E356

Timber products in new Government buildings

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Timber products in new Government buildings

1. CLIENT

Ministry of Agriculture & Forestry
101-103 The Terrace
Wellington 6015
New Zealand

2. SUMMARY

This report provides data on the potential use of timber in the structure and envelop of Government buildings. The estimate number of Government buildings that could be converted to greater timber use, and the associated carbon emission savings, are in Table 1.

Table 1 Government buildings potentially redesigned for increased timber use

Candidate Government buildings and their savings						
Calender year	**04**	**05**	**06**	**07**	**08**	**09**
Number of eligible projects	85	107	78	81	81	69
Embodied energy savings (GJ)	60100	75400	58800	63300	63300	54600
CO2 release savings (tonnes)	25900	32500	25300	27300	27300	23600
Eligible projects are Government buildings, over $750,000 and which are likely to be suitable for structural timber framing.						

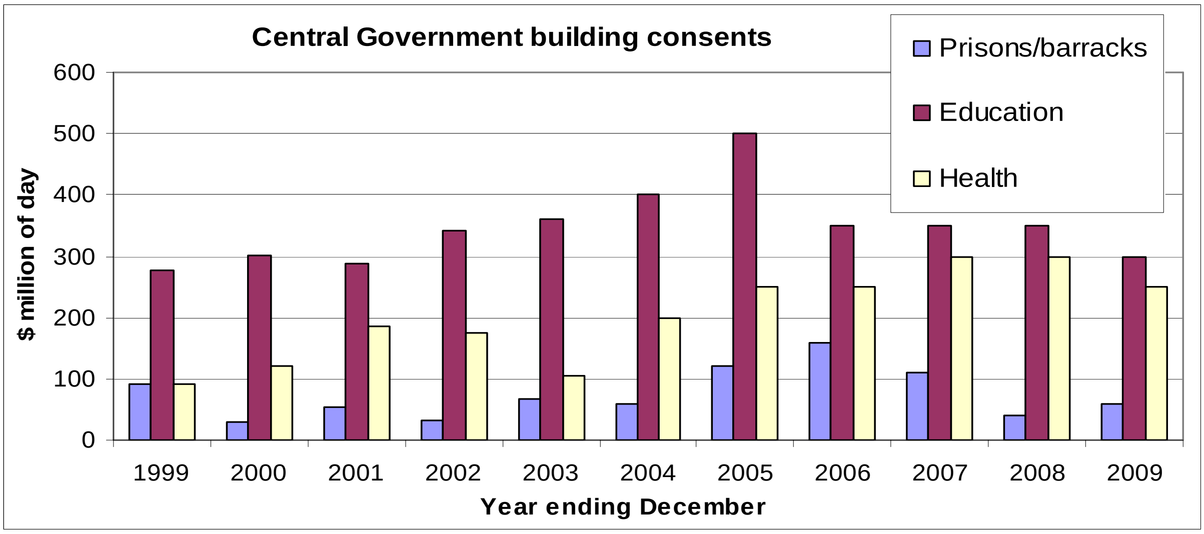
The numbers in the table allow for a proportion of the forecast large building projects to be converted to greater timber use, considering the type of building, and the typical number of storeys in such buildings. In many of these cases the building cost is expected to be less than for alternative designs using other materials. Assuming there is flow-on to the private sector, it is estimated that the savings in Table 1 can be increased by approximately 100%, giving about 160 eligible Government and private sector buildings per year.

