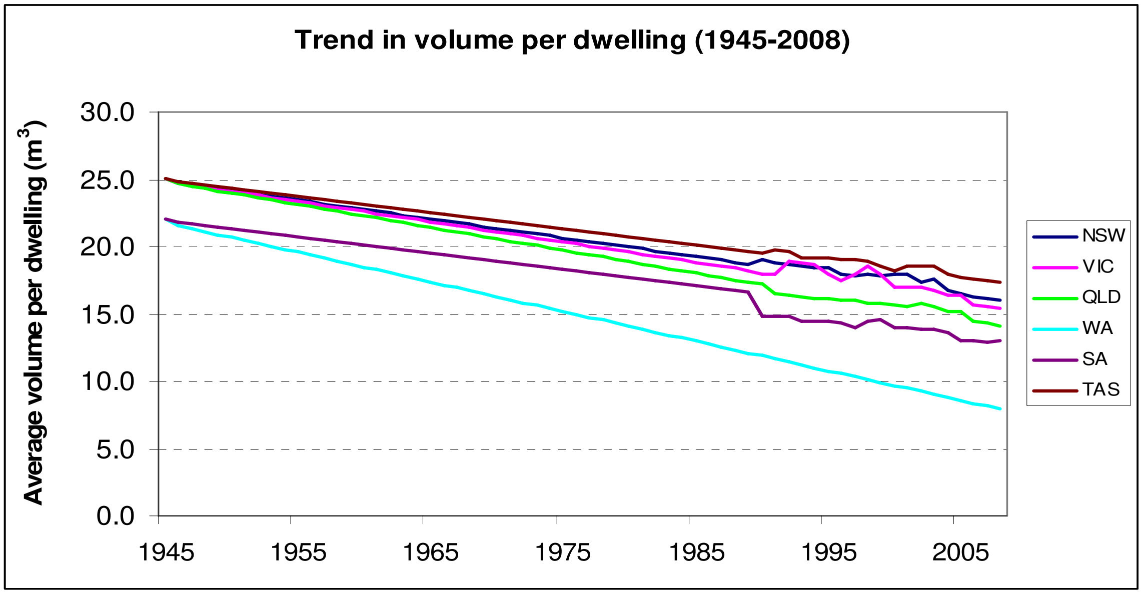

Figure 1.2 Trend in wood volume used in house construction across Australia

For actual average timber volumes per dwelling, see the Table in Appendix 3

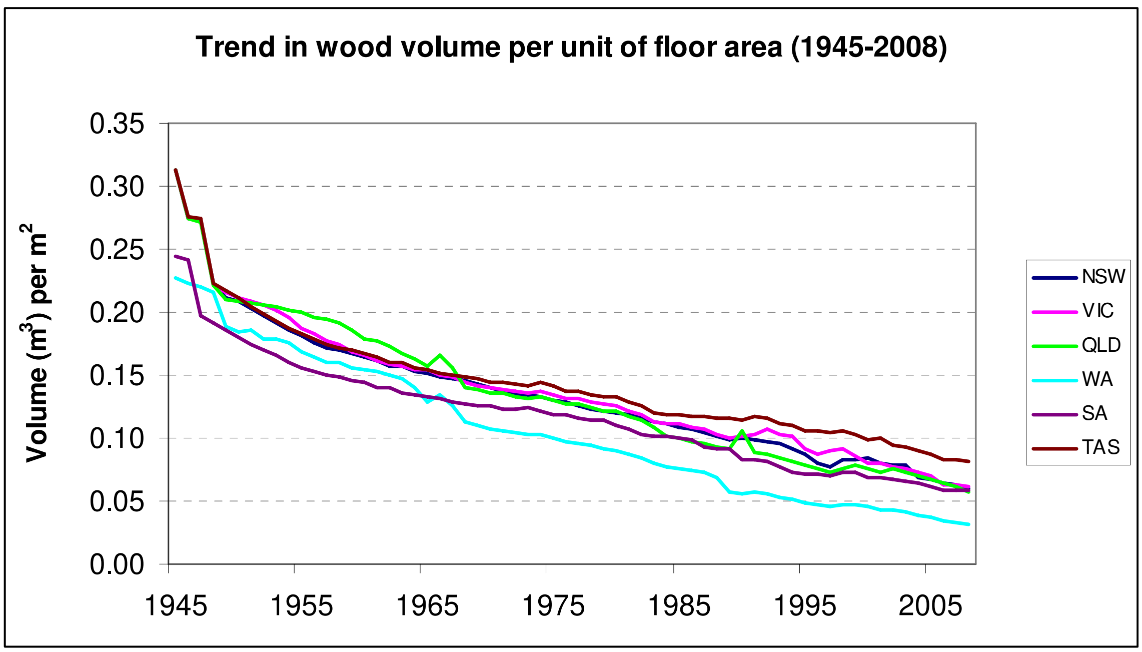

Figure 1.3 Trend in average wood volume used per square metre of floor area

On average, the estimated volume of timber used per unit m^2 of floor area has declined from about $0.29m^3$ in 1945 to 0.06 m^3 per m^2 of dwelling floor area in 2008 (Figure 1.3). Although the decline in has been gradual in the eastern States (with about 35% reduction in wood usage) over this period, Western Australia has experienced the most remarkable decrease since the 1960s when double brick slab-on-ground construction achieved ascendancy as the primary building form that still dominates today; thus over 60% reduction in wood usage in could have occurred in WA over the same period.

Part 2 Current level of wood product usage per unit of floor area

According to the Australian Bureau of Agricultural and Resource Economics (ABARE), 2007), 1.2 million m^3 of sawn hardwood and 4.04 million m^3 of sawn softwood were consumed in Australia in 2006/07. The volume of sawn wood used in residential dwellings in Australia accounts for approximately 70 percent of the total volume of sawn wood consumed in Australia (BIS-Shrapnel 2008). The volume of wood used in residential dwellings is projected to increase over time as shown in Table 2.1.

Table 1. Volume of wood used in residential dwellings in Australia in 2007 (Source: BIS-Shrapnel, 2008)

	2007		**2018-22**	
Construction activity	Softwoods (‘000 m^3)	Hardwoods (‘000 m^3)	Softwoods (‘000 m^3)	Hardwoods (‘000 m^3)
Detached Houses	1619	211	2330	287
Other dwellings	142	37	1999	41
Alt. and additions	1111	481	1499	460
Total	2872	730	4029	788

2.1 Volume of wood products per dwelling construction

Three approaches were used to estimate and cross-check the volume of wood products used in new dwelling construction:

(a) a national survey of builders
(b) consultation with the National Building Council/Master Builders of Australia (NBC/MBA)
(c) in-depth analysis of wood products usage in 11 detached house design in Victoria

Results of volume estimates are presented in Table 2.2 below. From the survey, average estimated average volume per dwelling (single-storey) was 13m^3. The estimate from NBC/MBA was 10m^3, while the weighted average volume for the 11 house designs was 18.6m^3. The average wood products usage from the three approaches was estimated as 14m^3 per dwelling.

Table 2.2 Volume estimates for selected dwelling designs

House Design	**Number of Storeys**	**Floor Area (m^2)**	**Wood Volume in Building Applications (m^3)**				**Total volume (m^3)**
			Ground floor - *Wall framing*	**First floor –** *Wall framing, flooring & covering*	**Roof**	**Other** *(e.g. joinery)*	
Newhaven36	Double	341	5.20	12.72	8.00	0.70	26.57
Tribeca36MK2	Double	340	6.39	8.66	4.80	3.64	23.50
Promade43	Double	399	8.20	7.48	7.02	1.04	23.74
Liberty42	Double	390	6.96	9.23	5.84	1.45	23.5
Aspen31	Single	294	8.00	-	7.29	0.82	16.11
Latitude36	Single	367	8.91	-	7.97	1.07	17.95
Coburn39	Single	366	10.42	-	9.17	2.34	21.93
Belize20Traditional	Single	189	4.99	-	4.21	0.49	9.69
Soho27Traditional	Single	254	6.98	-	5.96	0.67	13.61
Santorini29	Single	271	7.05	-	6.61	0.49	14.15
Lindeman27	Single	252	6.20	-	5.8	0.63	13.44
					Weighted average		18.6
NBC/MBA	Single	150	-	-	-	-	10
SURVEY	Single	235	-	-	-	-	13

2.2 Volume of wood products per square metre of floor area

Volume of wood products use per square metre of floor area was calculated by dividing the volume per dwelling by dwelling size (Figure 2.1). Average usage per unit of floor area for 2008 was estimated as 0.06 m^3.

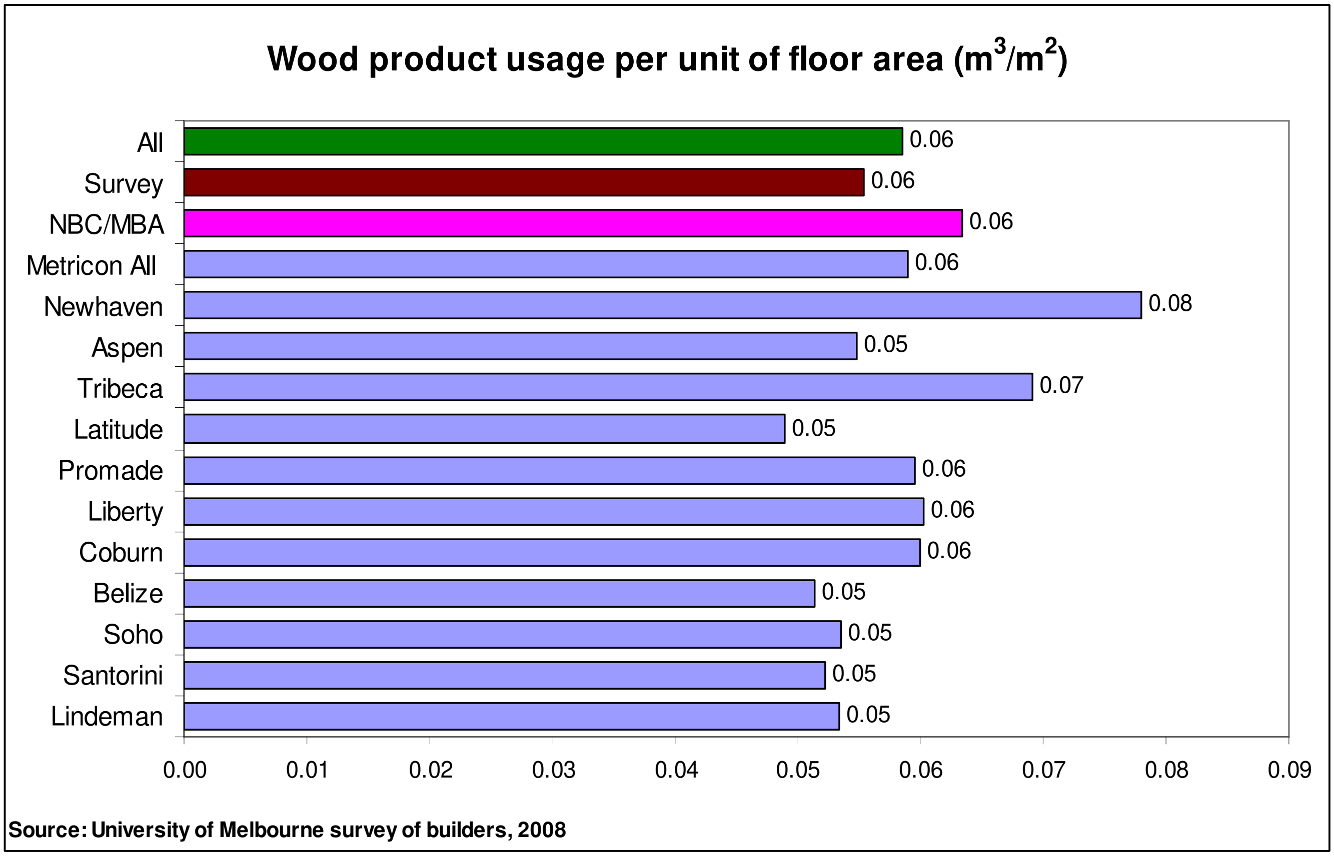

Figure 2.1 Average wood volume used per square metre of floor area. Data is from a range of sources. Newhaven to Lindeman are particular types of homes constructed by Metricon.

2.3 Wood products usage in various building applications

The survey asked large and other builders to estimate the proportion of wood products used in various building applications. For the few builders who built dwellings with sub-floors, less than 3% of wood products were used for that application. Estimates were also made on the basis of data obtained from South Australia Housing Trust and NBC/MBA. On average, 49% of wood products were used in residential wall systems, 43% in roof systems, and 8% in joinery. For the 11 house designs by Metricon Homes Pty Ltd.; 49% of wood products were used in residential ground floor wall systems, 7% in first floor wall systems, 39% in roof systems and 6% in joinery (Figure 2.2).

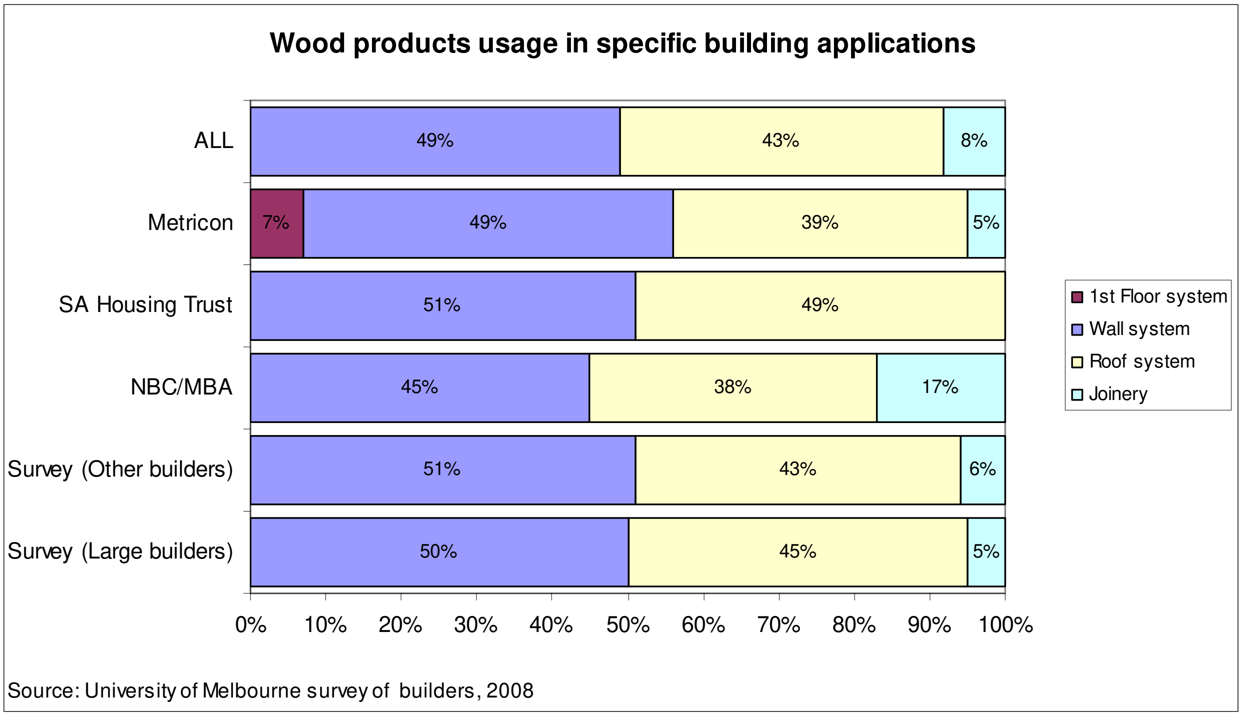

Figure 2.2 Wood product usage in building applications

2.4 Wood species usage by builders and frame & truss manufacturers

More timber from softwood than hardwood species was used in dwelling construction at the rate of 4:1 (Figure 2.3). There were variations between States, with Tasmania using about 30% more hardwood timber than softwoods. For other States, South Australia is the State with highest usage of softwood timber (98% of total market for wood).

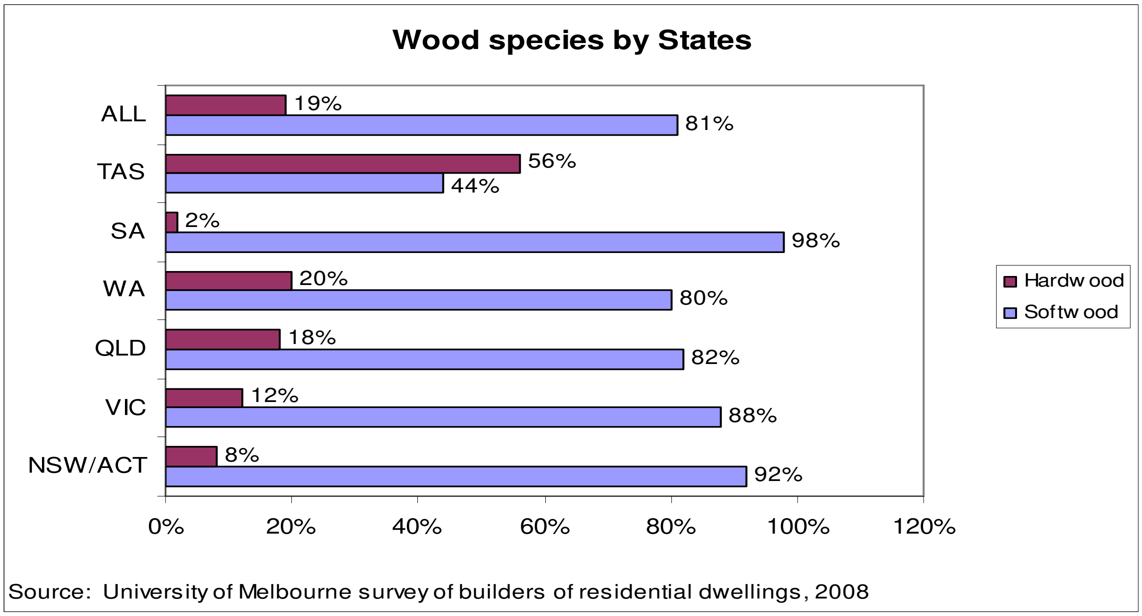

Figure 2.3 Proportion of wood species used in dwelling construction

There was no significant difference in timber species usage between large builders and other builders (ratio of 4:1) (Figure2.4).

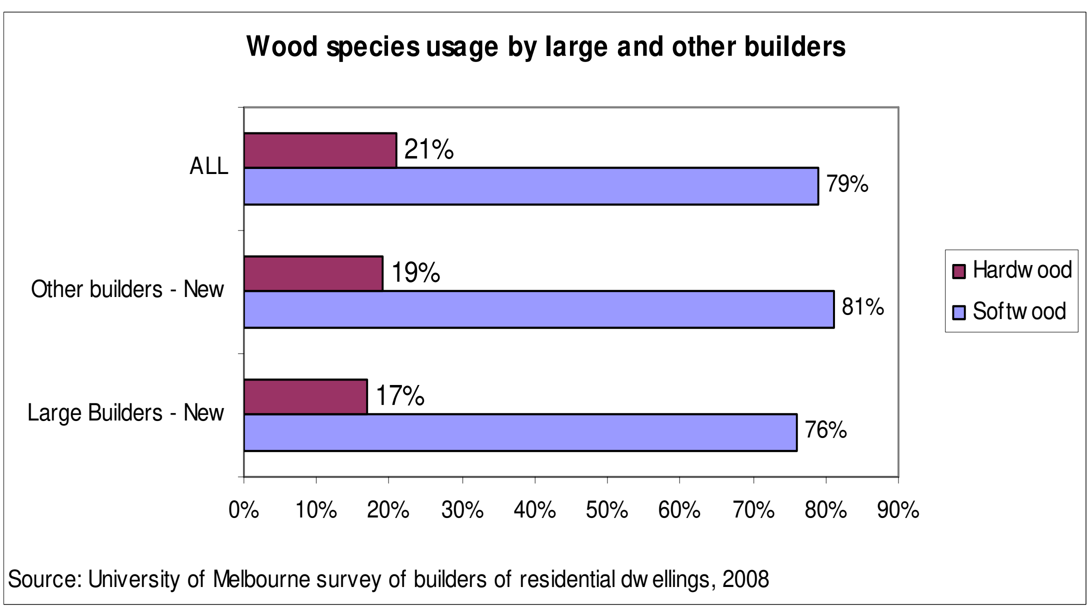

Figure 2.4 Proportion of wood species used by large and small builders

2.5 Preservative treated wood products in structural applications

A trend has emerged where preservative treated wood products are used in framing timber for structural applications. To understand the extent to which treated wood products were used, architects were asked whether they specified preservative treated wood products for dwelling construction. Over 60% of architects in the surveyed States specified treated timber, although only 33% did so in Tasmania (Figure 2.5).

Figure 2.5 Proportion of architects specifying treated wood products for construction

Likewise, builders and frame and truss manufacturers were asked if they used preservative treated wood products in structural applications. The lowest uptake of treated wood products was in Tasmania where only 18% of builders and frame and truss manufacturers used treated timber (Figure 2.6). The highest usage was in Western Australia (97%), New South Wales (94%) and Queensland (94%).

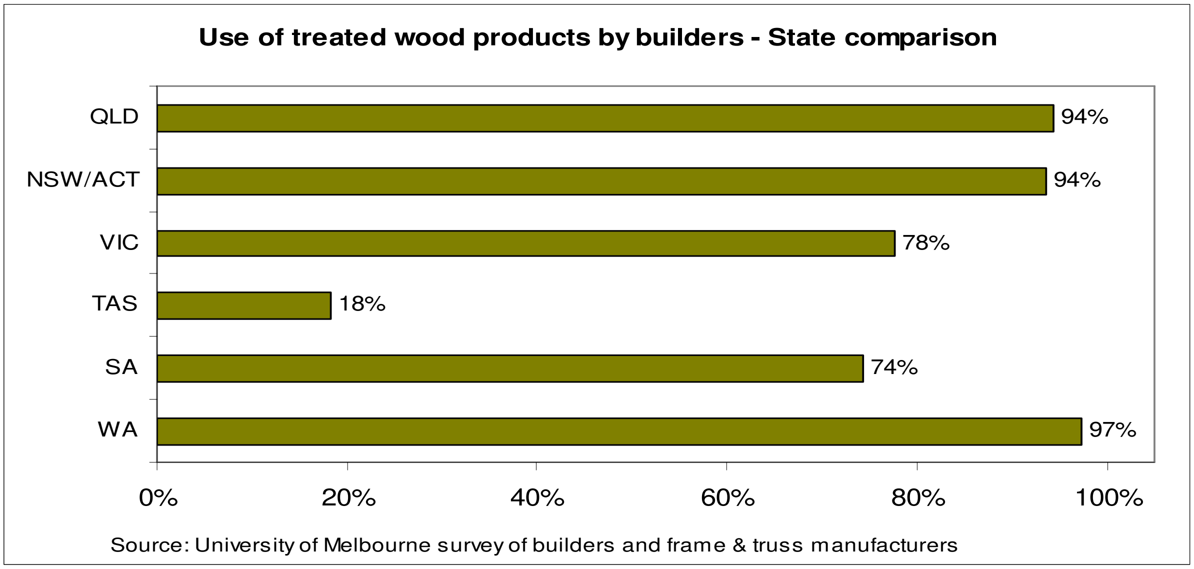

Figure 2.6 Proportion of builders using treated wood products for construction by State

There were no significant differences in the uptake of preservative treated wood products between builder categories (Figure 2.7).

Figure 2.7 Treated wood product usage by builder category

Treated wood products could impact the service life and/or the half-life of wood products in dwellings, which can subsequently increase the storage time of carbon in housing.

3.2 Types of demolished dwellings

Demolition contractors were asked to indicate the proportions of the common dwelling types that they demolished. Over 70% of demolished dwellings were detached houses (Figure 3.1).

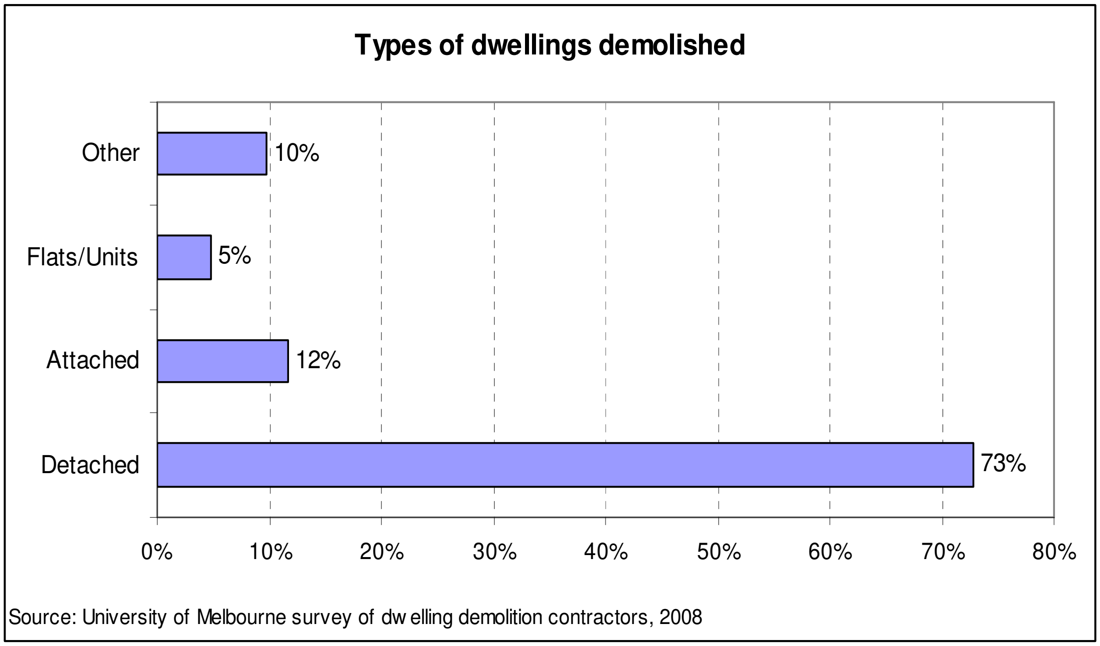

Figure 3.1 Proportion of dwelling types demolished

3.2 Construction style of demolished dwellings

Demolition contractors indicated that over 70% of demolished dwellings were built post World War II, aged between less than 25 years to about 58 years. The other 30% of demolished dwellings were built Pre-World War II and their age ranged between 80 years and over (Figure 3.2).

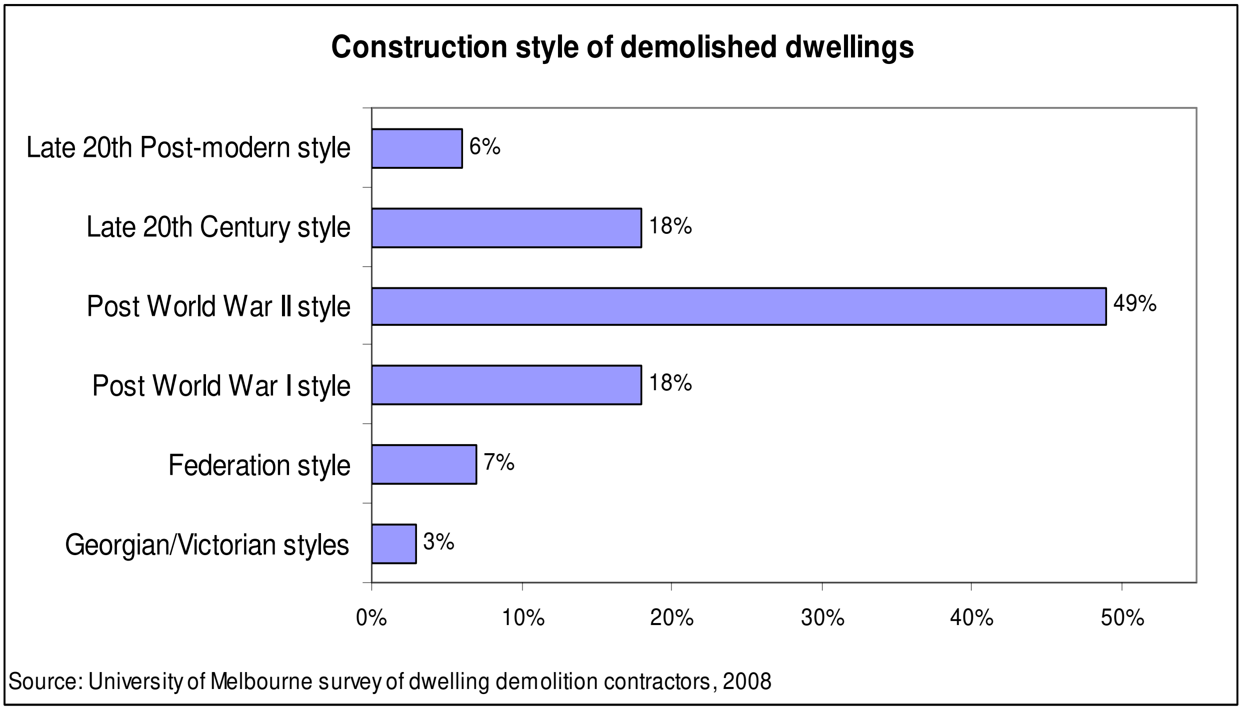

Figure 3.2 Construction style of demolished dwellings

3.3 Estimates of dwelling longevity by Architects

Architects were asked to estimate the lifespan of various residential dwelling types. The State estimates are presented in Figure 3.3.

The national summary of longevity estimates are given in Figure 3.4:

- detached house ($\bar{x}$ = 66 years, *SD* = 19.4), 62 years for
- attached dwellings ($\bar{x}$ = 62 years, *SD* = 20.8) and
- flats/units ($\bar{x}$ = 55, *SD* = .53)

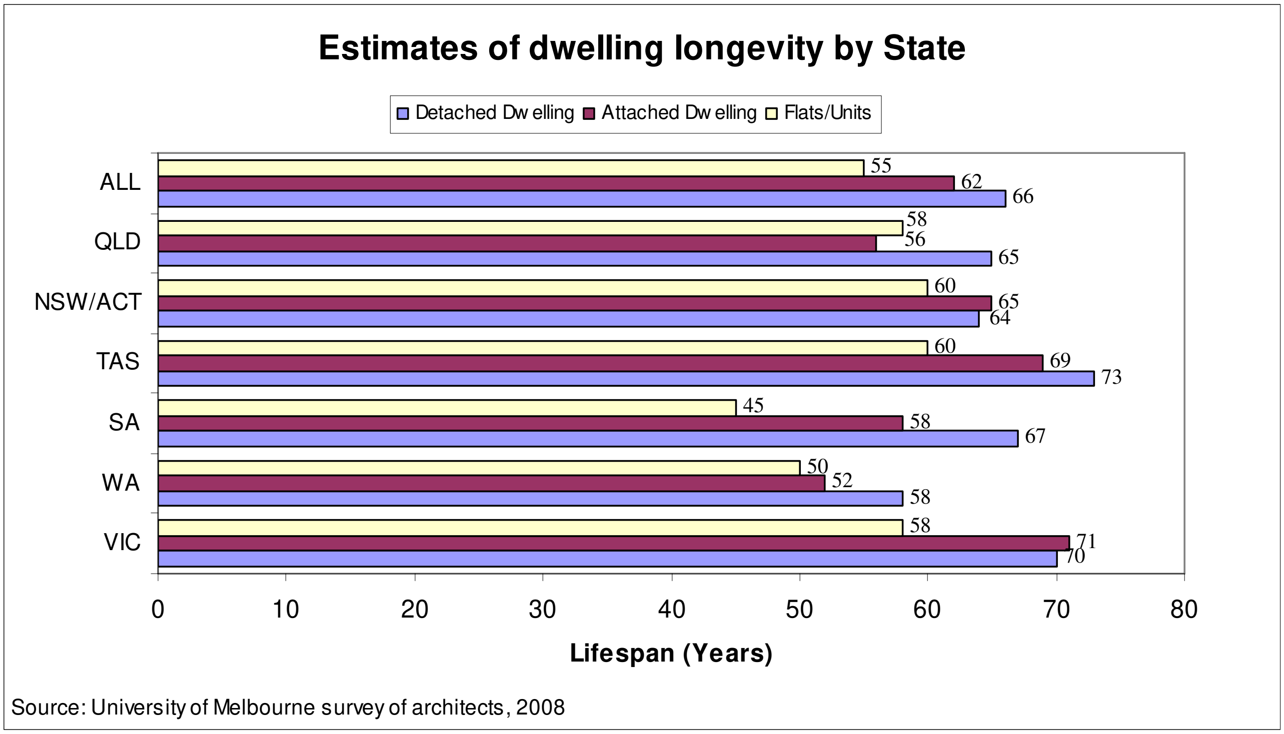

Figure 3.3 Estimated longevity of dwellings by State

On average, the Australian dwelling lifespan was estimated to be 61 years (*SD* = 20.5).These estimates were based on the architects' professional experience of Australian timber-framed residential dwellings in their respective practices.

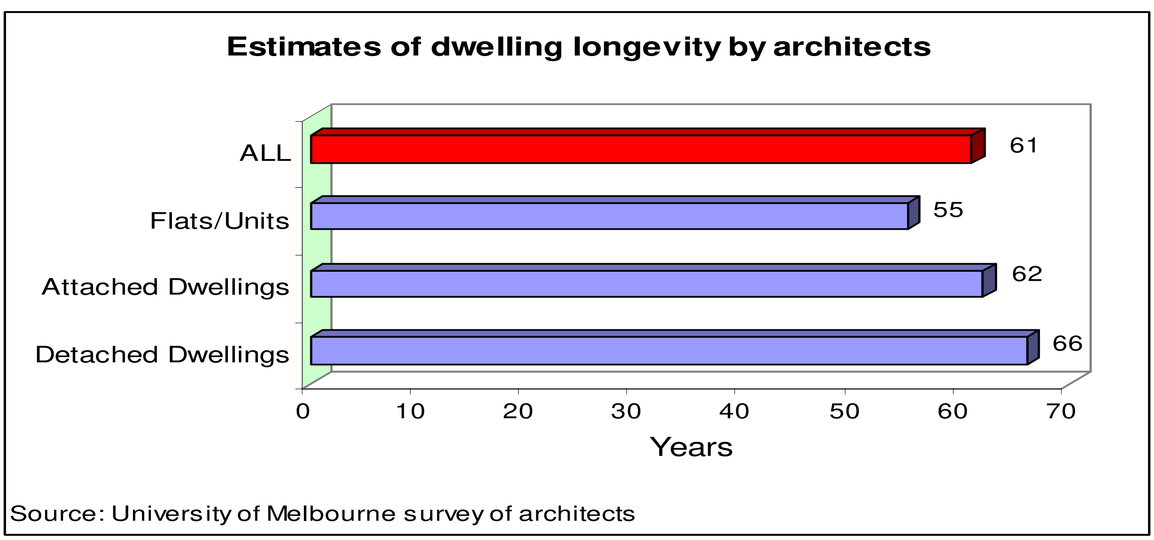

Figure 3.4 Estimated longevity of dwellings

3.4 Patterns of turnover of dwellings as estimated by Architects

The longevity of buildings has been used to indicate the life span of structural materials used in their construction, with timber-framed buildings believed to have the shortest lives (Gaston *et al*., 2001). However, when asked to indicate reasons why dwellings were demolished, the architects across the States indicated that dwellings were demolished:

- to make way for site redevelopment
- because they ceased to suit owners' needs
- because they became unserviceable
- for other reasons

The proportions of dwellings demolished for each reason are given below.

3.4.1 Site redevelopment

On average, a large proportion of dwellings (58%) were demolished to make way for site redevelopment due to, for instance, changing land values, which was completely unconnected to the physical state or life span of various structural components of the dwelling (Figure 3.5).

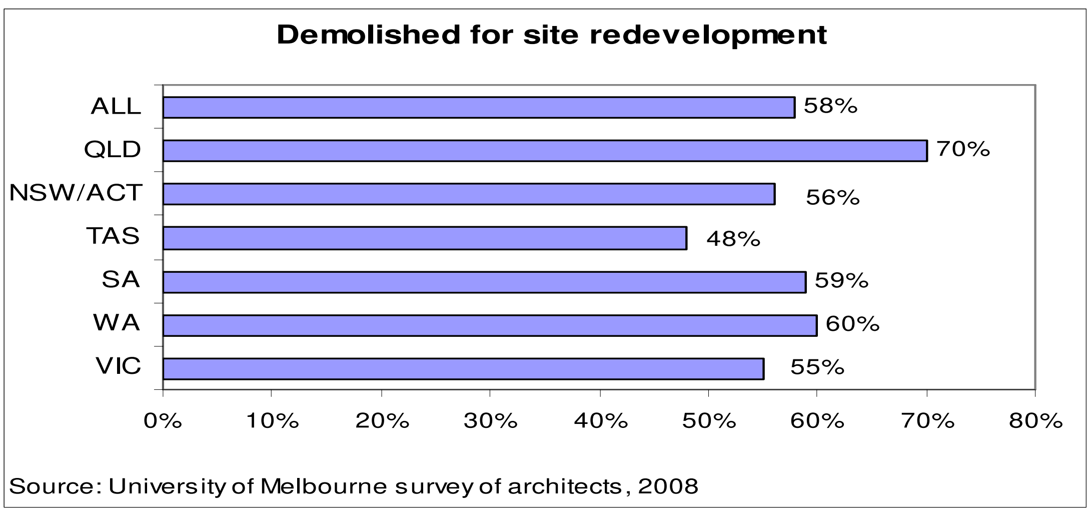

Figure 3.5 Proportion of dwellings demolished for site redevelopment

3.4.2 Dwelling ceases to suit owners' needs

Another reason given by architects for demolition was that the dwelling ceased to suit owners' needs (28%), due to changing notions of quality of life or indeed families simply outgrew a dwelling (Figure 3.6). This reason had nothing to do with the failure or otherwise of the building materials used for dwelling construction. Thus, the age at which the dwelling was demolished did not reflect the potential service life/life span of the building materials such as wood products.

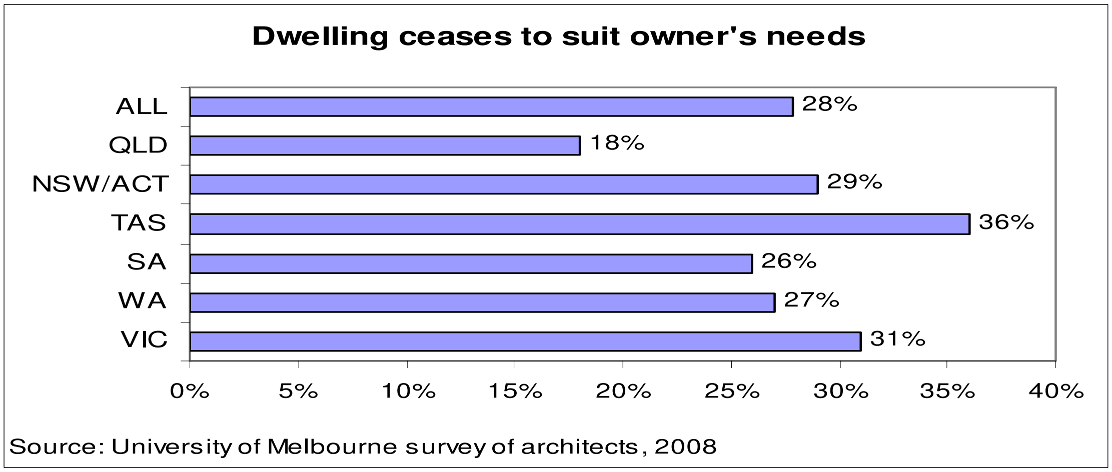

Figure 3.6 Proportion of dwellings demolished for not suiting owners' needs

3.4.3 Dwelling becomes unserviceable

A small proportion of dwellings (8%) were also demolished because they became unserviceable, either due to structural material failure resulting from decay or lack of maintenance of various structural components (Figure 3.7). The dwellings which were demolished for becoming unserviceable should be of interest for further investigation. While the structural system could presumably still be functional in those dwellings, failures in the other components could lead to a shortened service life for the entire dwelling. This study did not probe for details about those failures.

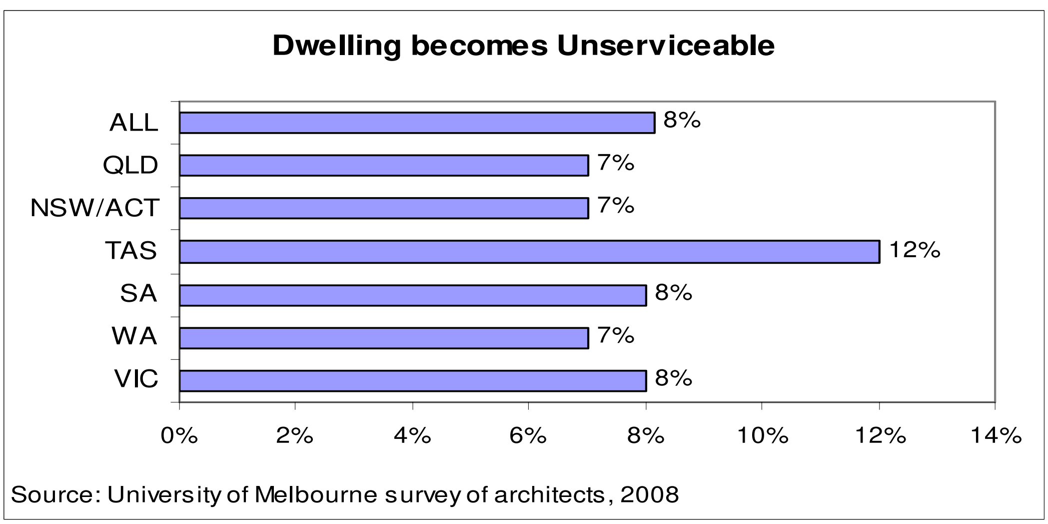

Figure 3.7 Proportion of dwellings demolished for becoming unserviceable

3.4.4 Other reasons

A small proportion of dwellings (6%) were demolished for other reasons, such as road construction, fire damage, flood or storm damage, etc (Figure 3.8). Again this was not connected to the failure of the structural components or materials (except if material is damaged by fire) used in constructing dwellings.

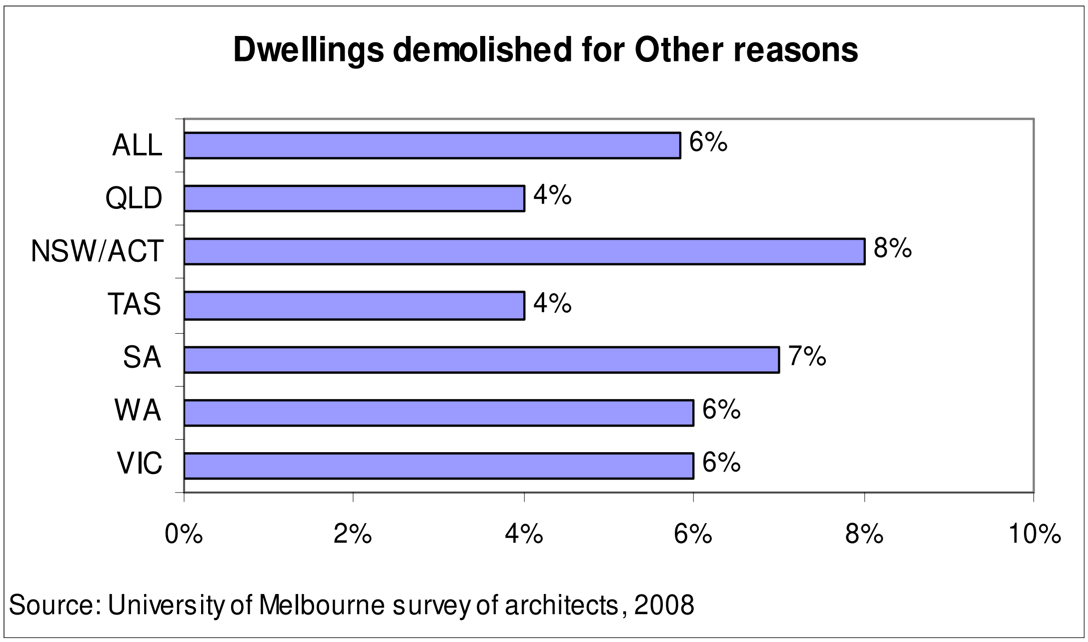

Figure 3.8 Proportion of dwellings demolished for becoming unserviceable

Part 4 Generation and fate of wood products waste

4.1 Wood products waste from dwelling construction

4.1.1 Actual timber used in dwelling construction

In order to clarify what builders reported as 'timber use per dwelling', the building practitioners were asked to choose which of the two statements below described their reported timber use per dwelling:

(a) Timber volume delivered to the building site as specified by the builder/quantity surveyor/architect;
(b) Timber volume delivered to the building site as specified less wastage and losses during construction.

The results showed that about 76% of builders surveyed indicated that what they reported as timber used in dwelling construction was the volume delivered to the building site as specified, not the net volume actually used in construction (Figure 4.1).

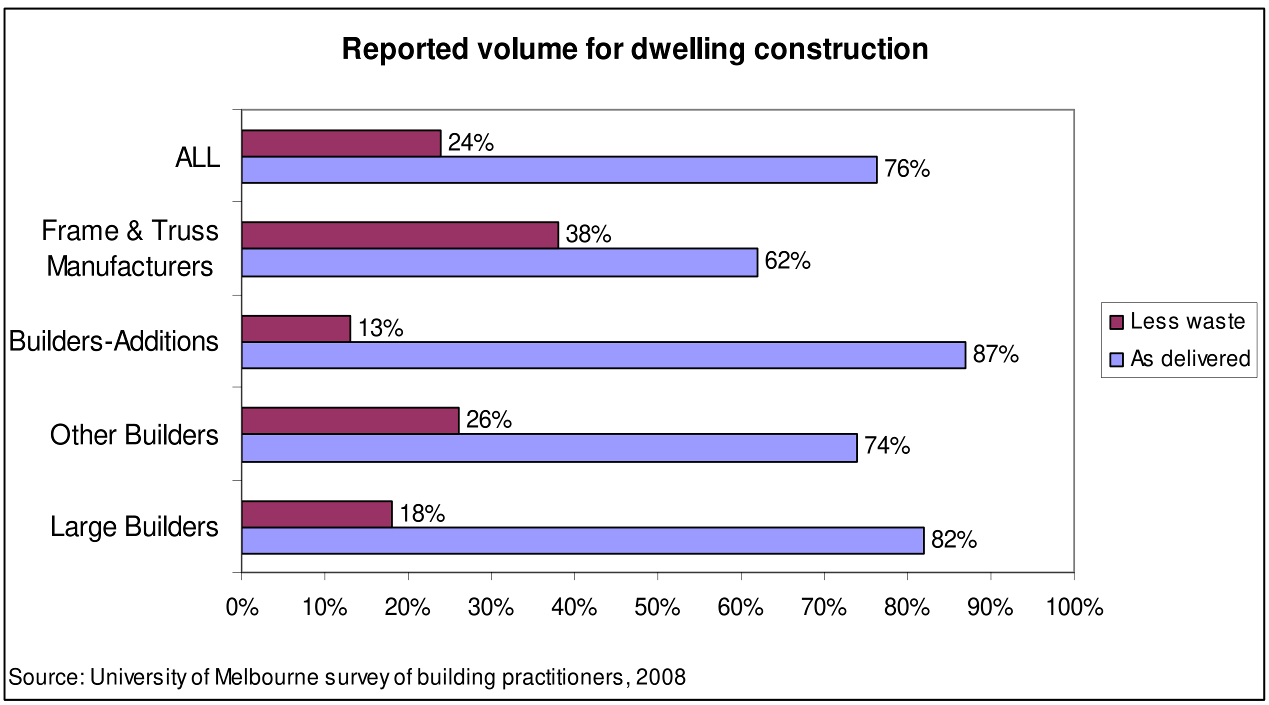

Figure 4.1 Reported volume as reported by builder category

This clarification is important in improving the accuracy of the volume of wood products and in reducing overestimation of future carbon stocks in residential housing.

4.1.2 *Allowance for wood waste during construction*

To determine the average proportion of wood waste at building construction, building practitioners were asked to estimate the amount of timber (as a percentage) added to ordered volume as allowance for losses, breakage and theft during construction. The results showed that practitioners allowed an average of 8% for construction wood waste when they ordered wood products, although other builders allowed slightly more (11%) for waste (Figure 4.2).