3. CENTRAL GOVERNMENT BUILDING ACTIVITY

3.1 Recent trends and forecasts

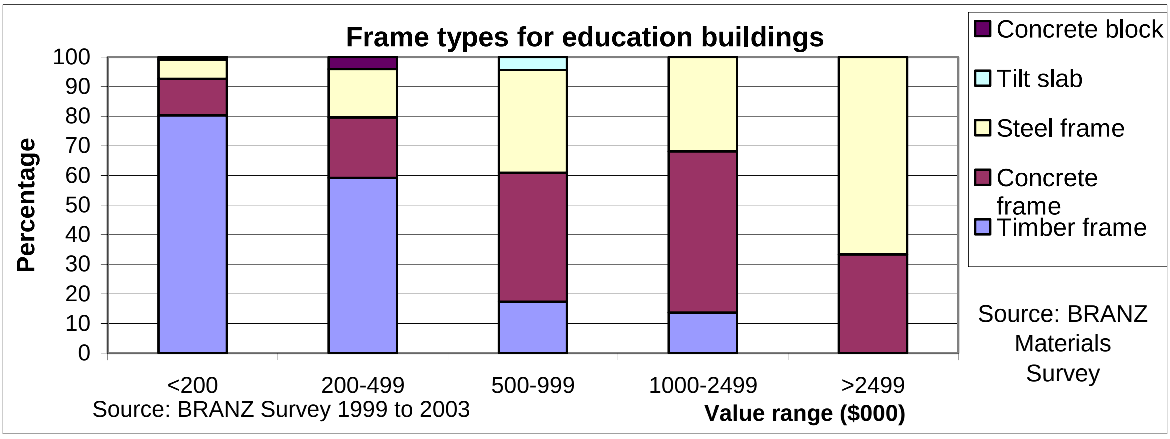
Figure 1 shows the value of central Government building consents in the recent past, and the BRANZ forecasts. Education buildings predominate, followed by health buildings and prisons/ defence barracks. Education building work peaks in 2005 to accommodate the student roll bulge, now moving from primary schools into secondary schools. There is a large health sector building programme underway, which is replacing the infrastructure built in the 1970s, and preparing for an expected increase in demand due to an aging population. In the prison sector there is a projected 25% increase in inmates over the next six years, and a large building programme has started.

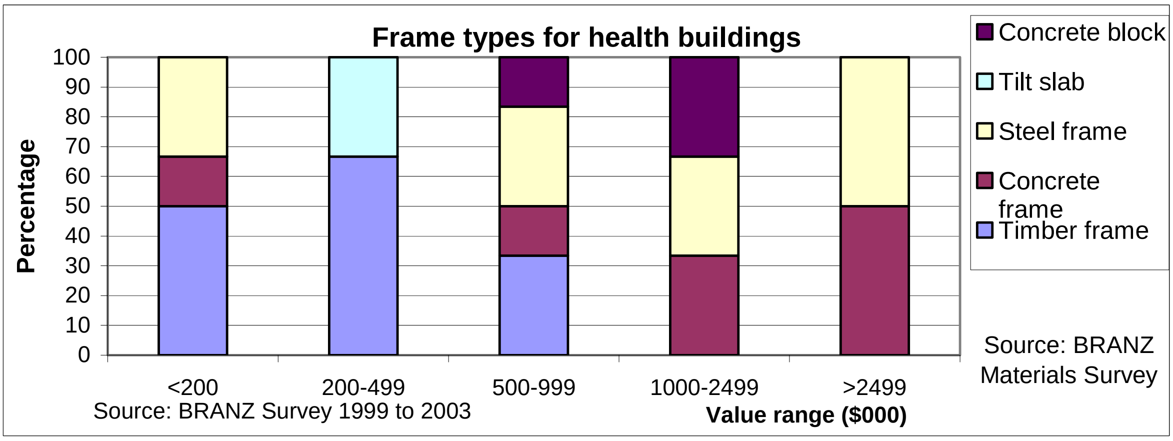
Figure 1 BRANZ Work activity forecasts



The Ministry of Agriculture and Forestry aims to promote the greater use of timber in Government buildings. Smaller buildings, below $500,000 in value, commonly use timber framing now, but larger Government buildings are normally built in steel and concrete, see Figure 2. Larger buildings have been suggested as a target for timber promotion programmes. Note that many large buildings already use significant volumes of timber as infill framing between the main frame, and for partition walls (non-load bearing walls).