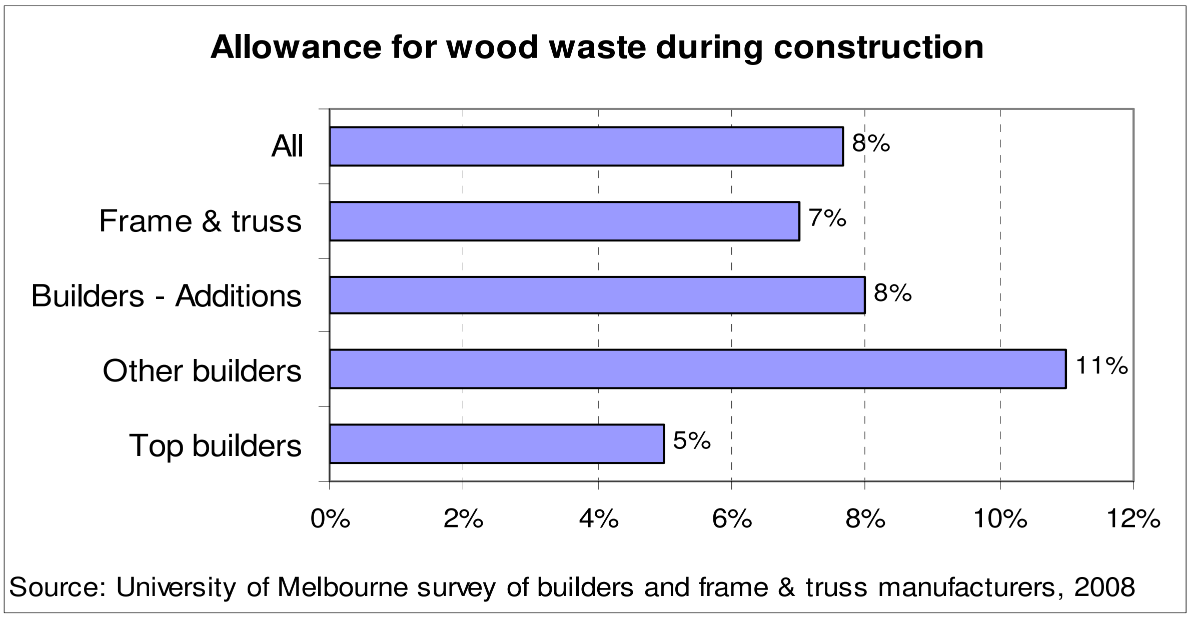

Figure 4.2 Proportion as allowance for wood waste during construction

The fate of construction wood waste is briefly discussed below and summarised in Figure 4.3.

4.1.3 *Proportion of construction wood products waste utilised/not utilised*

When asked about how much of the waste generated during construction was utilised in some way, building practitioners indicated that only 45% of construction wood waste was utilised either on the same or on another building site.

4.1.4 *Uses of recovered construction wood products waste*

About 53% of wood waste from construction sites was collected in waste skips and taken to waste transfer stations. From there, building practitioners did not know how it was used. However, further investigations at one transfer station in Melbourne revealed that most of this waste was mulched, and anecdotally, this was the fate of wood waste collected in skips to other transfer stations. Of the remainder, 19% was reused as noggings, packers and blocks, 15% was indirectly recycled (e.g. mulch) whilst 13% (mostly firewood) was used in energy recovery.

4.1.2 Disposal methods for construction wood products waste not recovered

Two methods were generally used to dispose of unrecovered wood waste; over 80% of wood waste ended up in landfills while the rest was disposed by other methods, mostly by burning as firewood.

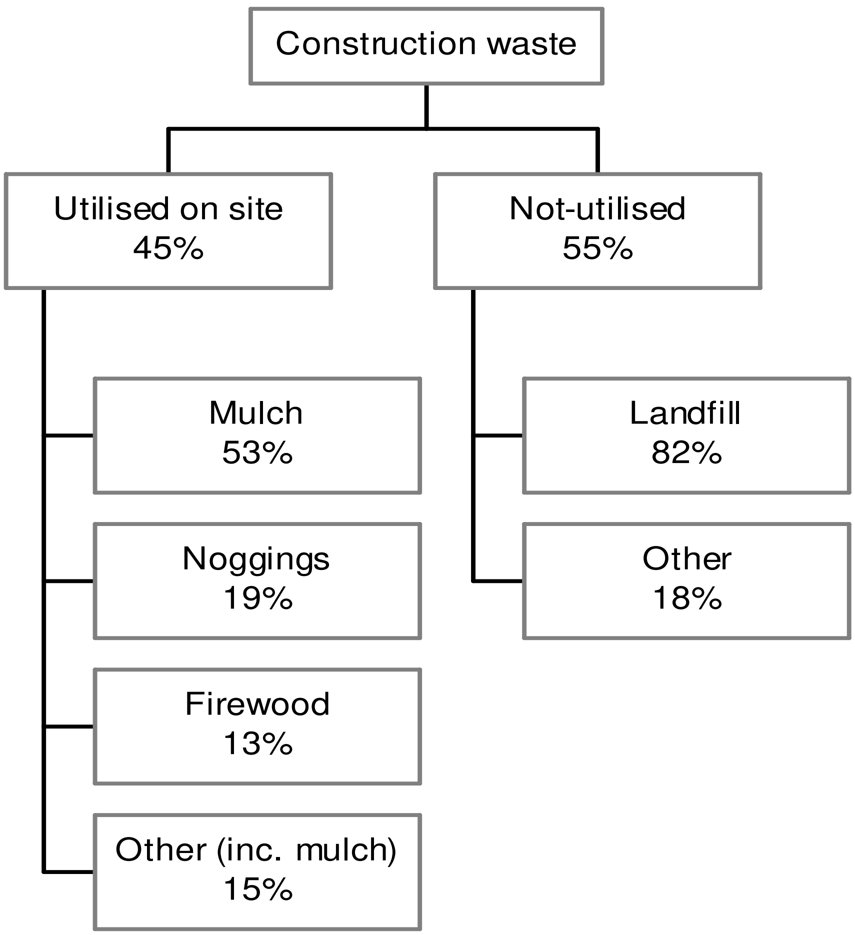

Figure 4.3 Generation and fate of construction wood waste

4.2 Wood products waste from dwelling demolitions

The recovery and fate of wood products from demolished dwellings by dwelling demolishers are discussed briefly below and results presented in a flow chart in Figure 4.4

4.2.1 Wood products salvaged from demolished dwellings

About 56% of wood products were salvaged from detached houses, 26% from attached dwellings and less than 18% from flats/units. Types of wood materials salvaged included roof beams, ceiling battens, sub-floor timbers, interior wall framing timbers (if not contaminated with asbestos fibres), built-in robs, floor boards, skirting/architrave, window frames, external hard core doors and internal plywood doors.

4.2.2 Uses of salvaged wood products waste from demolished dwellings

Demolition contractors indicated that most (and sometimes all) of salvaged wood products from demolished dwellings were taken to salvage/recycling yards or waste transfer stations for further processing or sale to various end users.

4.2.3 Disposal methods for wood products waste not salvaged

A large proportion (approximately 60%) of wood products not salvaged from demolition sites was disposed of in landfills. The rest (about 40%) is used for other purposes, for example, as firewood.

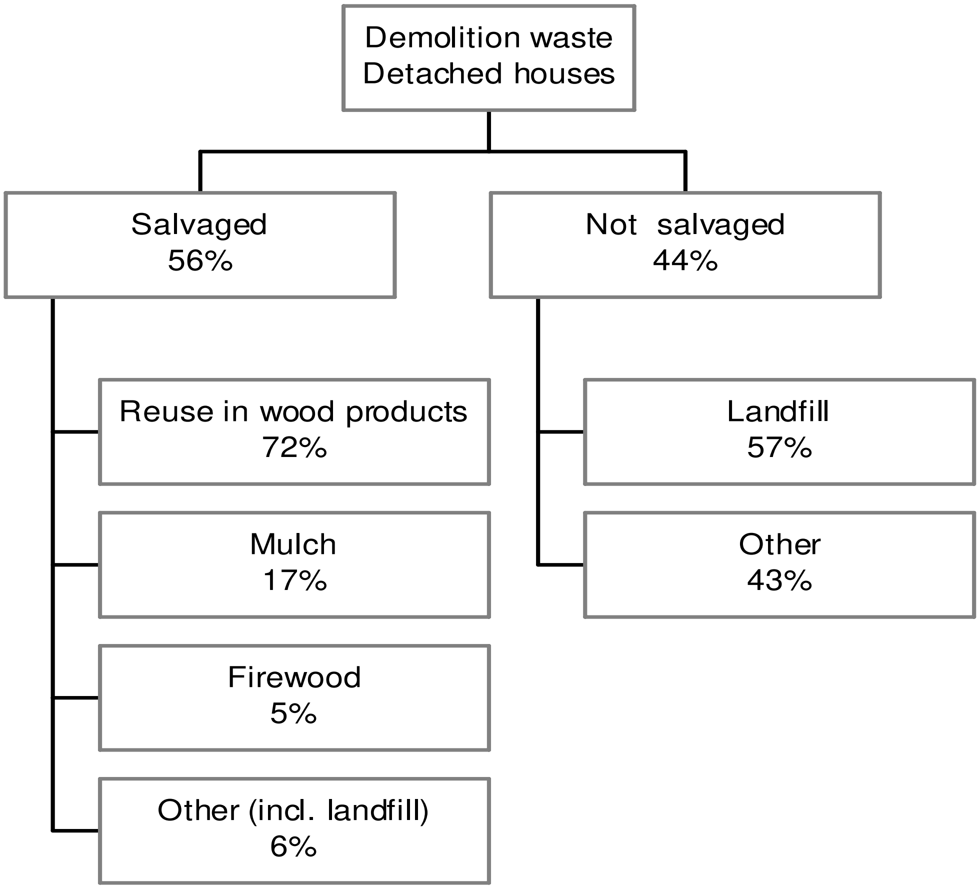

Figure 4.4 Recovery and fate of wood products from demolished dwellings

4.3 Wood products waste recycling

4.3.1 Sources of recycled wood products

Timber recyclers sourced most of their wood products from dwelling demolition sites (46%), commercial demolition (31%), and 12% each from dwelling construction and renovation sites (Figure 4.5).

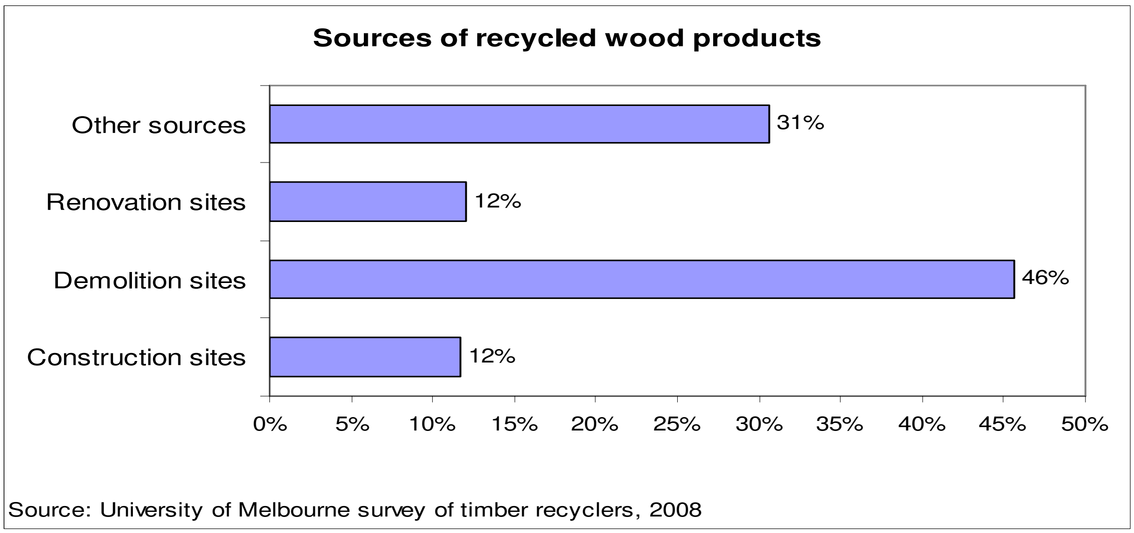

Figure 4.5 Where timber recyclers sourced wood products

4.3.2 Proportion of recycled wood products reused

Over 94% of wood products in the recycling yard were sold and reused in some way and only about 6% were disposed of (Figure 4.6).

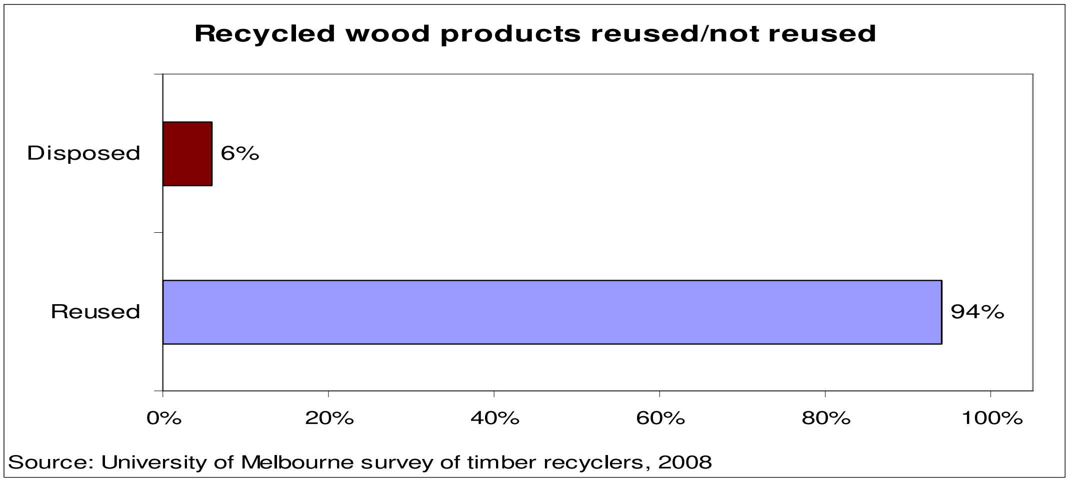

Figure 4.6 Proportion of recycled wood products reused/not reused

4.3.3 Uses of recycled wood products waste

About 77% of wood products were reused in new dwelling construction as flooring, internal wall paneling, ceiling, and in façades. Other reuses included outdoor furniture and children's playgrounds. About 18 % was mulched for animal bedding, etc and about 5% for energy recovery as domestic firewood (Figure 4.7).

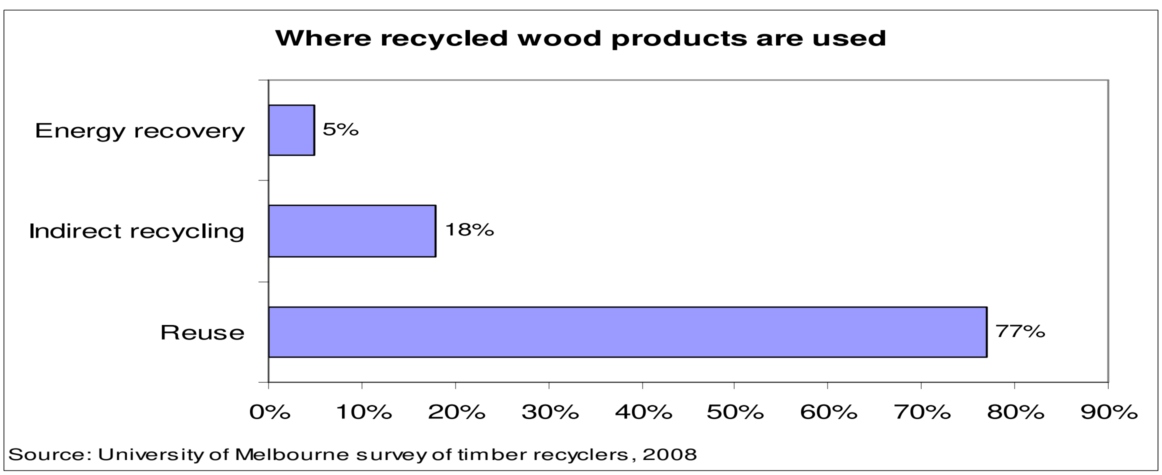

Figure 4.7 End uses of recycled wood products

4.3.4 Disposal methods for unused recycled wood products

Wood products that were not used or sold (66%) were largely used for energy recovery, mostly collected by locals for firewood. On average, about 34 % was disposed of in landfill (Figure 4.8).

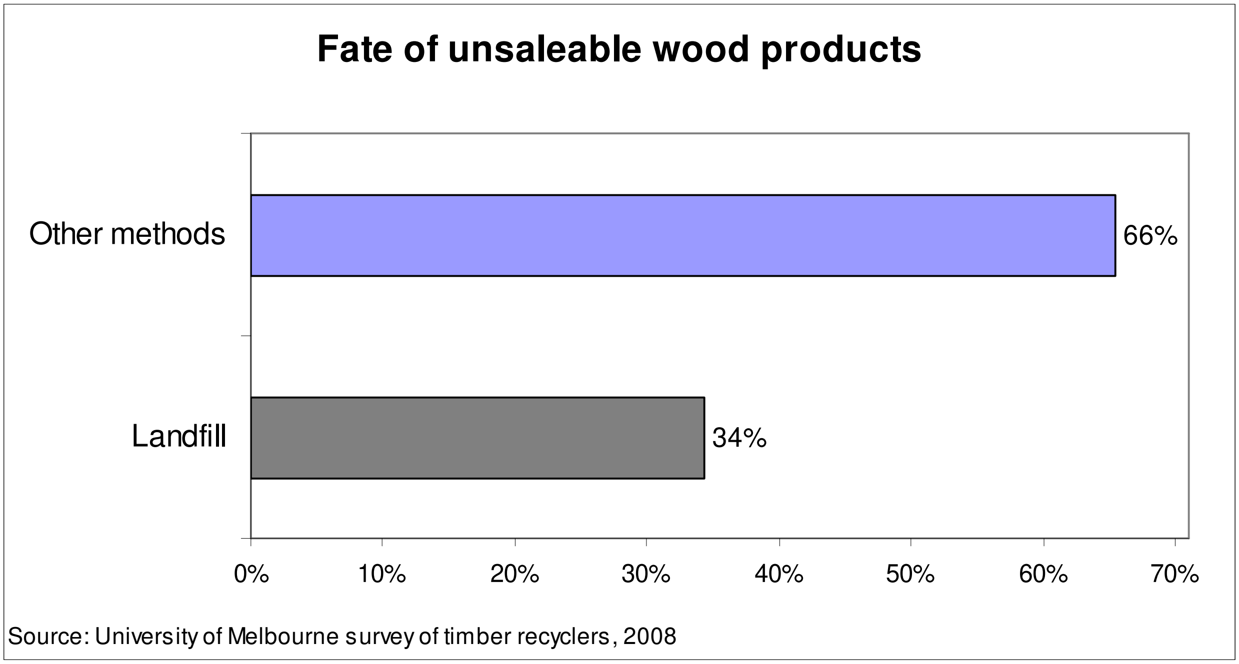

Figure 4.8 Fate of unsold recycled wood products

Part 5 Policy options to increase wood products usage

Government policy and/or actions by the forest industry, building practitioners, etc can result in increased wood products usage in dwelling construction thereby increasing the carbon stocks in housing. Thus building practitioners were asked to rank the following policy options in terms of their potential to increase the quantity of wood products used in residential dwelling construction:

Option 1: Better training and education for builders, building surveyors, building designers, etc on the carbon storage benefits of wood products.

Option 2: Reduction in the relative price of wood products compared to competing products as a result of emissions trading permits or a carbon tax.

Option 3: Changes to government building regulations or building codes, for example, to allow timber products to be used in a wider range of building applications than is currently allowed.

5.1 Ranking of individual policy options

The three charts below show the ranking of individual policy option, that is, the proportion of building practitioners who indicated the potential of the policy to increase wood products usage in dwellings (Figure 5.1, 5.2 & 5.3).

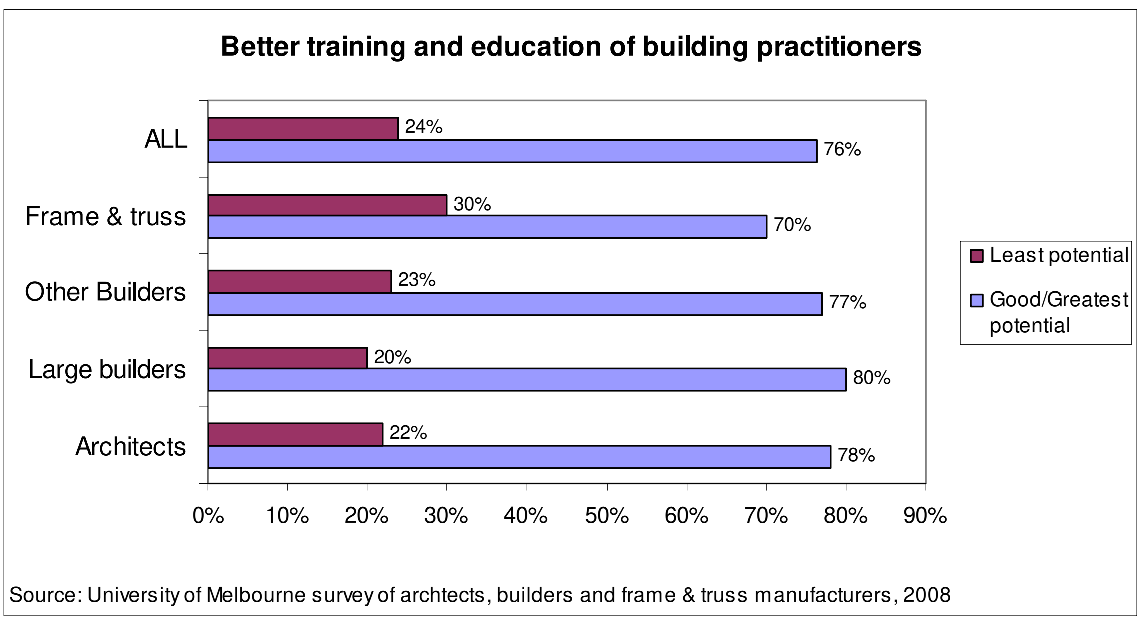

Figure 5.1 Potential of this policy option to increase wood usage

Figure 5.2 Potential of this policy option to increase wood usage

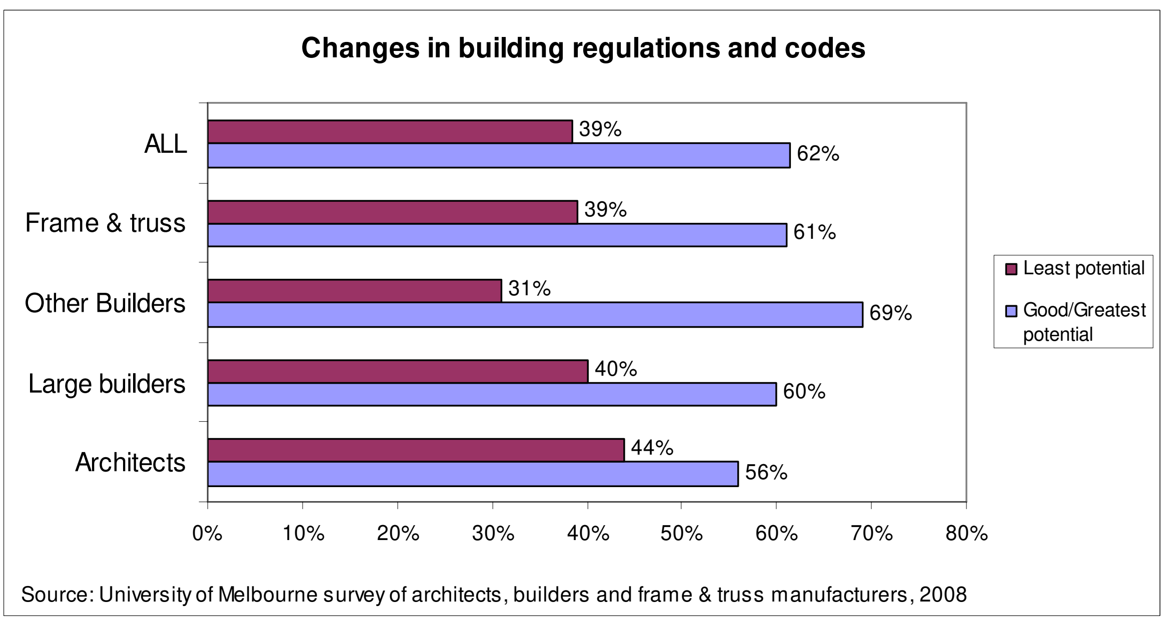

Figure 5.3 Potential of this policy option to increase wood usage

5.2 Overall ranking of policy options

The highest proportion (about 84%) of building professionals ranked reduction in the relative price of wood products to have ‘good’ to ‘greatest potential’ to increase wood products usage in dwelling construction.

Better education and training was ranked second. About (76%) thought better education and training for builders, building surveyors, building designers, etc on the carbon storage benefits of wood products would increase wood usage in dwelling construction.

Amendments or changes to building regulations and codes can technically play a major role as incentives for the use of wood to a greater extent in certain building applications. However, this policy option received a relatively low ranking, as only 62% of the building professionals thought it had ‘good’ to ‘greatest potential’ to increase wood usage in house construction.