Figure 2 Frame types in Government buildings

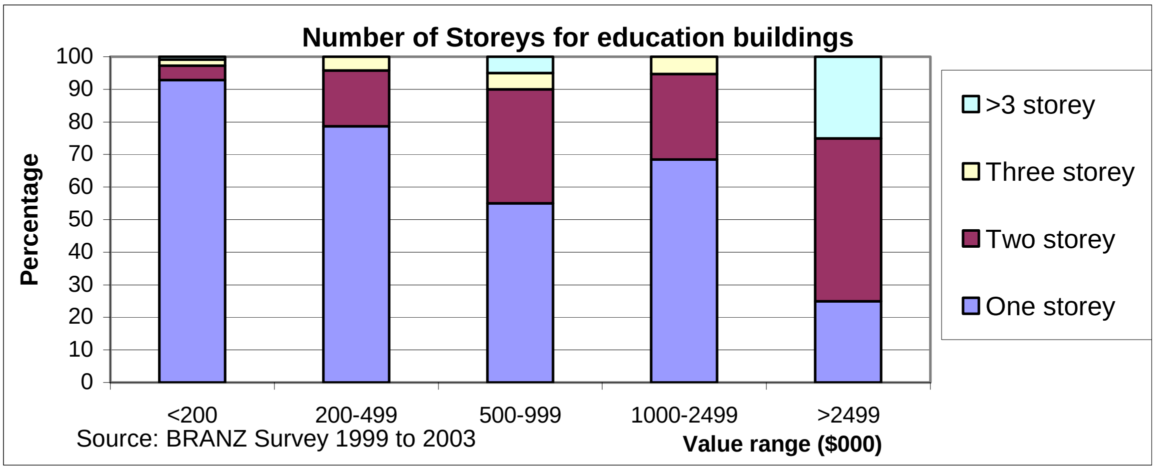


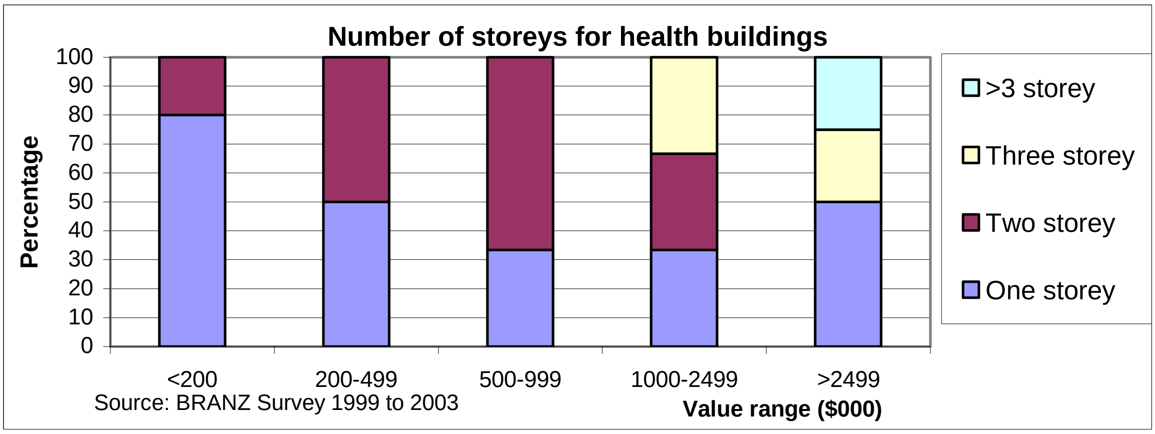


Figures 2 and 3 show characteristics of the education and health buildings, based on the BRANZ Materials Survey data. The number of buildings in the survey over $500,000 is quite low for health buildings, (20 buildings), whereas it is over 200 for education buildings. Hence the charts for education are more reliable. Only two returns were obtained for prisons/ barracks in the survey over the last 5 years and hence it has not been possible to include them in the charts. Generally prison buildings are low rise constructed in concrete masonry and tilt slab.