The ranking of options is shown in Figure 5.4.

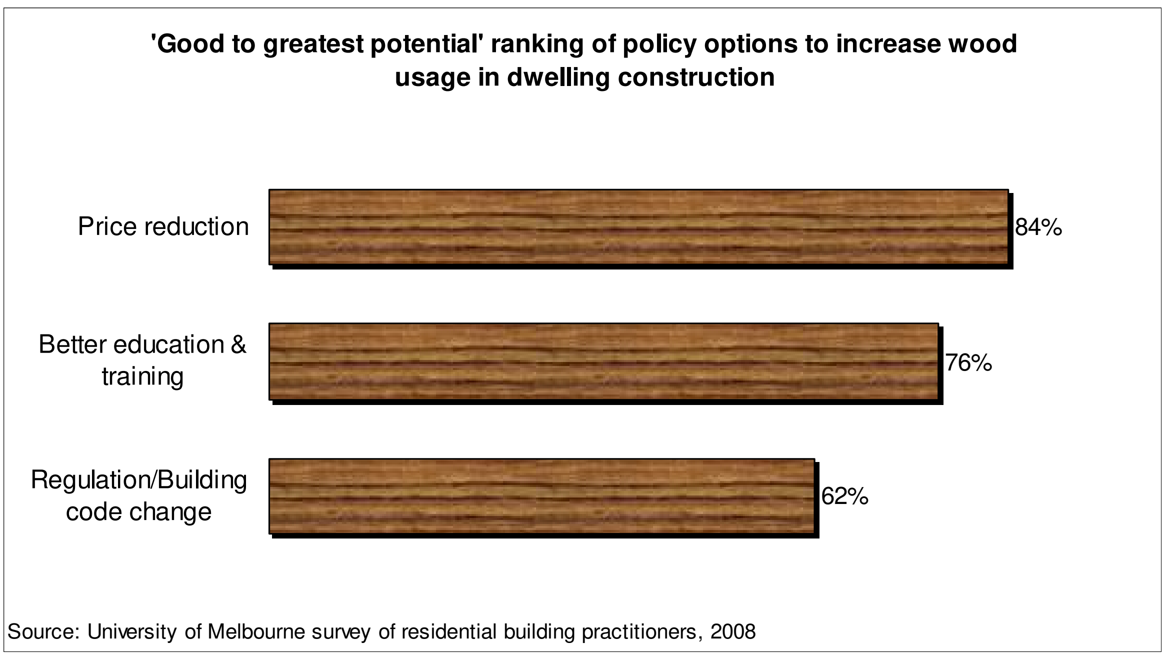

Figure 5.4 Overall ranking of the potential of policy options to increase wood usage

Part 6 Additional actions to increase wood products usage in dwelling construction: Suggestions from building practitioners

Building practitioners were asked for their opinion on additional actions that the Governments (both State and Federal), the forest industry and the building industry could take to increase wood products usage in constructing various types of residential dwellings. The suggestions are given in their entirety by type and location of respondent in Appendix 5.

The suggestions were analysed and coded into the following nine (9) underlying themes:

(a) Publicity, promotion and marketing of timber product environmental attributes
(b) Timber product development
(c) Education and training
(d) Provide better information to building practitioners
(e) Reduce relative cost of timber products
(f) Work to change regulation and building codes
(g) Timber design
(h) Invest in hardwood plantations
(i) Availability of timber products

6.1 Publicity, promotion and marketing of environmental attributes of timber

Building practitioners suggested a unified national advertising/education program with a focus on the environmental benefits of using timber for dwelling construction compared to other non-timber materials. Suggestions made could be summarised in the three points below

- More publicity about young trees/plantations absorbing more CO_2 and producing more O_2 than old growth forests
- Better education of the public/consumers about carbon storing benefits of using timber to create more user demand, i.e. promote the benefits of carbon storage in timber against carbon production of alternative products, e.g. steel, concrete, etc.
- Reinforce damage to the environment resulting from use of steel in building and construction through media, government regulation and education in building institutions. This will counter the misleading 'propaganda' regarding steel framing which has many disadvantages conveniently ignored.

6.2 Timber product development

Suggestions under this theme centered on understanding the current and emerging trends in timber usage for dwelling construction. In particular, that the forest products industry should

- Develop capacity to identify material usage trends in dwelling construction
- Focus on making timber products more attractive to satisfy fashion and trend. For example, work to fashionise timber products to match visual trends as opposed to focusing only on structural appeal
- Capitalise on trends regarding increased usage of timber for its aesthetic features in some building applications. For example, promote usage of more recycled timber to take advantage of the resurgence in its use as a feature in flooring, internal wall paneling, facades, ceiling, etc.
- Improve termite and fire resistance of timber products to meet fire resistance requirements that restrict the use of timber in attached dwellings to some extent. This includes, for example, developing timber windows that can deal with bushfire requirements is a huge issue and problem – bushfire areas will not allow use current timber windows forcing the use of aluminium.
- Develop, design and test timber materials for exposed/external applications to replace fibre-cement products and to resist any timber deterioration: more durable and better timber finishes - an improvement on current paint/stain to provide timber products with low maintenance and ease of replacement.
- Further development for engineered timber products, long span members, and more use in external applications

6.3 Education and training

This theme included

- Better education of the general public and building practitioners on timber, including sources, forest stewardship certification, the costs and environmental benefits of using timber in building, would improve the image and acceptability of timber products.
- Better, comprehensive building designer and structural engineer education about timber in house construction, including maintenance of timber structures.
- More training of carpenters by way of more attractive apprenticeships. This will be helpful in such states as WA where builders don't encourage timber frame because they do not have the trades or expertise to be as profitable as they are in double brick construction.

6.4 Better information to building practitioners

Improved quality and delivery of information to building professionals would be one way to increase timber usage in house construction. Suggestions included

- Better information to designers/architects/builders on how to work with timber to achieve long service life, including details to prevent rot, water damage, etc.

- Provide greater knowledge to professionals about availability and accessibility to timber product types. This is difficult and can be expensive in some states, e.g., Tasmania.
- Include information on specific uses and performance of timber in relevant scenarios with general specification, and relating it to structural, Building Code of Australia (BCA) and Australian Standard requirements. This should include better documentation of span tables, better party wall detail, and more consistent design methods. It was observed that this is in-exact at present.
- Provide better understanding of protection of timber against fire and fungal/borer infestation. This should include product manuals on how to achieve required fire rating limits, too.
- More information on environmental friendliness of timber, including comparisons or technical data relating to ecological positives of using timber to negatives of steel/masonry/fibre cement/aluminium. This may help overcome the prejudice of timber in some applications, e.g., cladding where brick seems to be obligatory at present
- The need for an accepted forestry management/stewardship certification so that only complying timber can be specified. 'Greener' stewardship certification requirement is difficult to achieve and all other timber is not accepted currently. This should include information on availability of environmentally certified sources of Australian timber

6.5 Reduction in relative cost of timber products

While building practitioners appreciated the importance of education of home owners on timber in housing, the relative cost of using timber should also be comparable to using other non-timber products. This may be achieved by

- Making it easier to source sustainable timber at prices that are more equitable with other non-wood products, e.g., hardwood timber decking, softwood timber windows versus aluminium windows.
- More off-site fabrication of timber components such as wall frames as is done for steel frames. This would make timber to have price advantage by (a) reducing material cost, and (b) reducing on-site labour costs.

6.6 Work to change regulation/building codes

Building practitioners suggested

- That the energy rating issues need to be reviewed as they have handicapped timber usage to a point that other non-timber products are chosen for such building applications as sub-floors. They suggested that the governments should take into account embodied energy in the energy (5 or 6 star) calculations. Alternatively audits of environmental performance of houses requiring 5 star (and above) energy performance should recognize environmental properties of timber or provide bonuses to offset energy rating penalties for timber.
- Mandating greater usage of locally produced timber products in public housing to start with. Government community housing could increase timber use in housing dramatically almost immediately

- A change in fire regulations - for Type 2 construction (Flats/units). Pushing more for multistory timber construction projects.
- Using more 'sense' (and use of building science) in relaxing NSW Rural Fire Service grip on construction materials.

6.7 Timber design

Under this theme, suggestions included

- Developing simple construction systems and span tables, particularly bracing, which are easy to comply with - AS 1684 too complicated and gets worse each edition.
- Promulgate successful timber framed projects and greater publicity of successful timber projects in mainstream media. This may include providing timber design examples regarding fire rating, and ease of construction. It may also include introduction of tested timber construction systems to conform to noise/fire separation requirements.
- Informing architects & designers & developers about design strategy, material selection & cost competitiveness - innovative ways to be shown as an example.
- Developing simple but thermal efficient floor systems
- Designing more cost effective cladding systems as current alternatives are considered more superior, stable, resistant to rot and heat movement and easy to install
- Ensuring party walls are designed using timber as the primary material - not concrete or steel solutions, including using timber cladding between party walls and simple fire/acoustic separation details.
- Designing timber structures for more end of life salvage
- Good timber design and less reliance on energy efficiency testing software

6.8 Investing in hardwood plantations

Building practitioners suggested more investment and good support for local hardwood plantations and forests that have a slower financial return but better for availability of attractive Class 1 timber like Meranti and Jarrah - so that usage of such timbers "does not make us feel guilty as specifiers".

6.9 Availability

Availability of plantation timber was the biggest problem in Tasmania. Practitioners also suggested increasing the availability of prefabricated timber components such as wall frames in South Australia

Part 7 Carbon stock estimation and uncertainty analysis

7.1 Model Results

7.1.1 Carbon stock estimates in residential dwellings

Since about 1950, there has been an addition of between 2 and 3 Mt CO_2-e per year to the carbon stock in residential housing (Figure 7.1). This peaked at around 3.0 Mt CO_2-e per year in the early 1970 but has declined to average of 2.0 Mt CO_2-e per year in the last 20 years. This is a result of the changes in building construction systems described above.

Generally, carbon stocks in timber in-use in housing have steadily increased between 1945 and 2008 in all States (Appendix 6). However, the average amount of carbon added to housing annually varied between States, with higher amounts in the eastern States than in Western and South Australia.

Wood products in residential housing store substantial quantities of carbon even after correcting for carbon loss as housing goes out of service. The total carbon stocks in residential dwellings has generally increased despite a marked decline in average timber usage per dwelling over time because there has been a general increasing trend in the number of new dwellings completed

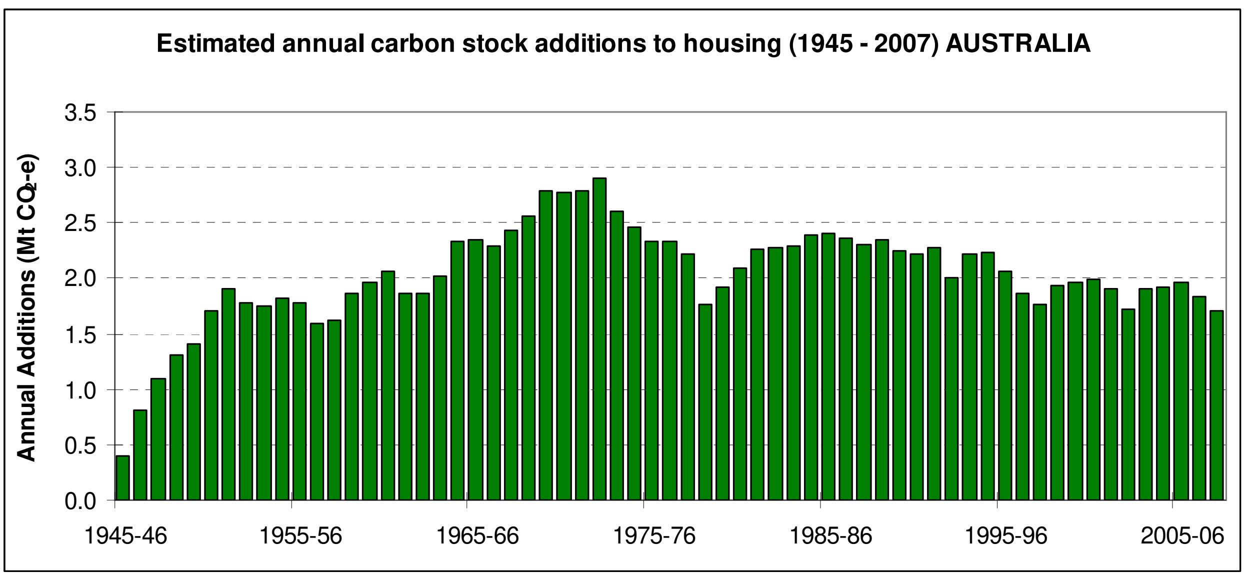

Figure 7.1 Estimated carbon stocks added to housing annually based on the number of completed dwellings

Figure 7.2 presents the estimated carbon stock (Mt CO_2-e) added to housing stock from one census year to the other. Estimated carbon stock additions have varied between Censuses with the higher additions occurring at 1921 (6), 1933 (14), 1947 (10), 1961 (7), 1966 (7), 1971 (9) and

1991 (6). Lower carbon stock additions of between 1 and 4 M tCO_2-e have occurred in the remaining census years.

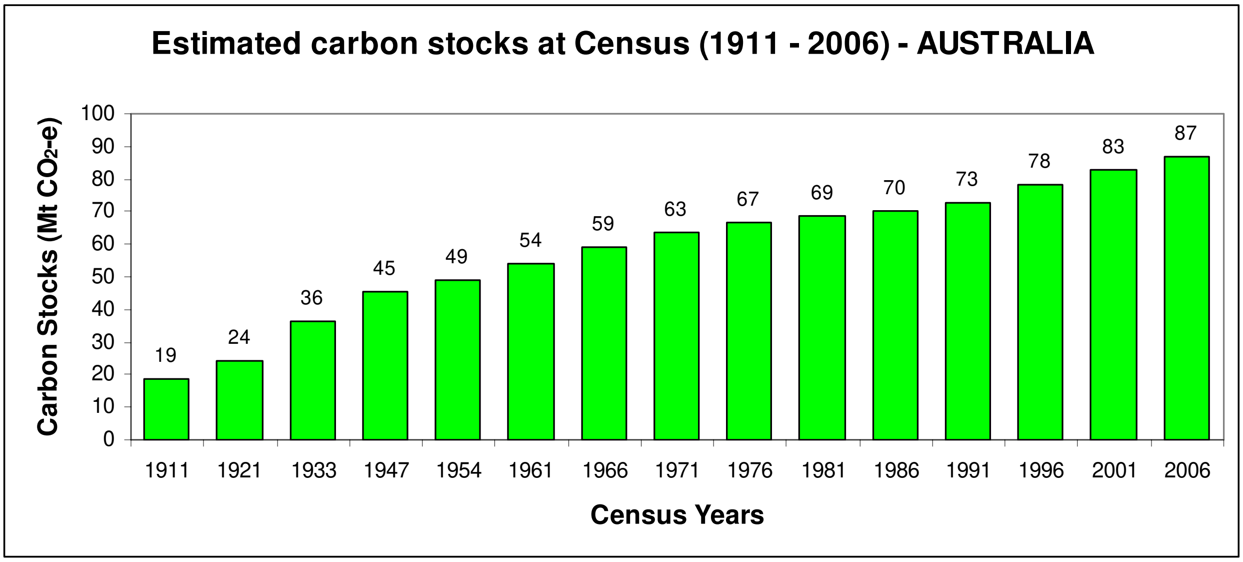

Figure 7.2 Estimated carbon stocks based on the number of dwellings at each census year

7.1.2 Comparison of carbon stock estimates

National carbon stock estimates (at Census) from the model in this study were compared to those for Pool 5 from the Department of Climate Change (DCC) and are presented in Figure 7.3. AGO/DCC used estimates of housing stocks starting 1945, corresponding with the the year that national timber production statistics began to be reported. "Pool 5" of the AGO/DCC model includes long-lived products other than those used in houses, such as furniture timber. Our model estimates of total carbon stock in housing are higher than the AGO/DCC's between 1947 and 1986, but become closer after this date (including projected stocks for 2011).

The estimates of annual additions are therefore generally lower in this study than in Richards et al. (2007), particularly between 1945 and 1990. The differences are generally due to different approaches used in the the two studies. The Jaako-Poyry-Australian Greenhouse Office studies (Jaako-Poyry 1999, 2001) on which Richards et al was based used domestic timber production and timber imports as the basis for analysis and applied assumptions relating to the proportions of timber going to different uses and their longevity. This study used estimates of housing stock, housing starts and timber volumes per unit dwelling area. The two studies also used different estimates of the longevity of the product in use. The higher estimates of net additions to the long-lived carbon pool are most probably due to the assumptions about the proportion of wood going into house construction and the time span that timber remains in this pool. The proportion of timber going into long-lived, non-housing products such as furniture might also account for some of this difference.

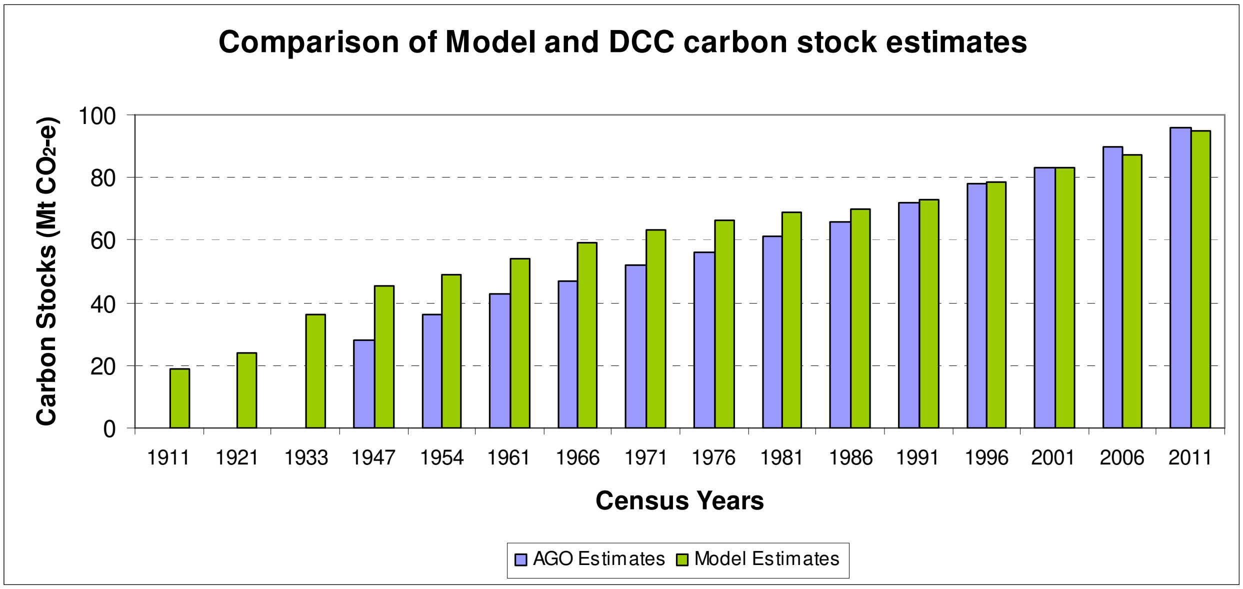

Figure 7.3 Results from the model used in this study compared with those from Richards et al. (2007) for the long-term wood in use pools using the Australian Greenhouse Office (now Department of Climate Change) model.

7.2 Carbon Stock Projection and Uncertainty Analysis

Monte Carlo analysis was undertaken using the @Risk add-in software by Palisade Corporation (Palisade, 2002) to the Excel spreadsheet model to

(a) simulate the projected carbon stocks to 2050 and 2051

(b) test the relative importance of the most "critical" inputs in the spreadsheet model in determining the future levels of carbon stocks in housing

Monte Carlo analysis is a traditional technique that uses random or pseudo-random numbers to sample from specified probability distributions (ranges) for nominated parameters. Probability distributions for values within ranges for each variable can be nominated, as can positive and negative correlations between variables so sampling can reflect these correlations (Richards *et al.* 2007). This sampling technique is entirely random, that is, any given sample may fall anywhere within the range of input distribution, and samples are more likely to be drawn in areas of the distribution which have higher probabilities of occurrence (Palisade, ibid.).

Triangular probability distribution was nominated for this analysis, where values within the ranges sampled formed a triangular distribution around a central most likely value (i.e. input or parameter values triangularly distributed with 'minimum value', 'most likely value' and 'maximum value' (Albright *et al*. 2003). The spreadsheet model variables and the distributions of their possible values used in the analysis are shown in Tables 7.1, 7.2 and 7.3. These Tables also show average percentage changes which were estimated from the respective time series data of variables in the spreadsheet model, and from the Australian Bureau of statistics (ABS, 2008; ABS, 2003; ABS; 2002; ABS, 2001) and Australia Housing and Urban Research Institute (AHURI, 2004). It should be noted that these estimates are based on past trends and do not reflect some of the major drivers in housing construction such as total population, age distributions or family size.

Table 7.1 Uncertainty and percentage change ranges of input variables used in the Monte Carlo Analysis (projection for annual carbon stock additions with decrease in wood usage)

Probability distribution for input variables (all triangular)			
	Minimum	Most likely	Maximum
Average volume per m^2	0.04	0.06	0.08
Average % change per annum	*-6.00%*	*-2.00%*	*5%*
Number of dwellings	117000	128000	150000
Average % change per annum	*-1%*	*2%*	*3%*
Weighted wood basic density	498	500	503
Average % change per annum	*-0.40%*	*0.00%*	*0.50%*
Average dwelling size	233	235	238
Average % change per annum	*-10.00%*	*2.00%*	*5.00%*

Table 7.2 Uncertainty and percentage change ranges of input variables used in the Monte Carlo Analysis (projection for annual carbon stock additions with increase in wood usage)

Probability distribution for input variables (all triangular)			
	Minimum	Most likely	Maximum
Average volume per m^2	0.04	0.06	0.1
Average % change per annum	-0.50%	1.00%	5%
Number of dwellings	117000	128000	150000
Average % change per annum	*-1%*	*2%*	*3%*
Weighted wood basic density	498	500	503
Average % change per annum	*-0.40%*	*0.00%*	*0.50%*
Average dwelling size	233	235	238
Average % change per annum	*-10.00%*	*2.00%*	*5.00%*

Table 7.3 Uncertainty and percentage change ranges of input variables used in the Monte Carlo Analysis (projection for carbon stocks in housing at Census)

Probability distribution for input variables (all triangular)			
	Minimum	Most likely	Maximum
Average volume per m^2	0.04	0.06	0.08
Average % change over 5 years	-25.00%	-9.00%	25%
Number of dwellings	9066559	9116559	9166559
Average % change over 5 years	-5%	8%	10%
Weighted wood basic density	498	500	503
Average % change over 5 years	-0.40%	0.00%	0.50%
Average dwelling size	233	235	238
Average % change over 5 years	-5.00%	5.00%	10.00%

There is no known correlation between variables of interest (wood volume per square metre of floor area, wood densities and number of dwellings), therefore no correlations were specified. This may increase the range of possible outcomes (Richards *et al*. 2007).

7.2.1 Results of carbon stock projections

The carbon stock projections presented in the graphs below are not predictions or forecasts, but are simply illustrations of carbon stock additions to the housing sector which would occur if certain assumptions about future levels of number and size of dwellings, wood usage per square metre of floor area, wood density, etc were to prevail over the projection period. The assumptions incorporate recent trends which indicate increasing dwelling size and decreasing levels of wood product usage in dwelling construction.

(a) Projected annual carbon stock additions

Figure 7.4 shows projection of annual carbon stock additions with a gradual reduction in wood usage per m^2 of floor area (2008 to 2050). The model projects annual carbon stock additions to fluctuate –dropping to 1.4 Mt CO_2-e in 2008, rising to about 1.6 Mt CO_2-e in early 2030s/2040s. Wood usage use per m^2 of floor area is projected to decline from 0.06 m^3 in 2008 to about 0.04 m^3 after 2030. Average dwelling size is projected to decrease from 236 m^2 in 2008 to 191 m^2 after 2050 (possibly due to urban consolidation of dwellings that would lead to increased proportion of other dwellings, namely, units/flats, and attached dwellings).

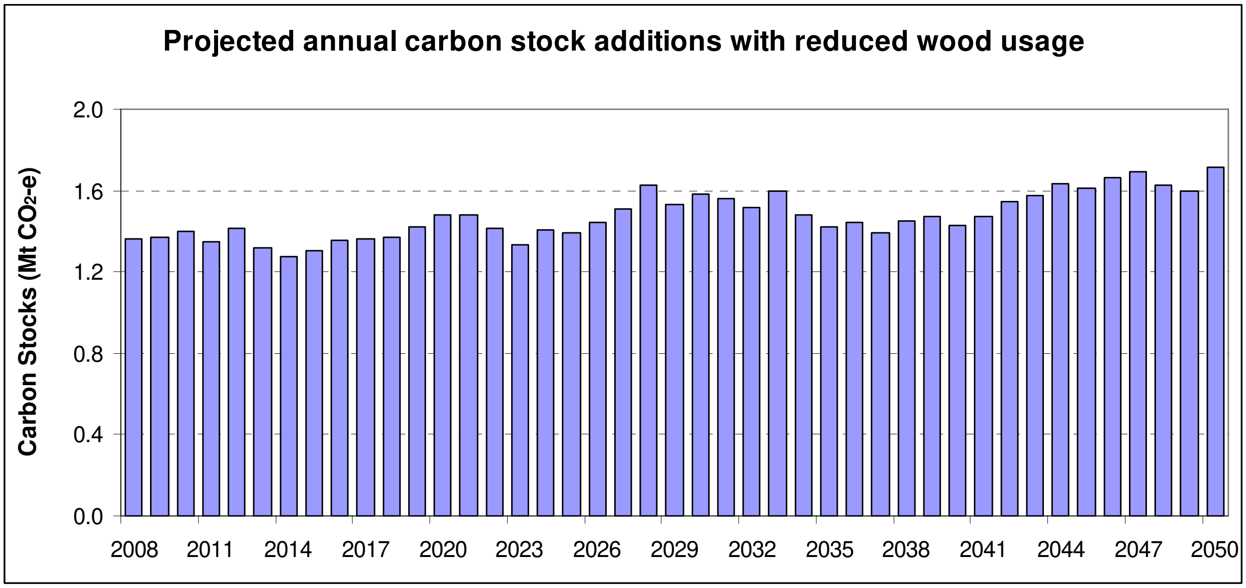

Figure 7.4 Projection of carbon stocks added to housing annually with gradual reduction in wood usage per m^2 of floor area

Projections of annual carbon stock additions with a potential gradual increase in wood usage are presented in Figure 7.5. The model projects annual carbon stock additions to gradually increase from 1.6 Mt CO_2-e in 2008 to over 4 Mt CO_2-e in early 2030s/2040s. Wood usage per m^2 of floor area is projected to increase from 0.06 m^3 in 2008 to 1970s level of about 0.14 m^3 after 2045.

To cross-check estimates/projections, sawn timber consumption was estimated first as a product of the housing starts, average floor area and the average wood usage per m^2 associated with the model estimates/projections. The estimates were then compared to estimates/projections by BIS-Shrapnel for sawn timber consumption in detached and other dwellings for the years 2003 to 2020 (BIS-Shrapnel, 2008, p. 179). The comparison is presented in Figure 7.6.

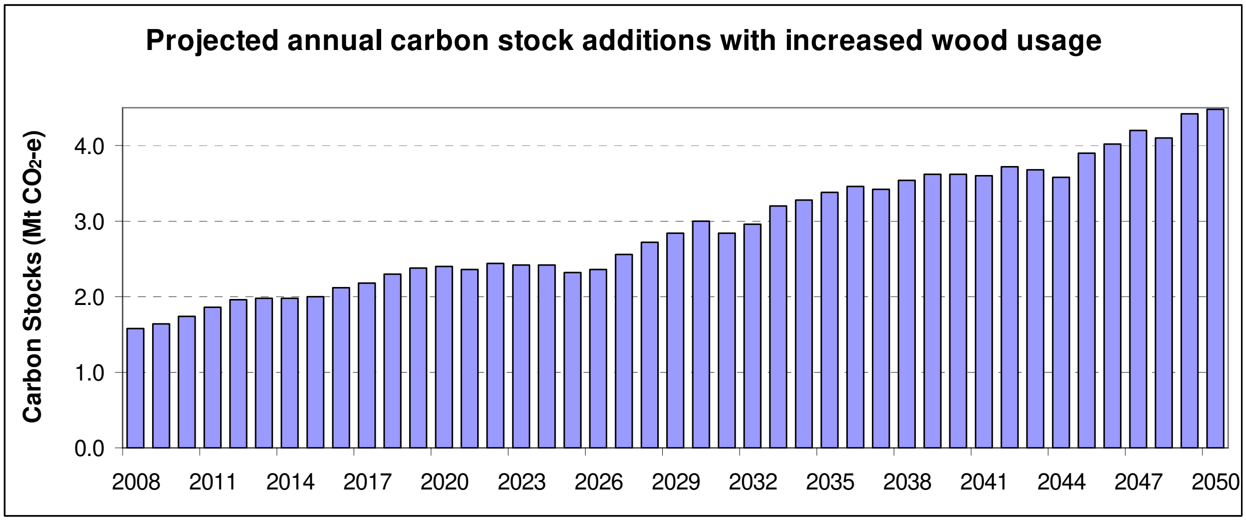

Figure 7.5 Projection of carbon stocks added to housing annually with potential increase in wood usage per m^2 of floor area

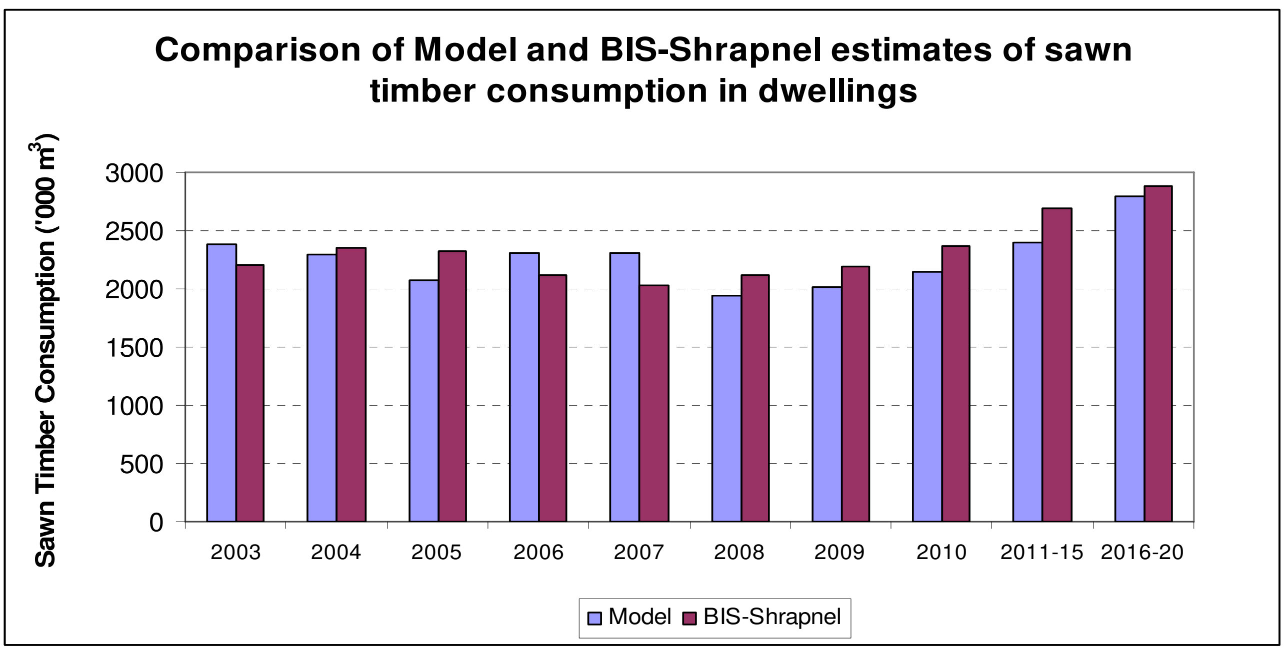

Figure 7.6 Results from the model used in this study compared with those from BIS-Shrapnel (2008) for sawn timber consumption in dwelling construction

The differences are generally due to different housing starts used for estimation/projection. The model used 'number of completed dwellings' while BIS-Shrapnel used 'number of dwellings commenced'. The differences are also due to assumptions regarding sawn timber volume per dwelling and the average dwelling size. The model projects a gradual decrease in dwelling size due to urban consolidation whereas BIS-Shrapnel projects an increase in dwelling size due to, for example, increased proportion of double storey dwellings (BIS-Shrapnel, 2008). Despite differences in approach and assumptions, the model estimates and projections are quite similar to those by BIS-Shrapnel.

(b) Projected carbon stock at future Census years

Figure 7.7 presents projections for carbon stocks at future Census years (2011 to 2051). Carbon stocks were projected to increase from 96 Mt CO_2-e in 2011 to over 200 Mt CO_2-e in 2051. These projections were based on the assumption that the housing stock would increase from about 9.1 million in 2011 to about 15 million in 2051. Assumptions for wood volume per m^2, average dwelling size and weighted wood basic density for Table 7.3 apply to these projections.

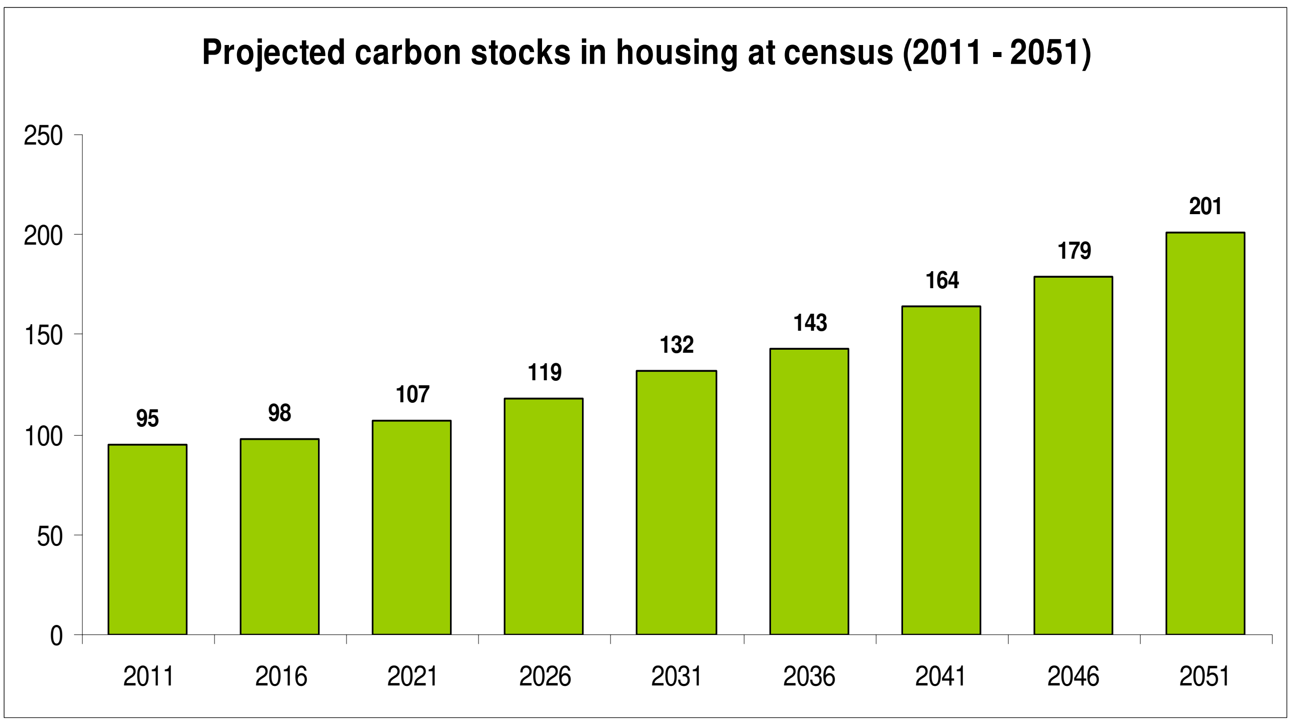

Figure 7.7 Projection of carbon stocks in housing at Census years

7.2.2 Results of sensitivity analysis

Results of the sensitivity analysis are presented using a 'Tornado' chart in Figure 7.8. The chart shows the critical model inputs and how sensitive the estimated carbon stock in housing is to each of these inputs over the ranges selected. In Figure 7.8, the bars are arranged from longest on top to the shortest on the bottom. The length of each bar shows the percentage change in the carbon stock in either direction, so the longer the bar, the more sensitive the carbon stock is to the particular input. Thus the graph shows that average wood volume per square metre of floor area has the largest effect on carbon stock, and average wood basic density has the smallest effect. Although not shown in Figure 7.8, dwelling floor area has significant effect on carbon stock because it is the key variable used to estimate (hence highly correlated with) wood usage per square metre. It was deliberately excluded from the analysis to increase the range of possible outcomes from the analysis (Richards *et al*. 2007).

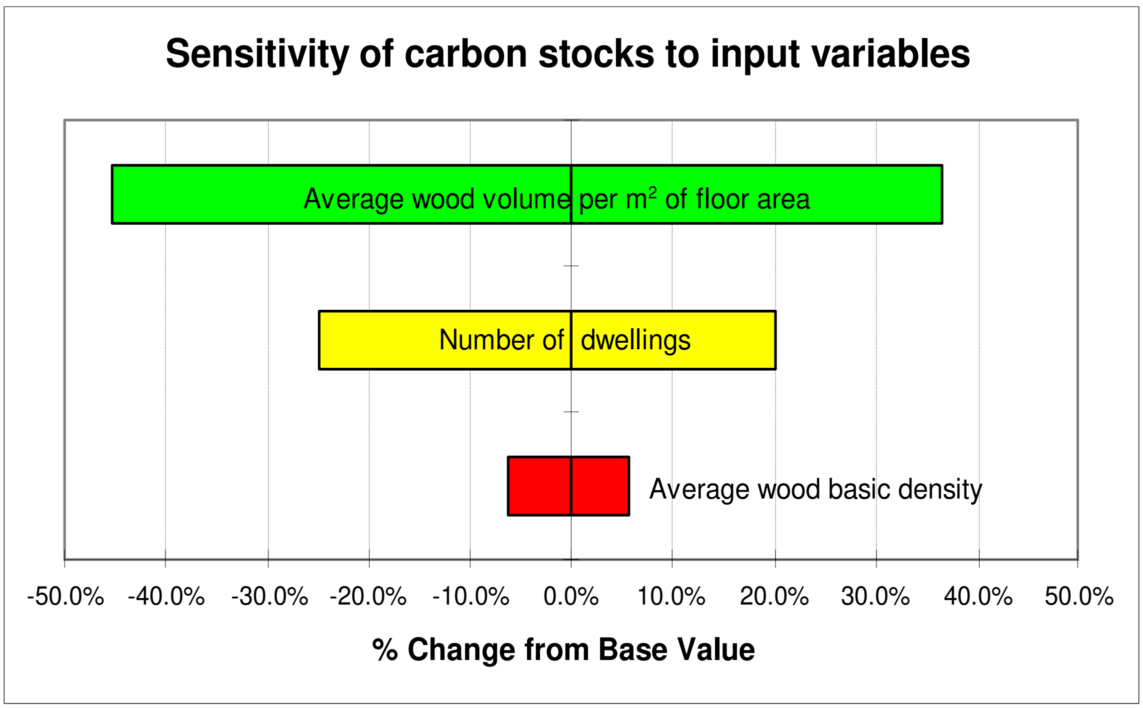

Figure 7.8 Tornado Chart for sensitivity of carbon stocks to input variable

The regression Tornado chart in Figure 7.9 was derived by using Regression Sensitivity technique, where sampled input variable values were regressed against estimated carbon stock values (output variable), leading to a measurement of sensitivity by input variable. In essence, the technique uses the standardised values of these variables in the regressions and shows the resulting regression coefficients in the Tornado chart. The coefficients show the expected number of standard deviations of change in estimated carbon stock when any input (average wood volume per m^2, number of dwellings, and average wood basic density) increases by one of its standard deviations.

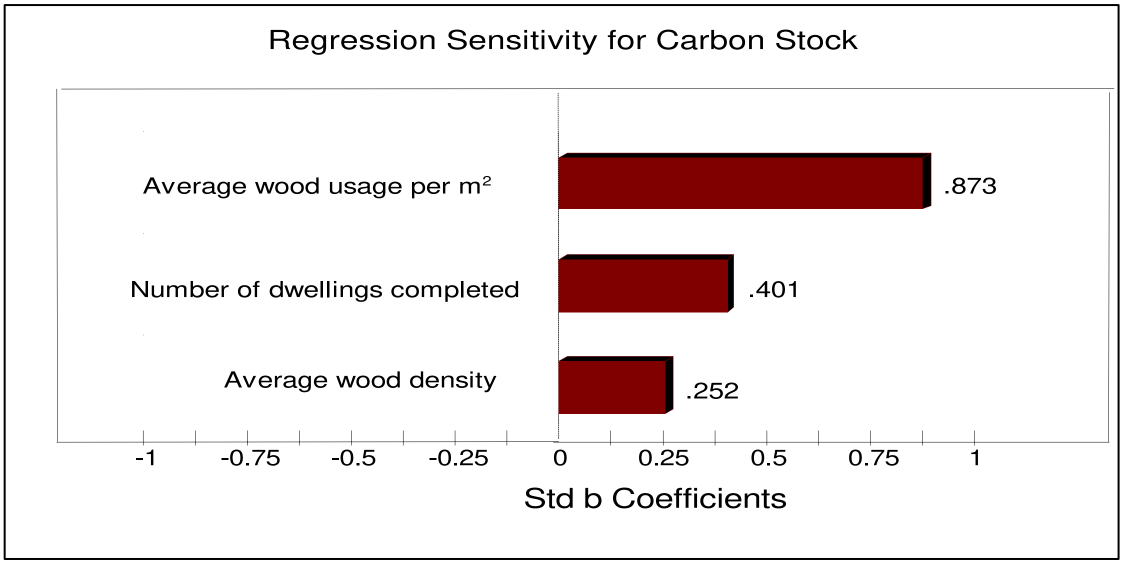

Figure 7.9 Regression Tornado Chart for sensitivity of carbon stocks to input variables

In Figure 7.9, when average wood usage per m^2 increases by 1 standard deviation (and the other inputs remain constant), the estimated carbon stock is expected to increase by 0.873 standard deviation. Likewise, when the number of dwellings and the average wood basic density each increase by 1 standard deviation, the estimated carbon stock is expected to increase by 0.401 and 0.252 standard deviations, respectively. This means increasing wood usage in dwellings would result in higher carbon stock additions to housing.

8 Conclusions

- The approach used in this study indicates that the carbon stock in housing has increased by between 1.5 to 2 Mt CO_2-e per year over the last 20 years. This has occurred despite a decline in the amount of wood used per dwelling, primarily because the average area and the number of new dwellings have increased.
- Comparison with current modeling approaches used by the Department of Climate Change suggests that their estimates of annual net additions of carbon to long-lived pools are greater than the net additions to residential housing derived in this study. This is due to differences in assumptions about housing longevity and the wood used per unit house area.

- Estimates of total carbon stocks and annual additions to the long-term carbon pool are most sensitive to the estimated wood used per square metre of house area. It is recommended that this value be reviewed periodically (e.g. 5 yearly) based on monitoring and survey of wood usage in dwellings. This could also serve as a tool to measure the effectiveness of industry campaigns to increase the use of wood in residential construction.
- There is significant capacity for increasing the rate of addition to carbon stocks in housing. This would require a reversal of the trend for reduced wood use in housing, for example by increasing the use of timber sub-floor systems and timber wall cladding.
- If there was an increase in the volume of wood used in houses over time to 0.14 m^3 per m^2 of house area (a level similar to that in the 1960s), the estimated additional annual C uptake in houses in Australia until 2050 could rise to over 4 Mt CO_2-e by 2050. This is about 0.7% of Australia's greenhouse gas emissions in 2006.
- The analysis does not include any estimates of long-term carbon storage and carbon emissions after houses are demolished and the wood products are recycled, burnt or disposed in landfills. Results from the survey suggest that the proportions of wood disposed in landfills from construction and demolition activity is decreasing. This is likely driven by the need to cut costs (construction materials as well as disposal fees) and by improved construction techniques.
- Building professionals suggested a number of ways to increase in the use of wood in residential housing. These included
    - (a) Publicity, promotion and marketing of the environmental attributes of timber products
    - (b) Better timber design and development of timber products to satisfy consumer preferences and to meet the needs of the construction industry
    - (c) Better education of the general public and building practitioners in the use of timber
    - (d) Reducing the relative cost of timber products
    - (e) Changing regulation and building codes

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APPENDIX 1: Stratification of data sources

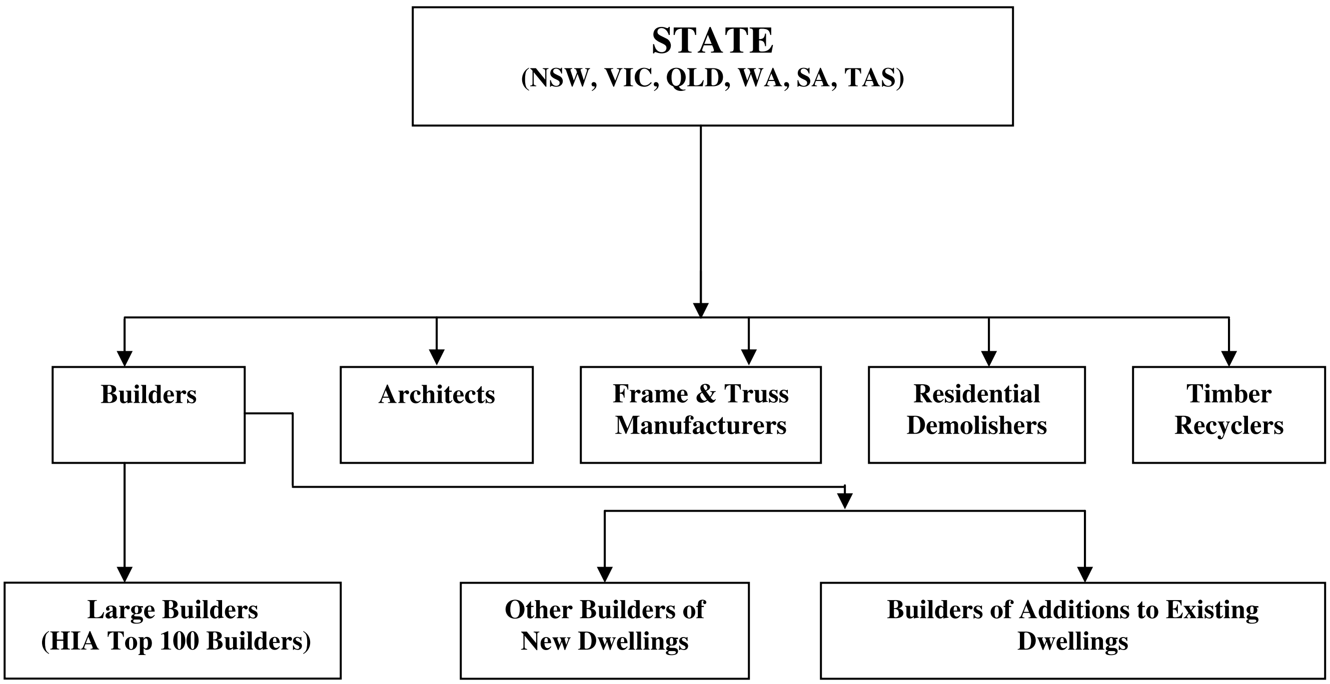


Figure 1 Revised stratification of data sources from Kapambwe *et al* 2007. Large builders are those listed by the Housing Industry Association (HIA)'s Top 100 Builders for 2006 - 2007.