Figure 3 shows the number of storeys by value group. Education buildings are likely to be single storey, up to quite large building values and include halls, performing arts, gyms and administration buildings. Health buildings are more likely to be multi-storey. However, as discussed later, the trend in new hospital design is for low rise, large footprint buildings.

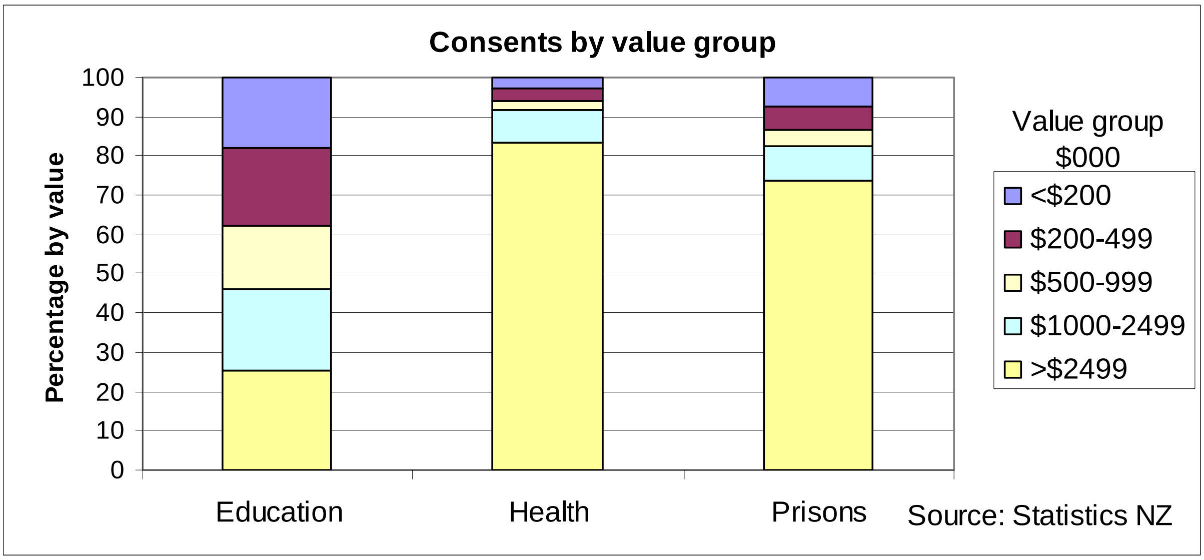
Figure 3 Storeys in Government buildings





The distribution of building consents by value range is shown in Figure 4. Education has a large number of low value consents typically for one or two classroom additions, and together these smaller projects have a significant percentage of the total value of work. Conversely in the health and prison sectors the projects are typically large in size and if $500,000 is the threshold for the target group then over 85% of the total expenditure is covered by these projects, whereas in education only 60% is covered.

Figure 4 Building consents by value range



4. TARGET MARKET

MAF wishes to encourage timber use in buildings, and the suggested timber value threshold for the target segment are buildings using $50,000 of timber. Most materials in a building are contained in the structural system (frame, and floors), the wall and roof claddings, and the interior linings. Of these components the main potential for timber is the frames. The structural system (roof and wall frames, foundations, and partition walls) is commonly 15% of the building cost, including fit-out and HVAC plant costs. Of this about 45% is the material cost so that $50,000 of timber materials is contained in a building costing $741,000 (=50,000/(0.15x0.45)). So the previously mentioned threshold of $500,000 is too low and a threshold of $750,000 is suggested.