APPENDIX 2: Survey administration & responses

Table 1 Target populations and response rates for various geographical locations

Location		Target Population: Architects	Other Builders	Top 100 Builders	Builders Additions	Frame & Truss Makers	House Demolishers	Timber Recyclers
VIC	Sent	100	-	28	-	43	29	55
	Responses	35	-	10	-	20	7	19
	Response Rate	35%	-	36%	-	47%	24%	35%
WA	Sent	100	100	12	79	20	30	16
	Responses	23	28	4	9	5	5	3
	Response Rate	23%	28%	33%	11%	25%	17%	13%
SA	Sent	100	42	6	21	10	20	12
	Responses	25	13	2	5	6	5	8
	Response Rate	25%	31%	33%	24%	60%	25%	67%
TAS	Sent	42	88	1	79	10	7	10
	Responses	27	19	1	10	3	1	5
	Response Rate	64%	22%	100%	13%	30%	14%	50%
NSW	Sent	96	96		97	53	45	26
	Responses	22	13	6	15	8	13	13
	Response Rate	23%	14%	%	16%	15%	29%	50%
QLD	Sent	107	98		103	35	51	25
	Responses	21	19	3	8	8	6	5
	Response Rate	19%	19%	%	8%	23%	12%	19%
ALL	**Sent**	**545**	**424**	**47**	**379**	**171**	**182**	**145**
	Responses	**153**	**92**	**27**	**47**	**50**	**20**	**53**
	Response Rate	**28%**	**22%**	**36%**	**12%**	**29%**	**21%**	**37%**
	OVERALL REPONSE RATE = 24%							

APPENDIX 3: Estimated average timber volume per dwelling

	NSW	VIC	QLD	WA	SA	TAS
1945	25.0	25.0	25.0	22.0	22.0	25.0
1946	24.7	24.7	24.7	21.6	21.8	24.8
1947	24.6	24.6	24.5	21.3	21.6	24.6
1948	24.4	24.4	24.3	21.1	21.5	24.5
1949	24.3	24.3	24.2	20.9	21.4	24.4
1950	24.2	24.1	24.0	20.7	21.3	24.3
1951	24.0	24.0	23.8	20.5	21.2	24.2
1952	23.9	23.8	23.6	20.2	21.0	24.0
1953	23.7	23.7	23.5	20.0	20.9	23.9
1954	23.6	23.5	23.3	19.8	20.8	23.8
1955	23.5	23.4	23.1	19.6	20.7	23.7
1956	23.3	23.2	23.0	19.4	20.6	23.6
1957	23.2	23.1	22.8	19.1	20.4	23.4
1958	23.0	22.9	22.6	18.9	20.3	23.3
1959	22.9	22.8	22.5	18.7	20.2	23.2
1960	22.8	22.6	22.3	18.5	20.1	23.1
1961	22.6	22.5	22.1	18.3	20.0	23.0
1962	22.5	22.3	21.9	18.0	19.8	22.8
1963	22.3	22.2	21.8	17.8	19.7	22.7
1964	22.2	22.0	21.6	17.6	19.6	22.6
1965	22.1	21.9	21.4	17.4	19.5	22.5
1966	21.9	21.7	21.3	17.2	19.4	22.4
1967	21.8	21.6	21.1	16.9	19.2	22.2
1968	21.6	21.4	20.9	16.7	19.1	22.1
1969	21.5	21.3	20.8	16.5	19.0	22.0
1970	21.4	21.1	20.6	16.3	18.9	21.9
1971	21.2	21.0	20.4	16.1	18.8	21.8
1972	21.1	20.8	20.2	15.8	18.6	21.6
1973	20.9	20.7	20.1	15.6	18.5	21.5
1974	20.8	20.5	19.9	15.4	18.4	21.4
1975	20.7	20.4	19.7	15.2	18.3	21.3
1976	20.5	20.2	19.6	15.0	18.2	21.2
1977	20.4	20.1	19.4	14.7	18.0	21.0
1978	20.2	19.9	19.2	14.5	17.9	20.9
1979	20.1	19.8	19.1	14.3	17.8	20.8
1980	20.0	19.6	18.9	14.1	17.7	20.7
1981	19.8	19.5	18.7	13.9	17.6	20.6
1982	19.7	19.3	18.5	13.6	17.4	20.4
1983	19.5	19.2	18.4	13.4	17.3	20.3
1984	19.4	19.0	18.2	13.2	17.2	20.2
1985	19.3	18.9	18.0	13.0	17.1	20.1
1986	19.1	18.7	17.9	12.8	17.0	20.0
1987	19.0	18.6	17.7	12.5	16.8	19.8
1988	18.8	18.4	17.5	12.3	16.7	19.7
1989	18.7	18.3	17.4	12.1	16.6	19.6

	NSW	VIC	QLD	WA	SA	TAS
1990	19.0	18.0	17.2	11.9	14.8	19.5
1991	18.8	18.0	16.5	11.7	14.8	19.8
1992	18.7	18.9	16.4	11.4	14.8	19.6
1993	18.6	18.8	16.3	11.2	14.4	19.2
1994	18.4	18.7	16.2	11.0	14.4	19.2
1995	18.4	18.0	16.1	10.8	14.5	19.1
1996	18.0	17.5	16.0	10.6	14.3	19.0
1997	17.8	18.0	16.0	10.3	14.0	19.0
1998	17.9	18.6	15.8	10.1	14.4	18.9
1999	17.8	18.0	15.8	9.9	14.6	18.5
2000	18.0	17.0	15.7	9.7	14.0	18.2
2001	17.9	17.0	15.6	9.5	14.0	18.5
2002	17.3	17.0	15.8	9.2	13.8	18.6
2003	17.6	16.8	15.5	9.0	13.8	18.6
2004	16.8	16.4	15.2	8.8	13.6	18.0
2005	16.5	16.4	15.2	8.6	13.0	17.7
2006	16.3	15.7	14.5	8.4	13.0	17.6
2007	16.2	15.6	14.3	8.1	12.9	17.4
2008	16.0	15.4	14.1	7.9	13.0	17.3

APPENDIX 4: Typical timber sizes used in dwelling construction

Typical timber sizes and species used in framing (VIC)

Dimensions		Description		
Width (mm)	Thickness (mm)	Application	Grade	Species
70	35	Noggings		Pine
	45	-	MGP10	Pine
90	35	Temp bracing		Pine
	35	Wall studs	MGP10	Pine
	45	-	MGP	Pine
	45	-	F17	K.D. HWD
	90	-	F5	K.D. Treated Pine
140	45	-	F17	K.D. HWD
190	35		F5	K.D. Pine
	45	-	F17	K.D. HWD
240	45	-	F17	K.D. HWD, Pine
290	45	-	F17	K.D. HWD
1200	4.8	Masonite brace board		
240	80	Laminated beams		Treated Pine
240	45	LVL		
360	45	"		
400	45	"		
42	42	Verandah material	F7	LOSP Treated Pine
90	42	" "	F7	LOSP Treated Pine
65	18	Eaves material		K.D. HWD
19	19	" "		Meranti
70	35	" "		Pine
138	18	" "		LOSP Treated pine
41	19	Others		DAR Pine
600	13			pineboard

Typical timber sizes and species used in roof trusses (WA)

Width	Thickness	Full Description
42	35	Pine Structural PR
	45	Pine Structural PR
50	25	WA H'Wood Str3 Sawn
	38	WA H'Wood Str3 Sawn
	50	WA H'Wood Str3 Sawn
70	35	Pine Non Structural PR
	35	Pine Structural PR
	45	Pine Structural PR
5	25	WA H'Wood Str3 Sawn
	38	WA H'Wood Str3 Sawn
	50	WA H'Wood Str3 Sawn
	75	WA H'Wood Str3 Sawn
90	35	Pine Non Structural PR
	35	Pine Structural PR
	45	Pine Structural PR
	90	Pine Structural PR
100	25	WA H'Wood Str3 Sawn
	38	WA H'Wood Str3 Sawn
	50	WA H'Wood Str3 Sawn
	75	Pine F7 Sawn
		WA H'Wood Str3 Sawn
120	35	Pine Structural PR
	45	Pine Structural PR
125	25	WA H'Wood Str3 Sawn
	38	WA H'Wood Str3 Sawn
	50	WA H'Wood Str3 Sawn
	75	Pine F7 Sawn
		WA H'Wood Str3 Sawn
140	35	Pine Structural PR
	45	Pine Structural PR
150	25	WA H'Wood Str3 Sawn
	38	WA H'Wood Str3 Sawn
	50	Karri KD F17 Sawn
		WA H'Wood Str3 Sawn
	75	Pine F7 Sawn
		WA H'Wood Str3 Sawn
170	35	Pine Structural PR

Width	Thickness	Full Description
175	25	WA H'Wood Str3 Sawn
	38	WA H'Wood Str3 Sawn
	50	Karri KD F17 Sawn
		WA H'Wood Str3 Sawn
	75	WA H'Wood Str3 Sawn
190	35	Pine Structural PR
	45	Pine Structural PR
200	25	WA H'Wood Str3 Sawn
	38	WA H'Wood Str3 Sawn
	50	Karri KD F17 Sawn
	50	WA H'Wood Str3 Sawn
	75	Pine F7 Sawn
		WA H'Wood Str3 Sawn
225	25	WA H'Wood Str3 Sawn
	38	WA H'Wood Str3 Sawn
	50	WA H'Wood Str3 Sawn
240	35	Pine Structural PR
	45	Pine Structural PR
250	25	WA H'Wood Str3 Sawn
	38	WA H'Wood Str3 Sawn
	50	Karri KD F17 Sawn
		WA H'Wood Str3 Sawn
	75	Pine F7 Sawn
		WA H'Wood Str3 Sawn
290	35	Pine Structural PR
	45	Pine Structural PR
300	25	WA H'Wood Str3 Sawn
	38	WA H'Wood Str3 Sawn
	50	Karri KD F17 Sawn
		WA H'Wood Str3 Sawn
	75	Pine F7 Sawn
		WA H'Wood Str3 Sawn

Timber usage in truss manufactured roof construction (VIC)

House Design	Total Volume of timber (m^3)	Softwoods (%)	Hardwoods (%)
Newhaven36	8.00	100	0
Tribeca36MK2	4.80	95.9	4.1
Promade43	7.02	91.3	8.7
Liberty42	5.84	96.2	3.8
Aspen31	7.29	97.5	2.5
Latitude36	7.97	89.85	10.15
Coburn39	9.17	88.2	11.8
Belize20Traditional	4.21	94.8	5.2
Soho27Traditional	5.96	100	0
Santorini29	6.61	95.75	4.25
Lindeman27	5.8	97.7	2.3

APPENDIX 5: Suggestions to increase wood usage

Publicity, Promotion & Marketing of timber products	1

Architects

VIC

- *What we need is a nationalized advertising/ education program where our industry can actually agree on the benefits of using timber, the grading of timber, product identification ie grading, treatment levels etc. at present it is disjointed, confusing and plays into the hands of competing products*
- *Promotion of reverse brick veneer with timber cladding/weatherboards*
- *Promotion of membrane roofing supported on plywood and timber beams as an alternative to flat roofing*
- *Promote structural advantages and time saving opportunities when using wood products*
- *Promotion of timber windows*
- *Promotion of energy efficient frame performance and lower embodied energy in manufacture*
- *More timber use in cladding and linings*
- *More promotion of timber in contrast with steel framework*
- *Market timber cladding to potential home owners - decrease reliance on brick*
- *Increase marketing of LVL and other engineered timber products to Architects, engineers, builders*

WA

- *Awareness in public domain of aesthetic benefits of timber construction*
- *Advertising comparisons with cavity brick construction in terms of climate benefits*
- *User awareness of environmental benefits of using timber*
- *WA market needs huge public education that timber is OK despite the termites and that it is a cheaper construction technique*
- *People in WA think light-weight construction is cheap but do not exude 'quality and solidity'. Combinations need to be marketed to overcome these*

TAS

- *Better education of the public/consumers about carbon storing benefits of using timber to create more user demand*
- *Demonstrate and promote sustainability of industry (environmental)*
- *Better education of consumers who seem to be averse to the use of timber*
- *Greater publicity of successful timber projects in mainstream media*
- *Political issues involved with forestry practices, pulp mill etc may decrease the current high proportion of timber used in housing construction. Education & awareness, raising of positive environmental impacts (with general public, potential clients more so than building industry) of timber use would address this*
- *More awareness of environmental benefits of using timber in buildings*
- *More publicity of timber awards - within AIA, MBA, & HIA. "Have a special award called 'BEST USE OF TIMBER' will have vast opportunity if public decides that it is beautiful, minimal maintenance and has a sense of permanence*

SA

- *Higher public awareness about environmental benefits of using timber*
- *Counter the misleading 'propaganda' regarding steel framing which has many disadvantages conveniently ignored. Their advertising is not wrong - it just omits all the above (greenhouse impacts)*
- *Proper marketing, availability and fitness for purpose of timber product will prevail*
- *Increased marketing of 'blue pine' termite resistant pine and superior thermal performance of timber framed walls*
- *Promote environmental benefits of timber framing/cladding compared to brick/brick veneer e.g. carbon storage and less energy usage (embodied)*

- *Promote timber use like in North America*
- *Highlighting the sustainable nature of timber i.e. its environmental advantag*es
- *Better environmental benefits model*

NSW

- *Concerted campaign about carbon/ GHG benefits of timber*
- *Emphasize embodied energy aspect of brick and concrete*
- *I found trade shows such as 'Form and Function' highly informative and learnt of products in timber such as cladding made of timber products*
- *Home owners need to be satisfied that timber will offer low maintenance*
- *Timber not perceived as a permanent material vs masonary*
- *Promotion of timber claddings & linings (including flooring) & window frames*
- *Promotion of value-added but using timber floors & window frames, joinery*

Top builders

VIC

- *Capitalise on trends regarding increased usage of timber for its aesthetic features in some building applications*
    - *Promote usage of more recycled timber to take advantage of resurgence in its use as a feature in flooring, internal wall paneling, facades, ceiling*
- *Promote timber products based on their superiority vis-à-vis environmental efficiencies*

WA

- *Currently double-brick could utilise timber framing as in the past - 100% increase in timber usage*
- *More advertising of benefits from brick veneer compared to double brick*

Frame and Truss

VIC

- *More marketing for timber clad houses, not brick dwellings*
- *More publicity about carbon storage in timber*
- *More publicity about young trees/plantations absorbing more* CO_{22} *and producing more* O_2 *than old growth forests*
- *More about timber as a renewable resource*
- *More about steel pollution in production*
- *Publicise environmental benefits of timber to consumers/public*
- *Promote embodied energy and green benefits and Carbon credits from timber*

WA

- *In WA, the market has not embraced timber framed construction for a variety of reasons but mainly consumer confidence in timber framed dwellings*
- *Homeowners rightly or wrongly believe double brick is better*
- *Consumer education via increased advertising of timber products*
- *More architectural/trendy timber products*
- *Marketing campaign to promote timber in wall framing in WA and timber in construction nationally*
- *Blue pine frame alliance TV advertising campaign with environmental benefits focus*

SA

- *Promoting the environmental benefits of timber over other products such as steel framing and concrete*
- *Reinforce damage to the environment resulting from use of steel in building and construction through media, government regulation and education in building institutions*
- *Public promotion of benefits of timber in greenhouse and termites protection*

TAS

- *Promote the benefits of carbon storage against carbon production of alternative products, e.g. steel, concrete, glued products*
- *Use more external wood base cladding*

QLD

- *More timber framed & clad house frames, sub-floors & flooring*
- *Promote the use of timber battens for roof & ceilings, rather than steel*
- *Promote use of timber floors on sloping sites to eliminate cut & fill & concrete*

Timber product development	**2**

Architects

VIC

- *Develop products to satisfy prevailing fashion and trend*
- *Improve longevity of timber products - coating (treatment) technology against termite attack and rot*
- *Improve fire resistance of timber products*
- *Provide products with low maintenance, with good finishes and ease of replacement*
- *More durable finishing product for timber cladding - an improvement on current paint/stain*
- *Develop, design and test timber materials including sheet and framing for exposed, external applications to replace fibre-cement products and to resist any timber deterioration (rot, etc)*

WA

- *More cost effective stress grading and fire-rating of timber materials*
- *Timber products with low maintenance characteristics, high versatility (in case of alteration), and improved performance in fire*
- *Even greater improvements in the areas of termite protection, sound proofing and thermal performance of light-weight framed construction generally*
- *Improve thermal performance of products (operational)*
- *Increase in development of timber products using low grade timber sources*
- *Improve fire rating of timber products in buildings*

TAS

- *Improve thermal performance of timber clad dwellings to make them appealing in this State*
- *Improve fire resistance of timber products to meet fire resistance requirements that restrict the use of timber in attached dwellings to some extent*

SA

- *Timber products with better quality - less warping, twisting*
- *Timber products with better durability against rot and termites*
- *Improve termite and fire resistance of timber*
- *Improve structural capabilities of timber products*
- *Further development for engineered timber products, long span members, and more use in external applications*
- *Fire proofing of timber*
- *Development of new timber materials and construction methods/techniques*

NSW

- *Improved finishes (less maintenance)*
- *Develop capacity to identify material usage trends in dwelling construction*
- *Greater emphasis on finishes (potential to minimise maintenance factor)*
- *Development of long life finishes*
- *More expensive and greater long term maintenance costs stops many clients from installing them*
- *Also timber windows that can deal with bushfire requirements is a huge issue and problem - bushfire will not allow you to use them in the two top ratings forcing the use of aluminium*
- *Very few use timber floors these days other than as floating floors as slabs have better insulation and heat storage capabilities than timber plus better sound proofing - need product alternativese that offer same outcomes*

- *For stud work, metal tends to be used more as it does not offer issues with termites and is predrilled for cabling and is quicker to install. Perhaps develop products that also offer the ease of installation and are pre-treated for termites*
- *I do not think policy is the answer - better to improve the product performance*

Top builder

VIC

- *Focus on making timber products more attractive. Fashionise timber products to match visual trends as opposed to structural appeal*
- *More cost effective cladding systems as current alternatives are considered more superior, stable, resistant to rot and heat movement and easy to install*

SA

- *More strength and spanning capabilities of timber beams". "Termite resistance (cheaper, more effective and advertised as such*

Frame and Truss

SA

- *The quality and availability of good treated H2 or T2 timber often indicates steel is preferred. We believe a balance of both is the way to go. There are times when a smaller steel product is cheaper and more functional than structural LVLs, etc, but generally we try to use timber products*

Education & Training	**3**

Architects

VIC

- *Better education of general population/clients and better information about where timber has come from*
- *Education of builders, engineers regarding sustainable timbers, Forest Stewardship Certification important*

WA

- *Better training and education for the public*
- *In WA, timber frame is not used as much as masonry construction, possibly due to public acceptability*

TAS

- *More education on environmental benefits of using timber*
- *Education to builders & designers on best practice use of timber products*

SA

- *Better, comprehensive structural engineer education about timber in house construction*
- *Maintenance of timber structures is a big problem in people's minds*
- *Educating designers and builders*
- *More training of carpenters – more attractive apprenticeships*
- *In WA, builders don't encourage timber frame because they do not have the trades or expertise to be as profitable as they are in double brick*
- *Builder education on cost comparisons to steel, etc*

NSW

- *Educate the developers on the costs and environmental savings*

Provide better information to building practitioners	4

Architects

VIC

- *Information regarding source of timbers". Information regarding carbon sink values*
- *Information regarding performance of timbers, this is very in-exact at the moment*
- *Better information provided to design professionals on wood products and sustainability*
- *Provide written document giving specific information on timber type, treatment type, etc, and its specific use in relevant scenarios with general specification and relating it to structural, Building Code of Australia (BCA) and Australian Standard requirements*
- *Overcome the prejudice of timber cladding so brick is not obligatory*
- *Better understanding of protection of timber against fire and fungal/borer infestation*

WA

- *Acceptance of timber by local authorities without additional certification, i.e. structural engineers input*
- Bu*ilding industry acceptance of preference for timber over steel framing*
- *Further information to architects on fire resistance of timber products*
- *More information on durability/environmental friendliness of timber*
- *Fire rating : Product manuals on how to achieve required fire rating limits*

TAS

- *Greater knowledge of professionals about available products, accessibility to products (Difficult and expensive in Tasmania*
- *Provide sourcing information of timber - from sustainably managed supply*
- *All we need is an accepted forestry management/stewardship certification so that only complying timber can be specified. 'Greener' FSC requirement is difficult to achieve and all other timber is not accepted currently*
- *Information on availability of environmentally certified sources of Australian timber (Forest stewardship certification, etc)*
- *More availability of forest stewardship certified timber*

SA

- *Comparisons/Technical data relating to ecological positives of using timber to negatives of steel/masonry/fibre cement/aluminium*
- *Also assurances that the timber is sourced from mixed species sustainable forests*
- *Use timber from plantation certified sources*
- *Better understanding of light timber framing options*
- *Greater awareness of lightweight construction benefits*

NSW

- *Generally conventional stud framing (timber) is widely used. Timber cladding in lieu of FC, zinc could be better embraced by specifiers especially the environmental positives. Get the info out to specifiers*
- *Provide information to designers/ architects/ builders on how to work with timber to achieve long life and details to prevent rot, water damage*

Frame and Truss

QLD

- *Better documentation of span tables, better party wall detail, more consistent design methods*

Reduce relative cost of timber products	5

Architects

VIC

- *Make timber windows frames competitive. At present, aluminium products are cheaper than timber e.g. windows*

SA

- *Reduction in the cost of timber compared to steel*
- *Off-site fabrication of wall frames. Timber needs to have a price advantage - two ways to achieve this: (1) reduce material cost (2) reduce on-site labour by fabricating more wall frames off-site as is done for steel frames*

NSW

- *Make timber more affordable than steel or aluminium*
- *Finding it easier to source sustainable timber at prices that are more equitable with other products, i.e., hardwood timber decking, softwood timber windows versus aluminium windows*
- *Education of the client is the more important goal but we need to be able to say that timber versus other materials is cost neutral*

Top Builders

SA

- *Timber cost has increased and availability is becoming harder*

Frame & Truss

QLD

- *Price and availability plus new products and technology*

Work to change regulation/building codes	6

Architects

VIC

- *Bonuses to offset 5-star energy rating penalties for timber flooring*

WA

- *Audits of environmental performance of houses requiring 5 star (and above) energy performance to recognize environmental properties of timber*

SA

- *Mandate greater usage of locally produced timber products*
- *Change in Government regulation/codes; Educating designers and builders*

NSW

- *Sense (and use of building science) in relaxing NSW Rural Fire Service grip on construction materials*
- *Greater dis-incentives on high Embodied Energy materials (e.g. metal framed windows)*
- *Making it a statutory requirement that 'treated timber' should be used for framing - wall, roof etc*

Top builders

VIC

- *Government should take into account embodied energy in the energy (5 or 6 star) calculations. At present timber is disadvantaged. All builders are going to concrete slabs because of thermal mass. There is an argument that we (timber) may be worse off, if embodied energy was taken into account*

WA

- *Sustainable sources of timber and Government bans on rainforest timber*

NSW

- *Change in fire regulations - for Type 2 construction (Flats/units)*

Frame & Truss

VIC

- *The 5 or 6 star rating system for energy etc is against timber and it handicaps it to a point that other products are chosen*
- *Government community housing could increase timber use in housing dramatically almost immediately*

NSW

- *Allow 3 storey timber construction*
- *Remove the ban on CCA wood use*
- *Allow the use of more timber engineering in unit/townhouse construction*
- *Pushing more for multistory timber construction projects*

QLD

- *I believe the energy rating issues need to be reviewed as this can severely impact on the use of timber in sub-floors*

Timber Design	**7**

Architects

VIC

- *Use of timber cladding between party walls*
- *Simple thermal efficiency of floor systems*
- *Simple fire/acoustic separation details*
- *Good design and less reliance on energy efficiency testing software*
- *Improve the economy of construction and fire rating of timber products*

SA

- Design for more end of life salvage and more plantations
- *Develop simple construction systems and span tables particularly bracing which are easy to comply with - AS 1684 too complicated and gets worse each edition*
- *Design examples regarding fire rating, ease of construction, environmentally sustainable development (ESD) benefits, ESD disbenefits of steel, concrete, etc*
- *Introduction of tested timber construction systems to conform with noise/fire separation requirements*
- *Improve lightness and economy of structure*
- *Eco-houses, in natural environments - use of timber in conservation zones to demonstrate its ability to blend with the environment*
- *Better acoustic control*

NSW

- *Promulgate successful timber framed projects*
- *Inform architects & designers & developers about design strategy, material selection & cost competitiveness - innovative ways to be shown as an example*
- *Design details to prevent rot, water damage*

Top builders

VIC

- *Develop competitive sub-floor systems similar to what the 'one stop floor shop' used to provide*
- *More cost effective cladding systems as current alternatives are considered more superior, stable, resistant to rot and heat movement and easy to install*
- *More engineered timber - stronger, lighter*

WA

- *Good design & integrity of structures (lower cost; sound proofing)*

Frame and Truss

VIC

- *Use of light-weight roofing materials and enable engineers to design in timber not steel*
- *Ensure party walls are designed using timber as the primary material - not concrete or steel solutions*
- *95% is steel studs at present. We supply many jobs in finger-jointed non-structural product that competes very well on price and application. The challenge is to have it designed more often*

QLD

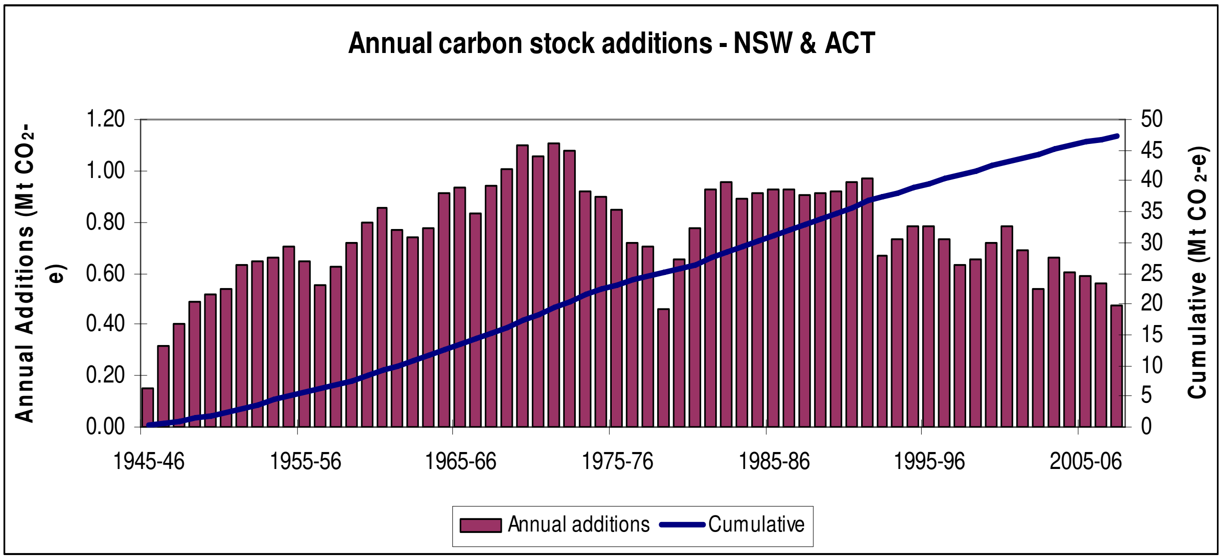
- *Use of timber and CSR or Hardies board products in party walls. Timber sub-floors & flooring*

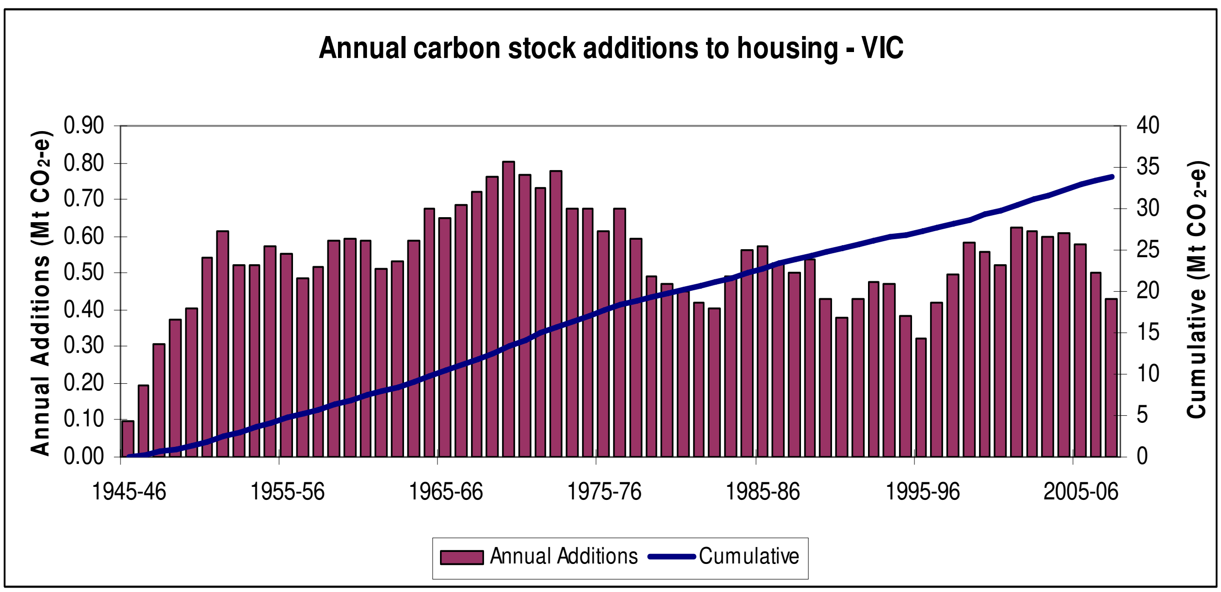
Invest in hardwood plantations	8
Architects *VIC* • *Investment and good support for local hardwood plantations and forests that have a slower financial return but better for future* • *Investment in growing attractive Class 1 timber locally - like Meranti & Jarrah so that the concept of using timber like these does not make us feel guilty as specifiers*	

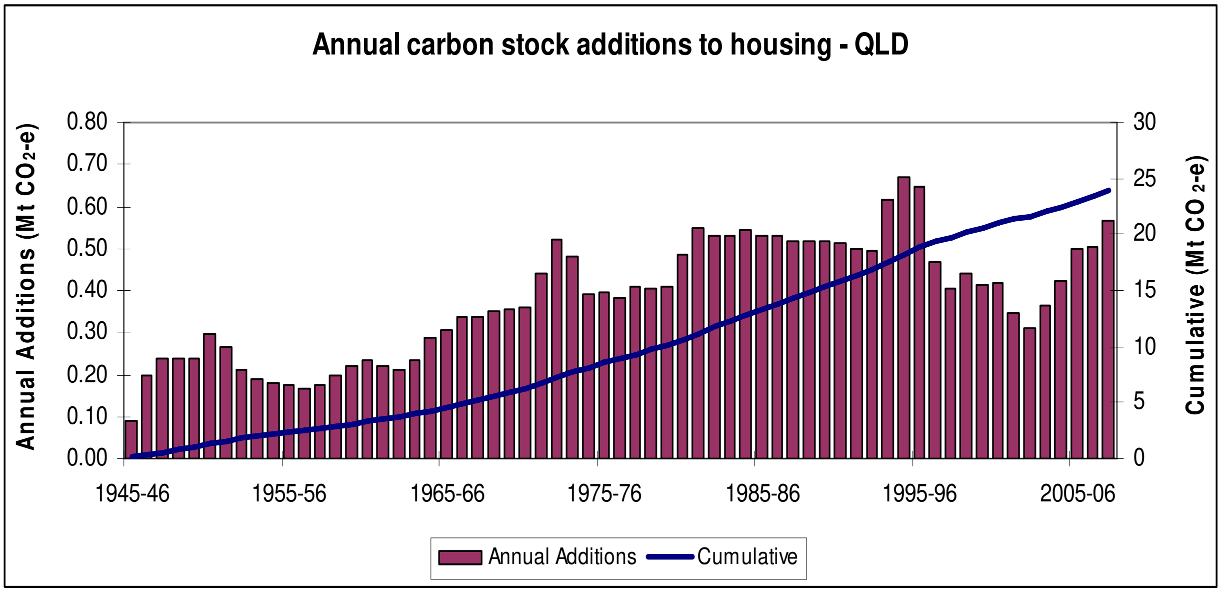
Availability	9
Architects *TAS* • *Availability is the biggest problem at present - more plantations should help* *SA* • *Increase availability of timber sizes* • *Increase availability of prefabricated timber components such as wall frames*	

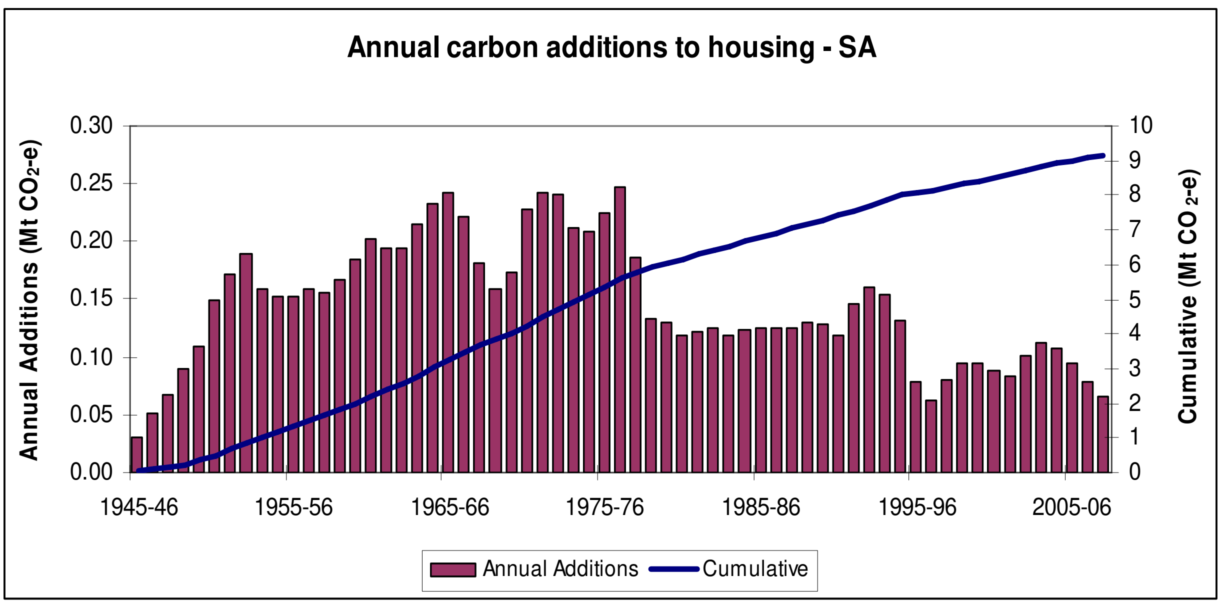
Other	0
Top builders *TAS* • *Timber cladding could be used a lot more* Frame and Truss *VIC* • *By reducing multi-storey and* allow urban sprawl will enable timber construction as opposed to concrete floors and brick walls • *Change all pine to H2/T2 treated* • *Reinforce current practices* *NSW* • *Development of a high temp power plant capable of burning treated off-cuts in which case the thousands of cubes of waste being dumped could be diverted to energy production* • *Removal of the requirement to identify the source of the offcuts before they are burnt to keep the green power ticket/ credits*	

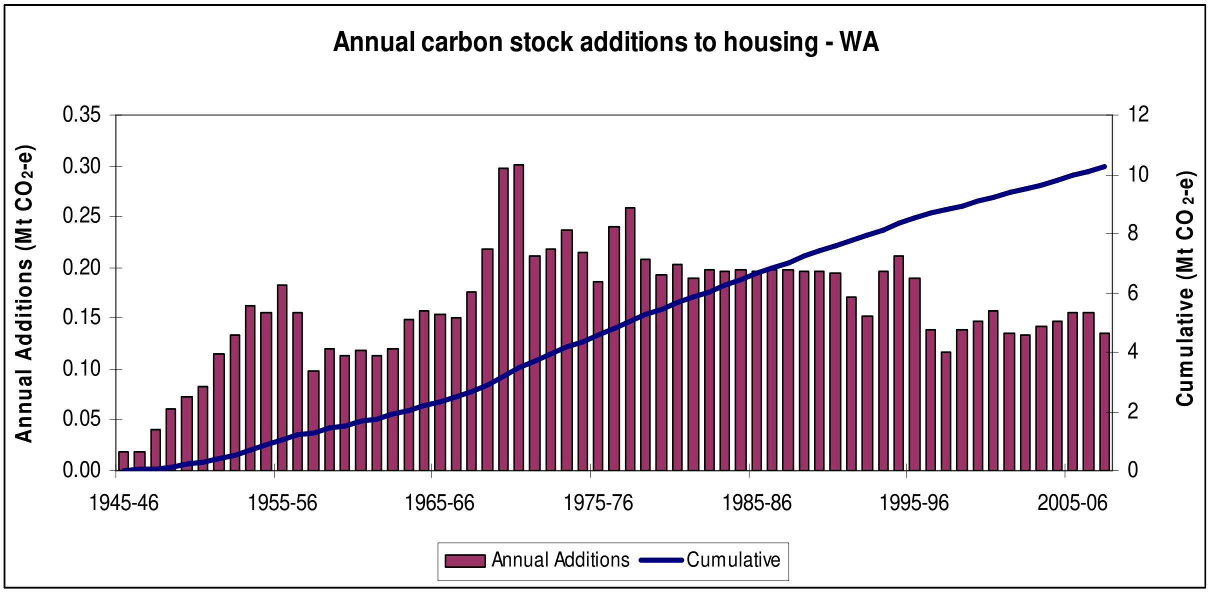
APPENDIX 6: Carbon estimates for States & Territories

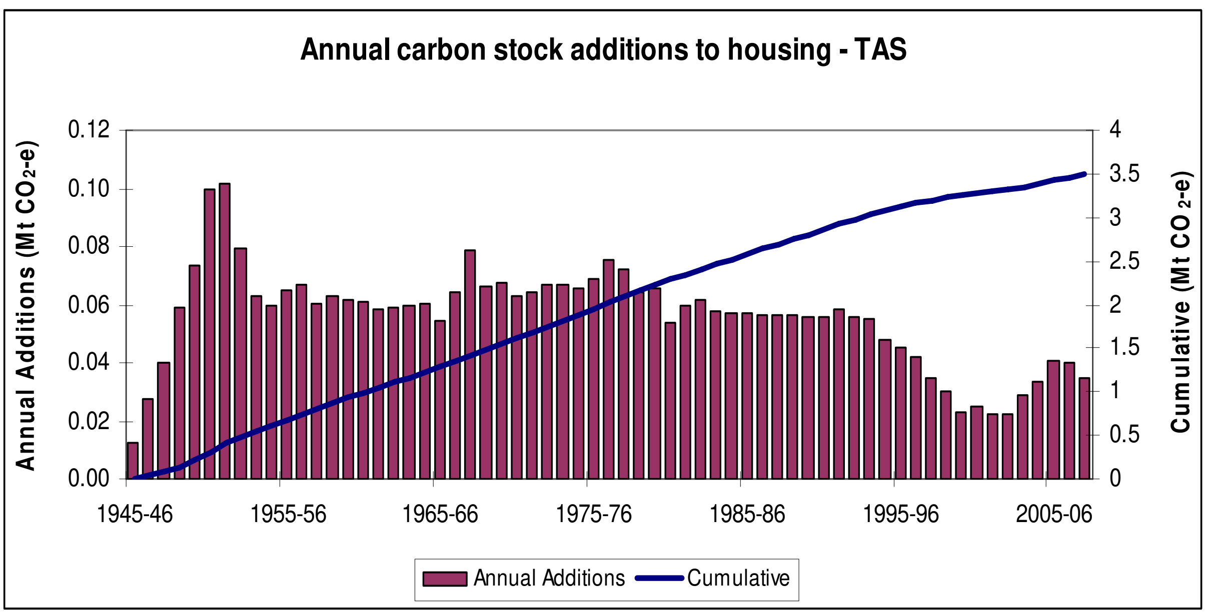





Annual carbon stock additions to housing - QLD
Annual Additions (Mt CO2-e)
Cumulative (Mt CO 2-e)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
30
25
20
15
10
5
0
1945-46
1955-56
1965-66
1975-76
1985-86
1995-96
2005-06
Annual Additions
Cumulative


Annual carbon additions to housing - SA
Annual Additions (Mt CO2-e)
Cumulative (Mt CO2-e)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
10
9
8
7
6
5
4
3
2
1
0
1945-46
1955-56
1965-66
1975-76
1985-86
1995-96
2005-06
Annual Additions
Cumulative


Annual carbon stock additions to housing - WA
Annual Additions (Mt CO2-e)
Cumulative (Mt CO2-e)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
12
10
8
6
4
2
0
1945-46
1955-56
1965-66
1975-76
1985-86
1995-96
2005-06
Annual Additions
Cumulative


Annual carbon stock additions to housing - TAS
Annual Additions (Mt CO2-e)
Cumulative (Mt CO2-e)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
4
3.5
3
2.5
2
1.5
1
0.5
0
1945-46
1955-56
1965-66
1975-76
1985-86
1995-96
2005-06
Annual Additions
Cumulative

APPENDIX 7: Assumptions used in carbon stock estimation

Wood species and density

Weighted wood basic densities used in the model are presented in the Table below.

Year	Softwoods %	Hardwoods %	Weighted basic density
1945	20	80	646
1955	29	71	613
1965	33	67	604
1975	45	55	545
1985	64	36	516
1995	69	31	511
2005	83	17	500

Carbon content

A carbon content of 50% carbon by dry weight was used, as it is the default factor used for wood products.

Proportion of carbon stock leaving the pool in use per year

A constant decay rate of 1.11% over 90 years (not 61 years estimated in this study) was assumed. It is the constant decay rate used in carbon stocks and flows model for Australia by the Department of Climate Change.

Assumed proportion of housing stock at Census that is timber-framed

	% of timber-framed dwellings
1911	0.87
1921	0.88
1933	0.88
1947	0.89
1954	0.89
1961	0.88
1966	0.86
1971	0.82
1976	0.82
1981	0.83
1986	0.83
1991	0.81
1996	0.85
2001	0.9
2006	0.92

Calculations for carbon stocks

Equations (1) and (2) were used to estimate carbon stocks based on number of completed dwellings per year. Equation (3) was used to estimate carbon stocks based on housing stock at Census years.

$$CS_J = Q \cdot A \cdot V \cdot D \cdot C \cdot R \cdot L / (MC \cdot 10^6) \quad (1)$$

$$CS_{Australia} = CS_{NSWACT} + CS_{VIC} + CS_{QLD} + CS_{SA} + CS_{WA} + CS_{TAS} \quad (2)$$

$$CS_{Census} = H \cdot A \cdot V \cdot D \cdot C \cdot R \cdot L / (MC \cdot 10^6) \quad (3)$$

where CS = estimated carbon stock

J = State or Territory

Q = number of dwellings per year

H = housing stock at Census (90% timber framed)

A = average floor area of dwellings

V = average wood volume per square metre of floor area

D = weighted wood basic density

C = carbon content of wood

R = ratio of atomic weights of carbon and oxygen

L = proportion of carbon stock remaining in use

MC = conversion factor for wood moisture content

Calculations for carbon losses from the pool

To estimate losses from the pool, a simple first order relationship in Equation 4 was used to convert the half-life into a decay curve that allowed the calculation of the fraction of carbon remaining in use as a function of time.

$$F = [1/ 1+(0.69315/H)]^T \quad (4)$$

where

F = fraction of carbon remaining in use in year T

H = half-life (years)

T = elapsed time/lifespan (years)

Although the average longevity or life span of dwellings (and wood) in this study was estimated as 61 years, further results regarding the fate of wood in demolished dwellings indicated that about 77 % of recycled timber is used in dwelling new construction. This extends the life span of wood well beyond the estimated 61 years. Using the life span of 61 years would therefore over-estimate the percentage of carbon losses per year (i.e. 1.64 %) instead of 1.11 % used by the DCC. A 90 year life span (consistent with DCC) was assumed in Equation 4 to estimate carbon losses from the pool at 1.11 % per year.

APPENDIX 8: Survey templates used

INFORMATION SHEET

National Research Survey: Dynamics of Carbon Stocks in Timber in Australian Residential Housing

The University of Melbourne is undertaking a project to improve the estimates of stocks and dynamics of carbon in timber products used in house construction in Australia. Increasing carbon storage in wood products in housing is a potentially important contribution to Australia's effort to reduce greenhouse gas emissions but more robust methods are required to support effective accounting of this component of the carbon cycle. This project is being supported by the Forest and Wood Products Research and Development Corporation.

We are surveying builders, quantity surveyors, house demolition companies, residential structural engineers, waste recycling companies and architects to collect data on timber usage, timber waste and timber waste disposal for this study.

The survey should take 20 – 25 minutes to complete. Your answers are completely confidential and will in no way be traceable to individual respondents once the survey process has been concluded. Questionnaire responses will be aggregated to give a total picture of the overall dynamics of carbon stocks in Australian housing. No individuals or individual firms will be referred to, and all identifying contextual information will be removed. In accordance with the university's Code of Conduct for Research principles, all data will be destroyed after five (5) years from the date of any publication which is based upon it.

Your organisation and contact details were obtained at random from *Websites* (Master Builders Associations; Australian Institute of Quantity Surveyors; The Association of Consulting Engineers Australia; Eco-Recycle Victoria); Business Listings of the Yellow Pages and various industry publications.

The project is supervised by me (Chief Investigator). Participation in the survey is voluntary, and you will be free to withdraw any unprocessed data previously supplied. However, the University of Melbourne will greatly appreciate your assistance and will gladly make available the results of this research to you at your request.

For any concerns about the conduct of this research project, please contact the Executive Officer, Human Research Ethics, The University of Melbourne. Ph: 8344 2073; Fax 9347 6739. For clarifications, please contact Dr Misheck Kapambwe on (03) 8344 7214, mobile: 0431129944, email: misheckk@unimelb.edu.au or Mr Fabiano Ximenes (DPI NSW) on (02) 9872 0143, email: fabianox@sf.nsw.gov.au

Please take the time to complete the appropriate questionnaire by **30 May 2008** and return it in the enclosed reply-paid envelope

Sincerely,

Professor Rod Keenan

ARCHITECTS' QUESTIONNAIRE

SECTION 1 BACKGROUND INFORMATION

1.1 Please indicate the following

Respondent Name …………………………………… Position/Title ……………………………..
Company Name ……………………………………………………………………………………….
Address ………………………………………………………………………………………………..
Postcode ………………… Telephone Number ………………… Fax Number ……………….
E-mail ………………………………………………………………………………………………..
Location(s) of your projects: Cities……………………………………………………………………
Regional Areas…………………………………………………………..

1.2 Please indicate the range that best describes the average number of your employees (average of last 3 years). **Please select one box only**

1 ☐ Less than 5
2 ☐ 5 - 9
3 ☐ 10 - 24
4 ☐ 25 - 39
5 ☐ 40 or more

1.3 Which of the following broad categories best describes your company's average total annual turnover (fees inclusive) over the last 3 years? **Please select one box only**

1 ☐ $1million or less
2 ☐ $1 to $5 million
3 ☐ $5 to $10 million
4 ☐ $10 to $15 million
5 ☐ $15 million or more

1.4 Please indicate the number of dwelling projects (complete new dwellings and extensions) you do per year (average of last 3 years) **Please select one box only**

1 ☐ Less than 5
2 ☐ 5 - 10
3 ☐ 10 - 15
4 ☐ 15 - 20
5 ☐ 20 or more

SECTION 2 LIFE SPAN OF AUSTRALIAN DWELLINGS

Please answer the following questions based on your professional experience of Australian timber-framed residential dwellings in your practice

2.1 Please estimate the average lifespan of the following Australian dwelling types

1 Detached house ☐ <25yrs ☐ 25yrs ☐ 50yrs ☐ 75yrs ☐100yrs ☐
100yrs

2 Attached dwelling ☐ <25yrs ☐ 25yrs ☐ 50yrs ☐ 75yrs ☐100yrs ☐
100yrs

3 Flat or unit ☐ <25yrs ☐ 25yrs ☐ 50yrs ☐ 75yrs ☐100yrs ☐
100yrs

4 Other (specify)

……………………. ☐ <25yrs ☐ 25yrs ☐ 50yrs ☐ 75yrs ☐100yrs ☐
100yrs

2.2 Below are some of the reasons for demolishing dwellings in Australia. Please estimate the proportion of dwellings demolished for each reason.

(a) Reason for demolishing dwellings	(b) Proportion of dwellings Demolished for this reason
1 ☐ Site redevelopment (e.g. existing dwelling is inadequate, existing dwelling making way for more dwellings, etc)	☐ (%)
2 ☐ Dwelling ceases to suit the owner's need (e.g. change in family size, aging, etc)	☐ (%)
3 ☐ Dwelling becomes unserviceable (e.g. fire damage, termite or European house borer damage, etc)	☐ (%)
4 ☐ Other (Please specify) …………………………………. ……………………………………………………………	☐ (%)

SECTION 3 TREATED FRAMING IN HOUSE CONSTRUCTION

Treated framing is either being considered for use or is being used in dwelling construction by some builders. '*Treated framing' means using preservative treated timber and timber products in structural applications in dwelling construction.*

3.1 Do you specify treated framing for dwelling construction?
Please select one box only.

1 ☐ Yes

2 ☐ No

3.2 If your answer for Question 3.1 is **'Yes'**, on what proportion of dwellings have you specified treated framing?.

1 ☐ 5%

2 ☐ 10%

3 ☐ 15%

4 ☐ Other (*Please specify)*……………%.

3.3 What would be your reason(s) for specifying treated framing for dwelling construction?.

1 ☐ To prevent fungi attack

2 ☐ To prevent termite/borer attack

3 ☐ To provide fire resistance

4 ☐ Other (*Please specify)*…………………………………………………

3.4 If your answer for Question 3.1 is **'No'**, what would be your reason(s) for **NOT** specifying treated framing for house construction?

(a)……………………………………………………………………………………….

(b)……………………………………………………………………………………….

(c)……………………………………………………………………………………….

(d)……………………………………………………………………………………….