The number of projects over the threshold are summarised in Table 2. This has been derived by counting all the projects $1 million and larger, plus 50% of the projects in the $500,000 to $999,000 value group. The latter is an adjustment to only count those projects with more than $50,000 of timber, as calculated above. Details of the number of projects by value range are in the Appendix. The lower part of Table 2 shows the number of projects over the threshold that already have timber framing, as derived from the BRANZ Materials Survey. The forecast number of timber buildings assumes that the percentage of these large buildings designed in timber remains the same as the current percentage. This assumes no change in designer or owner preferences for timber buildings and is a "building as usual" scenario. The difference between the two parts of the Table is the non-timber buildings and is the potential market for expansion of timber framing. For example in the current year only 20 of the larger buildings in the Government sector are estimated to be constructed in timber and another 144 will be built in other materials. The next section discusses what are the opportunities and barriers for use of timber in large buildings.

Table 2 Government buildings over the value threshold

Government buildings over the value threshold											
Calender yr	**99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**
Number of building consents over the threshold											
Prisons	18	10	17	9	4	4	7	9	6	2	4
Education	68	70	82	107	108	120	150	105	105	105	90
Health	24	39	29	16	21	40	49	49	59	59	49
Total	109	118	128	132	133	164	206	163	170	166	143
Estimated number designed/ would be designed in timber (1)											
Prisons	0	0	0	0	0	0	1	2	1	0	0
Education	8	9	11	14	14	16	19	14	14	14	12
Health	2	3	2	1	2	4	5	5	6	6	5
Total	10	12	13	15	16	20	25	21	21	20	17

The threshold is a consent value of $750,000 or greater.
(1) Historic numbers based on BRANZ survey results, future numbers are "building as usual".

5. POTENTIAL FOR TIMBER PENETRATION IN GOVERNMENT BUILDINGS

5.1 Factors affecting market penetration

The main market for timber is in framing including structural framing and non-load bearing partition walls. There is also some limited potential for increased use as wall claddings, mainly plywood sheet, and timber weatherboard. In the residential sector timber composite panels, such as the Fletchers Maxim system has a small (1.5%) but growing market share, and has some potential in low rise non-residential buildings.

Table 2 indicates that approximately 12% of large Government buildings are likely to be built in timber framing over the current year in a "business as usual" scenario. What are the factors that determine whether this share can be increased and how can perceptions be changed? There is very little work on this topic in New Zealand. One paper [1] that was found for the NZ context puts the material choice drivers into four categories:

- Historic systems
- Performance
- Cost
- Ease of design.

In the residential sector the **historic** position works in favour of timber use. However for non-residential buildings the traditional materials of concrete and steel are rarely queried by designers and owners. The latter are usually reluctant to try a new system and would need to see a history of performance.

The **performance** of building materials is increasingly important, particularly in the light of the weather-tightness problems in the residential sector. Material stability, durability and surface finish are a high priority for most buildings, including Government buildings. In this regard timber may have perception problems.

[1] Banks W, 2001, Alternatives to timber framed construction. NZ Timber Design Journal, Issue 3 Vol 10.

Forest Research (FR) engineers suggested that more hybrid buildings could be designed in the non-residential sector. These have a steel or concrete frame to take lateral loads while timber is used for the secondary frame including floor beams and joists and for the columns. Timber is stronger in compression than tension so the steel frame would take the tension forces associated with lateral loading, and timber members would carry the gravity loads. Flooring could be as for housing, i.e. particleboard on timber joists, or composite concrete and timber floor systems could be used. They also note that for larger member sizes the fire resistance of timber is better than for steel. Timber chars at a fairly low rate in fires and strength loss is low, reducing the need for fire protection compared to steel.

Cost is a key driver of choice, though probably less so in the Government sector where durability and maintenance tends to be given more consideration than commonly occurs in the private sector. Timber framing is often cheaper than the alternatives for multi-storey construction, as discussed later. For partition walls steel is usually cheaper. Often quantity surveyors are involved at the feasibility and design stages, in the costing of the alternatives. They are a very conservative group, and are afraid of producing estimates that later prove to be wide of the tender prices. Hence they treat alternative material designs conservatively, which often unfairly penalises timber use in non-traditional areas.