SECTION 4 POLICY OPTIONS FOR INCREASING TIMBER USE IN CONSTRUCTION

Wood products used in building construction are an important store of carbon. By increasing the usage of wood products in specific building applications we can potentially increase the storage of carbon, which will assist in the reduction of greenhouse gases in the atmosphere.

This section is asking your opinion on what can be done by State/Federal governments, builders, forest products industry, etc to increase the usage of timber and timber products in specific building applications of residential dwellings.

4.1 Based on your expertise, please rank the following policy options in terms of the potential to increase the quantity of wood products used in residential dwelling construction, **using a scale of 1 to 3, where 1= greatest potential, 2=good potential , 3=least potential**

	Policy Option	Ranking
1	Better training and education for building surveyors, building designers and builders on the carbon storage benefits of wood products	☐
2	Reduction in the relative price of wood products compared to competing products as a result of emissions trading permits or a carbon tax	☐
3	Changes in the government regulations or building codes, for example, to allow timber products to be used in a wider range of building applications than is currently allowed.	☐

4.2 In your opinion, what additional actions could increase the quantity of timber and timber products used in constructing the following types of residential dwellings in Australia. Please indicate the potential increase (%) in timber quantities due to such action(s).

(a) Detached house
…………………………………………………………………………………………………
…………………………………………………………………………………………………

(b) Attached dwelling (townhouse, semi-detached, terrace)
…………………………………………………………………………………………………
…………………………………………………………………………………………………

(c) Flat/unit
…………………………………………………………………………………………………
…………………………………………………………………………………………………

(d) Other (please specify…………………………………)
…………………………………………………………………………………………………
…………………………………………………………………………………………………

BUILDERS OF NEW DWELLINGS QUESTIONNAIRE

SECTION 1 BACKGROUND INFORMATION

1.1 Please indicate the following

Respondent Name …………………………………… Position/Title ………………………………....

Company Name………………………………………………………………………………………

Address……………………………………………………………………………………………….

Postcode ………………… Telephone Number ………………… Fax Number……………………….

E-mail ……………………………………………………………………………………………

Location(s) of your projects: Cities…………………………………………………………………

Regional Areas……………………………………………………………

1.2 Please indicate the range that best describes the average number of your employees (average of last 3 years) **Please select one box only**

1 ☐ Less than 10

2 ☐ 10 - 25

3 ☐ 25 - 40

4 ☐ 40 - 55

5 ☐ 55 or more

1.3 Which of the following broad categories best describes your company's average total annual turnover over the last 3 years? **Please select one box only**

1 ☐ $1million or less

2 ☐ $1 to $5 million

3 ☐ $5 to $10 million

4 ☐ $10 to $15 million

5 ☐ $15 million or more

1.4 Please indicate the number of dwellings constructed per year (average of last 3 years)

Number of dwellings ☐

SECTION 2 ESTIMATED TIMBER USAGE IN DWELLINGS

This Section requires you to estimate timber usage in dwelling construction. You can base the estimates on any of your recent projects. To do this, you are to

- First, select or nominate the **Construction system** that represents the largest proportion of residential dwellings built by your company.
- Select or nominate the **Type of dwelling**
- Select or nominate the **Size of dwelling** on which you will base your estimates.

Then answer Question 2.4 to estimate the timber usage.

2.1 Which of the following construction systems does your company use to construct the largest proportion of residential dwellings?

1 Timber framed with brick veneer ☐ %

2 Double brick ☐ %

3 Other ☐ (please nominate) ☐ %

2.2 Please select or nominate the Type of dwelling on which you will base your timber usage estimates.

1 ☐ Detached house single storey

2 ☐ Detached house double storey

3 ☐ Single storey Attached dwelling (townhouse, semi-detached, terrace)

4 ☐ Double storey Attached dwelling (townhouse, semi-detached, terrace)

5 ☐ Single storey Flat/Unit

6 ☐ Double storey Flat

7 ☐ Other (please nominate) ☐

2.3 Please select or nominate the Size of dwelling on which you will base your timber usage estimates.

1 ☐ 150 m^2

2 ☐ 200 m^2

3 ☐ 400 m^2

4 ☐ Other (please nominate) ☐ m^2

Please answer Questions 2.4 on the basis of your selections or nominations in Questions 2.1, 2.2, and 2.3.

2.4 (a) In the Table below, please indicate in the box (☒) whether timber or non-timber products were used in the sub-floor and ground floor framing, upper floor framing, wall framing and roof framing of the dwelling type and size that you selected/nominated?

1	2	3		1	2	3
Framing Members	Timber Material Used	Non-timber Material used		Framing Members	Timber Material Used	Non-timber Material used
Sub-floor				**Wall Framing**		
Stumps & Posts	☐	☐		Wall plates	☐	☐
Sub-floor Bracing	☐	☐		Studs	☐	☐
				Heads & Lintels	☐	☐
Ground Floor Framing & Flooring				Nogging	☐	☐
Bearers	☐	☐				
Floor Joists	☐	☐		**Wall Bracing**		
Floor trusses	☐	☐		Timber	☐	☐
Laminated veneer lumber (LVL)	☐	☐		Plywood	☐	☐
				Wall Lining		
Sheet Flooring				Particleboard	☐	☐
Particleboard	☐	☐		Plywood	☐	☐
Floor Covering				MDF	☐	☐
Solid timber	☐	☐				
Floating floor	☐	☐		**Roof Framing**		
Plywood	☐	☐		Ceiling Joists	☐	☐
				Ceiling trimmers	☐	☐
Upper Floor Framing & Flooring				Hanging beams	☐	☐
Floor Joists	☐	☐		Rafters	☐	☐
Engineered Joists	☐	☐		Ridge/hip	☐	☐
Flange & web	☐	☐		Battens	☐	☐
Composite				Purlins	☐	☐
Floor trusses	☐	☐		Struts	☐	☐
Sheet Flooring				Strutting beams	☐	☐
Particleboard	☐	☐		Collar tie	☐	☐
Floor Covering				Valley boards	☐	☐
Solid timber	☐	☐				
Floating floor	☐	☐		**Roof Trusses**	☐	☐
Plywood	☐	☐				

2.4 (b) In terms of volume, which of the following is your best estimate of the total volume of timber and timber products used in the above Table?

1 ☐ 8-9 m^3

2 ☐ 10-11 m^3

3 ☐ 12-13 m^3

4 ☐ 14-15 m^3

5 ☐ 16-17 m^3

6 ☐ Other ____ m^3

2.5 What percentage (%) of the timber and timber products volume in Question 2.4 is used in the following building applications?

1. Floor system			
	Sub-floor		% (To the nearest 5%)
	Upper-floor		% (To the nearest 5%)
2. Wall system			% (To the nearest 5%)
3. Roof system			.% (To the nearest 5%)
4. Joinery and fittings			.% (To the nearest 5%)
5. Other (please specify) ………………………			% (To the nearest 5%)
	Total to equal	**100 %**	

2.6 Please indicate the proportions (%) of softwood and hardwood timber used in residential dwelling construction?

1	Softwoods		% (To the nearest 5%)
2	Hardwoods		% (To the nearest 5%)

SECTION 3 TREATED FRAMING IN DWELLING CONSTRUCTION

Treated framing is either being considered for use or is being used in dwelling construction by some builders. '*Treated framing' means using preservative treated timber and timber products in structural applications in residential dwelling construction.*

3.1 Do you use treated framing in dwelling construction?
Please select one box only.

1 ☐ Yes

2 ☐ No

3.2 If your answer for Question 3.1 is **'Yes'**, how long have you used treated framing in dwelling construction?

1 ☐ 5 years

2 ☐ 10 years

3 ☐ 15 years

4 ☐ Other (*Please specify)……………%.*

3.3 **W**hat proportion of the dwellings you construct use treated framing?

1 ☐ 5%

2 ☐ 10%

3 ☐ 15%

4 ☐ Other (*Please specify)……………%.*

3.4 What would be your reason(s) for using treated framing for dwelling construction?.

1 ☐ To prevent fungi attack

2 ☐ To prevent termite/borer attack

3 ☐ To provide fire resistance

4 ☐ Other (*Please specify)*……………………………………………………………

3.5 If your answer for Question 3.1 is **'No'**, what would be your reason(s) for **NOT** using treated framing for house construction?

(a)……………………………………………………………………………………….

(b)……………………………………………………………………………………….

(c)……………………………………………………………………………………….

(d)……………………………………………………………………………………….

SECTION 4 TIMBER WASTE AND DISPOSAL METHODS

4.1 When you order timber quantities, how much (%) do you allow for timber wastage and other losses during the construction process?

Please select one box only

1 ☐ 10%
2 ☐ 15%
3 ☐ 20%
4 ☐ 25%
5 ☐ Other (please specify) ☐

4.2 What proportion of your timber waste is:

(a) utilised in some way (e.g. recycled, firewood, mulched, etc..) ☐ (%)

(b) disposed of (e.g. in landfill or burnt without energy recovery) ☐ (%)

Total to equal **100 %**

4.3 Where do you use timber waste from your construction sites? In the Table below, please

(a) select the major end uses of timber waste, and
(b) indicate the proportion of timber waste used for each major end-use

(a) Major end-use of timber waste			(b) Proportion used for this end-use
1	☐	Reused (e.g. for pallets, furniture, etc)	☐ (%)
2	☐	Direct recycling (e.g. manufacture of other wood materials like particleboard, finger-jointing, etc)	☐ (%)
3	☐	Indirect recycling (e.g. mulch, compost, animal bedding, etc)	☐ (%)
4	☐	Energy recovery (e.g. pellets, boiler fuel, electricity, process heat, etc)	☐ (%)
5	☐	Other (Please specify) ……………………………………….	☐ (%)
		Total to equal	**100%**

4.4 How do you dispose of the timber waste that you do not reuse or recycle? In the Table below please

(a) select the method(s) used to dispose of timber waste, and
(b) indicate the proportion disposed using the method(s)

(a) Disposal Method		(b) Proportion disposed by this method
1 ☐	Landfill	☐ (%)
2 ☐	Other (Please specify) ……………………………..	☐ (%)
	Total to equal	**100%**

SECTION 5 ACCURACY OF ESTIMATES

5.1 How would you rate the accuracy of your estimates in the above questions in relation to the following?

	Very accurate (± 10%)	*Somewhat accurate (± 30%)*	*Somewhat inaccurate (± 50%)*	*Very inaccurate (± 100%)*
1 Timber usage (*Section 2*)	☐	☐	☐	☐
2 Treated framing usage (*Section 3*)	☐	☐	☐	☐
3 Timber waste and disposal methods (*Section 4*)	☐	☐	☐	☐

SECTION 6 POLICY OPTIONS FOR INCREASING TIMBER USE IN CONSTRUCTION

Wood products used in building construction are an important store of carbon. By increasing the usage of wood products in specific building applications we can potentially increase the storage of carbon, which will assist in the reduction of greenhouse gases in the atmosphere.

This section is asking your opinion on what can be done by State/Federal governments, forest products industry, builders, etc to increase the usage of timber and timber products in specific building applications.

6.1 Based on your expertise, please rank the following policy options in terms of the potential to increase the quantity of wood products used in residential dwelling construction, **using a scale of 1 to 3, where 1= greatest potential, 2=good potential , 3=least potential**

	Policy Option	Ranking
1	Better training and education for building surveyors, building designers and builders on the carbon storage benefits of wood products	☐
2	Reduction in the relative price of wood products compared to competing products as a result of emissions trading permits or a carbon tax	☐
3	Changes in the government regulations or building codes, for example, to allow timber products to be used in a wider range of building applications than is currently allowed.	☐

6.2 In your opinion, what additional actions could increase the quantity of timber and timber products used in constructing the following types of residential dwellings in Australia. Please indicate the potential increase (%) in timber quantities due to such action(s).

(a) Detached house
…………………………………………………………………………………………………
…………………………………………………………………………………………………

(b) Attached dwelling (townhouse, semi-detached, terrace)
…………………………………………………………………………………………………
…………………………………………………………………………………………………

(c) Flat/unit
…………………………………………………………………………………………………
…………………………………………………………………………………………………

(d) Other (please specify…………………………………)
…………………………………………………………………………………………………
…………………………………………………………………………………………………

MANUFACTURERS OF TIMBER WALL FRAMES & TRUSSES QUESTIONNAIRE

SECTION 1 BACKGROUND INFORMATION

1.1 Please indicate the following

Respondent Name …………………………………… Position/Title ………………………………...

Company Name………………………………………………………………………………………

Address……………………………………………………………………………………………….

Postcode ………………… Telephone Number ………………… Fax Number……………………….

E-mail ………………………………………………………………………………………………

Location(s) of your projects: Cities………………………………………………………………………

Regional Areas……………………………………………………………

1.2 Please indicate the range that best describes the average number of your employees (average of last 3 years) **Please select one box only**

1 ☐ Less than 10
2 ☐ 10 - 25
3 ☐ 25 - 40
4 ☐ 40 - 55
5 ☐ 55 or more

1.3 Which of the following broad categories best describes your company's average total annual turnover over the last 3 years? **Please select one box only**

1 ☐ $1million or less
2 ☐ $1 to $5 million
3 ☐ $5 to $10 million
4 ☐ $10 to $15 million
5 ☐ $15 million or more

SECTION 2 TREATED FRAMING IN DWELLING CONSTRUCTION

Treated frames/trusses are either being considered for use or are being used in dwelling construction by some builders and home owners. '*Treated frame/truss' means using preservative treated timber and timber products to manufacture frames/trusses for use in residential dwelling construction.*

2.1 Do you use treated timber and timber products in frame/truss manufacturing? **Please select one box only**.

1 ☐ Yes

2 ☐ No

2.2 If your answer for Question 2.1 is **'Yes'**, how long have you used treated timber and timber products in frame/truss manufacturing?

1 ☐ 5 years

2 ☐ 10 years

3 ☐ 15 years

4 ☐ Other (*Please specify)……………%.*

2.3 What proportion of the frames/trusses you manufacture use treated timber and timber products?

1 ☐ 5%

2 ☐ 10%

3 ☐ 15%

4 ☐ Other (*Please specify)……………%.*

2.4 What would be your reason(s) for using treated timber and timber products in frame and truss manufacturing?

1 ☐ To prevent fungi attack

2 ☐ To prevent termite/borer attack

3 ☐ To provide fire resistance

4 ☐ Other (*Please specify)*…………………………………………………………….

2.5 If your answer for Question 2.1 is **'No'**, what would be your reason(s) for **NOT** using treated timber and timber products in frame/truss manufacturing?

(a)……………………………………………………………………………………….

(b)……………………………………………………………………………………….

(c)……………………………………………………………………………………….

(d)……………………………………………………………………………………….

SECTION 3 TIMBER WASTE AND DISPOSAL METHODS

3.1 Which of the following two statements describes your reported timber products usage in frame and truss manufacturing?

1 ☐ Timber products volume delivered to the manufacturing site as specified by the architect/quantity surveyor/builder.

2 ☐ Timber products volume delivered to the manufacturing site as specified by the architect/quantity surveyor/builder **LESS** losses, breakage, misuse, and theft during frame/truss manufacturing

3.2 When you order timber quantities, how much (%) do you allow for timber wastage and other losses during frame/truss manufacturing process?

Please select one box only

1 ☐ 10%

2 ☐ 15%

3 ☐ 20%

4 ☐ 25%

5 ☐ Other (please specify) ☐

3.3 What proportion of your timber waste is:

(a) utilised in some way (e.g. recycled, firewood, mulched, etc..) ☐ (%)

(b) disposed of (e.g. in landfill or burnt without energy recovery) ☐ (%)

Total to equal **100 %**

3.4 Where do you use timber waste from your manufacturing sites? In the Table below, please

(a) select the major end uses of timber waste, and
(b) indicate the proportion of timber waste used for each major end-use

		(a) Major end-use of timber waste	(b) Proportion used for this end-use
1	☐	Reused (e.g. for pallets, furniture, etc)	☐ (%)
2	☐	Direct recycling (e.g. manufacture of other wood materials like particleboard, finger-jointing, etc	☐ (%)
3	☐	Indirect recycling (e.g. mulch, compost, animal bedding, etc)	☐ (%)
4	☐	Energy recovery (e.g. pellets, boiler fuel, electricity, process heat, etc)	☐ (%)
5	☐	Other (Please specify) ……………………………………….	☐ (%)
		Total to equal	**100%**

3.5 How do you dispose of the timber waste that you do not reuse or recycle? In the Table below please

(a) select the method(s) used to dispose of timber waste, and
(b) indicate the proportion disposed using the method(s)

		(a) Disposal Method	(b) Proportion disposed by this method
1	☐	Landfill	☐ (%)
2	☐	Other (Please specify) ……………………………..	☐ (%)
		Total to equal	**100%**

SECTION 4 POLICY OPTIONS FOR INCREASING TIMBER USE IN CONSTRUCTION

Wood products used in building construction are an important store of carbon. By increasing the usage of wood products in specific building applications we can potentially increase the storage of carbon, which will assist in the reduction of greenhouse gases in the atmosphere.

This section is asking your opinion on what can be done by State/Federal governments , forest products industry, builders , etc to increase the usage of timber and timber products in specific building applications.

4.1 Based on your expertise, please rank the following policy options in terms of the potential to increase the quantity of wood products used in residential dwelling construction, **using a scale of 1 to 3, where 1= greatest potential, 2=good potential , 3=least potential**

	Policy Option	Ranking
1	Better training and education for building surveyors, building designers and builders on the carbon storage benefits of wood products	☐
2	Reduction in the relative price of wood products compared to competing products as a result of emissions trading permits or a carbon tax	☐
3	Changes in the government regulations or building codes, for example, to allow timber products to be used in a wider range of building applications than is currently allowed.	☐

4.2 In your opinion, what additional actions could increase the quantity of timber and timber products used in constructing the following types of residential dwellings in Australia. Please indicate the potential increase (%) in timber quantities due to such action(s).

(a) Detached house
………………………………………………………………………………………………………
………………………………………………………………………………………………………

(b) Attached dwelling (townhouse, semi-detached, terrace)
………………………………………………………………………………………………………
………………………………………………………………………………………………………

(c) Flat/unit
………………………………………………………………………………………………………
………………………………………………………………………………………………………

(d) Other (please specify…………………………………)
………………………………………………………………………………………………………
………………………………………………………………………………………………………

SECTION 5 ACCURACY OF ESTIMATES

5.1 How would you rate the accuracy of your estimates in the above questions in relation to the following?

	Very accurate (± 10%)	*Somewhat accurate (± 30%)*	*Somewhat inaccurate (± 50%)*	*Very inaccurate (± 100%)*
1 Treated framing usage (*Section 2*)	☐	☐	☐	☐
2 Timber waste and disposal methods (*Section 3*)	☐	☐	☐	☐

RESIDENTIAL BUILDING DEMOLITIONS QUESTIONNAIRE

SECTION 1 BACKGROUND INFORMATION

1.1 Please indicate the following

Respondent Name …………………………………… Position/Title ……………………………

Company Name……………………………………………………………………………………

Address………………………………………………………………………………………..….

Postcode ………………… Telephone Number ………………… Fax Number……………….

E-mail ………………………………………………………………………………………...

Location(s) of your projects: Cities…………………………………………………………………

Regional Areas……………………………………………………..

1.2 Please indicate the range that best describes the average number of your employees (average of last 3 years) **Please select one box only**

1 ☐ Less than 10
2 ☐ 10 - 25
3 ☐ 25 - 40
4 ☐ 40 - 55
5 ☐ 55 or more

1.3 Which of the following broad categories best describes your company's average total annual turnover over the last 3 years? **Please select one box only**

1 ☐ $1million or less
2 ☐ $1 to $5 million
3 ☐ $5 to $10 million
4 ☐ $10 to $15 million
5 ☐ $15 million or more

1.4 Please indicate the number of dwelling demolitions you carry out per year (average of last 3 years). **Please select one box only**

1 ☐ Less than 5
2 ☐ 5 - 10
3 ☐ 10 - 15
4 ☐ 15 - 20
5 ☐ 20 or more

SECTION 2 CHARACTERISTICS OF DEMOLISHED DWELLINGS

2.1 Please select the most common dwelling types that your company demolished between 2005 and 2007. Please indicate the proportion (%) for each selected dwelling type.

1 Detached house ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

2 Attached dwelling ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

3 Flat or unit ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

4 Other (specify)
…………………… ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

2.2 Please give an estimate (%) of the construction style for the demolished dwelling(s) you selected in Question 2.1.

1 ☐ Colonial Georgian style (1788-1850)

Proportion ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

2 ☐ The Victorian style (1850-1900).

Proportion ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

3 ☐ Federation style (1901-1916)

Proportion ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

4 ☐ Post-world war I style (1920s-1930s)

Proportion ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

5 ☐ Post-world war II (1950s-1960)

Proportion ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

6 ☐ Late twentieth century (1960s-1980s)

Proportion ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

7 ☐ Late twentieth century post-modern (1980s onwards)

Proportion ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

SECTION 3 SALVAGED TIMBER

3.1 Please give an estimate of the average quantity (%) of timber you salvage per type of dwelling you selected in Question 2.1.

(a) Detached house

☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other ☐

(b) Attached dwelling (townhouse, semi-detached, terrace)

☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other ☐

(c) Flat or unit

☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other ☐

3.2 What are the major end-uses of salvaged timber? In the Table below, please

(a) select the major end uses of recovered timber, and
(b) indicate the proportion of recovered timber for that end use

(a) Major end-use of timber waste		(b) Proportion used for this end-use
1	☐ Reused (e.g. for pallets, furniture, flooring, etc)	☐ (%)
2	☐ Direct recycling (e.g. manufacture of other wood materials like particleboard, finger-jointing, etc)	☐ (%)
3	☐ Indirect recycling (e.g. mulch, compost, animal bedding, etc)	☐ (%)
4	☐ Energy recovery (e.g. pellets, boiler fuel, electricity, process heat, etc)	☐ (%)
5	☐ Other (Please specify) ……………………………………….	☐ (%)
	Total to equal	**100%**

SECTION 4 DISPOSAL OF UNSALVAGED TIMBER

4.1 What method(s) do you use to dispose of the timber waste that you do not salvage from demolition sites? In the Table below, please

(a) select the method(s) used to dispose of timber waste, and
(b) indicate the proportion disposed using the method(s)

(a) Disposal Method			(b) Proportion disposed by this method
1	☐	Landfill	☐ (%)
2	☐	Other (Please specify) …………………………..	☐ (%)
		Total to equal	**100%**

SECTION 5 ACCURACY OF ESTIMATES

5.1 How would you rate the accuracy of your estimates in the above questions in relation to the following?

	Very accurate (± 10%)	*Somewhat accurate (± 30%)*	*Somewhat inaccurate (± 50%)*	*Very inaccurate (± 100%)*
1 Characteristics of demolished dwellings (*Section 2*)	☐	☐	☐	☐
3 Fate of salvaged timber (*Sections 3 & 4*)	☐	☐	☐	☐

RESIDENTIAL BUILDING DEMOLITIONS QUESTIONNAIRE

SECTION 1 BACKGROUND INFORMATION

1.1 Please indicate the following

Respondent Name …………………………………… Position/Title ……………………………
Company Name…………………………………………………………………………………….
Address……………………………………………………………………………………..….
Postcode ………………… Telephone Number ………………… Fax Number……………….
E-mail ……………………………………………………………………………………...
Location(s) of your projects: Cities………………………………………………………………
Regional Areas……………………………………………………..

1.2 Please indicate the range that best describes the average number of your employees (average of last 3 years) **Please select one box only**

1 ☐ Less than 10
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2 Attached dwelling ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

3 Flat or unit ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

4 Other (specify) ……………………… ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

2.2 Please give an estimate (%) of the construction style for the demolished dwelling(s) you selected in Question 2.1.

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Proportion ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

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Proportion ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

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Proportion ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

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Proportion ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

5 ☐ Post-world war II (1950s-1960)

Proportion ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

6 ☐ Late twentieth century (1960s-1980s)

Proportion ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

7 ☐ Late twentieth century post-modern (1980s onwards)

Proportion ☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other

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☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other ____

(b) Attached dwelling (townhouse, semi-detached, terrace)

☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other ____

(c) Flat or unit

☐ 5% ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ other ____

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2	☐	Direct recycling (e.g. manufacture of other wood materials like particleboard, finger-jointing, etc)	____ (%)
3	☐	Indirect recycling (e.g. mulch, compost, animal bedding, etc)	____ (%)
4	☐	Energy recovery (e.g. pellets, boiler fuel, electricity, process heat, etc)	____ (%)
5	☐	Other (Please specify) …………………………………………..	____ (%)
		Total to equal	**100%**

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(a) Disposal Method			(b) Proportion disposed by this method
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2	☐	Other (Please specify) …………………………..	☐ (%)
		Total to equal	**100%**

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3 Fate of salvaged timber (*Sections 3 & 4*)	☐	☐	☐	☐