Ease of design is a factor, particularly if the material decision is left with the designer. The availability of design tools, software, charts and manuals is a major factor, as speed of design improves the profits for the designer. In NZ we have suitable design standards, e.g. NZS3604:1999 Timber Framed Buildings, for low rise (less than 4 storeys) buildings, and the more general NZS3603:1993 Timber Structures Standard. The two main timber processing companies have produced design aids for their products, including their relatively recent range of “engineered” joists and beams. There is generally adequate knowledge among designers on timber design. But because of the inherent variability of the physical properties of timber there is often no reliable data on characteristic stresses for the large section sizes that are needed for the main load carrying members. In contrast the physical properties and performance of steel and concrete materials are consistent, and well understood.

Discussions held with FR engineers confirmed these views. Timber buildings are often cost competitive and there is a lot of technical information, but designers are unable to go to a “one-stop” source of data and design aids (unlike steel and concrete). They tend to be more comfortable designing with the latter materials, which have greater emphasis than timber in design courses at university and polytechs. As few designers use timber it is difficult to find peers whom can exchange experience and techniques of timber design. In contrast the Cement and Concrete Association, and the Heavy Engineering Research Association provide extensive data, technical aids and examples of concrete and steel designs. Timber prefabricators provide a design service for the roof trusses for smaller buildings, but in contrast Auckland steel fabricators provide complete designs including standard connection details for low rise large span buildings such as warehouses. Other disadvantages of timber noted by FR include acoustic problems with timber floors, and difficulty in manoeuvring timber partition studs in lifts, compared to nested steel studs when doing fit-outs.

Work has been carried out in Australia on design professional attitudes to structural timber.[2]
The key findings were:

- Timber is underutilised in non-residential buildings.
- Professionals suffer from a lack of timber building information.
- They are generally positive about timber as a material.

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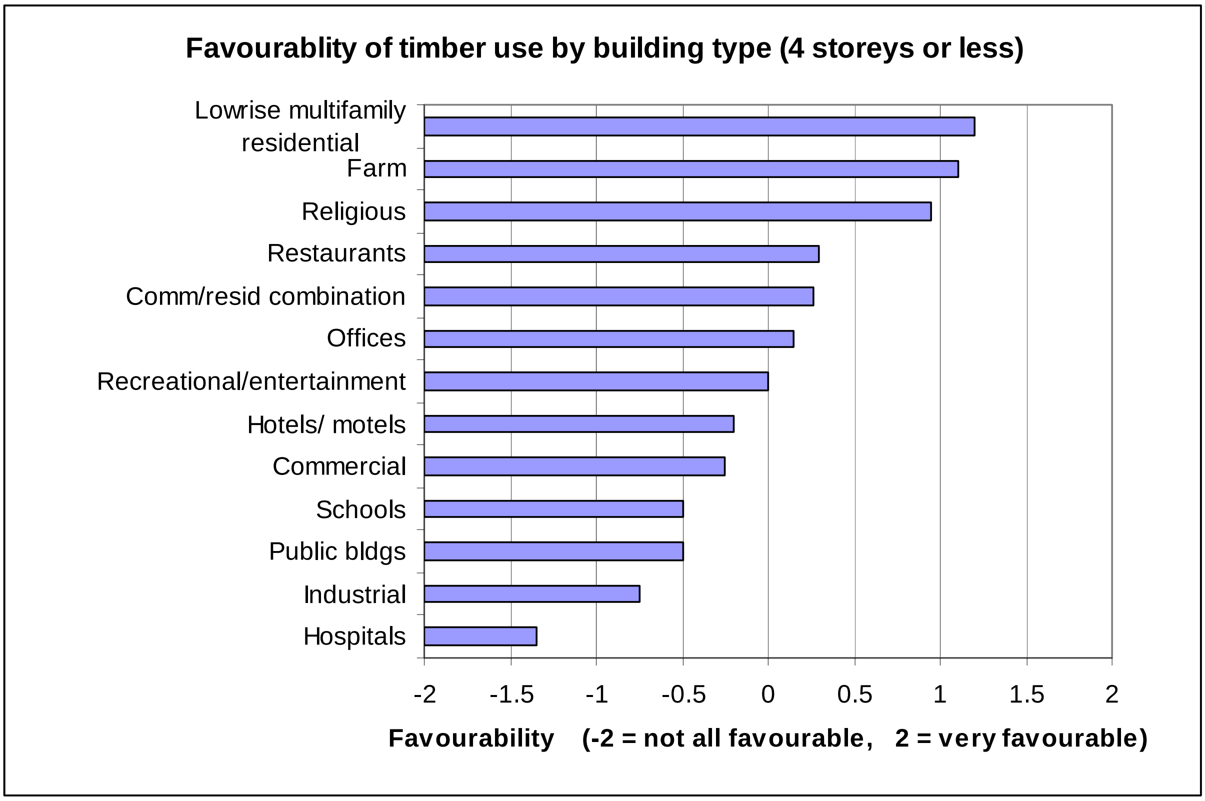
[2] Nolan et al,(2000) “Factors that influence design professionals when they use structural timber in Australia.” – NZ Timber Design Journal Issue 4 Vol 9.

- Competing materials recognise design professionals' requirements for technical support, whereas the timber industry's supply of information to professionals is low.
- Designers rate timber as an aesthetically pleasing material and there was no evidence they thought it inherently unreliable.

The study found that professionals favour pre-fabricated and assembly systems because design and documentation time is reduced, and non-timber materials are well developed in this regard. Timber framing manuals are adequate for domestic construction but not for non-residential work, and 53% of structural engineers thought non-residential timber structures were complicated to design and document. The study found confusion about the cost of timber structures. 84% of frequent architectural designers of timber thought timber was economic but only 55% of non-users responded the same way. None of the professionals polled suggested that structural timber was restricted due to want of timber technology. Simpler concerns, such as obtaining reliable timber data, recommendations, and design information are more significant.

A similar study was carried out in North America[3]. Timber framing use varies by region from 22% to 47% in non-residential buildings below five storeys, with very little used over four storeys. The designers' perceptions of the suitability of timber framing, by building type, is in Figure 5. It is notable that the most favourable response is for social/ cultural buildings, and some commercial buildings (restaurants, offices). Public buildings, education and health buildings are perceived by designers to be unsuitable for structural timber. The paper surmises that specifiers have misconceptions and fears about the durability, strength and the fire resistance of timber in public/ institutional buildings, and that marketing strategies need to address these concerns.

Figure 5 North American perceptions of timber suitability



[3] Kozak and Cohen (1999) "Architects and structural engineers: An examination of wood design and use in non-residential construction." Forest Products Journal Vol, 49, No. 4.

The perceived disadvantages of timber, in the North American study, were:

- Not fire resistant.
- Fire protection is difficult to build in.
- It is not strong.
- It is not durable.
- It deteriorates.
- Some newer timber products are not yet proven.
- It is not priced consistently.
- Its supply is inconsistent.

The perceived advantages of timber were:

- It is warm, inviting and comfortable.
- It is attractive.
- It is functional.
- It is inexpensive to buy and install.
- Building costs are low.
- Older timber products have proven performance.
- It is environmental friendly.

We believe that these findings from Australia and North America are generally applicable to the New Zealand market, though we probably have better design information available for professionals, because of our engineering based timber design standards. Structural timber is now widely used in buildings up to three storeys in New Zealand. Many of the multi-unit townhouse/ terraced housing developments in the main centres uses timber framing, primarily because of the cost advantages, and because builders can transfer their skills directly from stand-alone housing into these multi-unit projects. Our performance based building codes enable designers to provide for fire resistance, fire protection, and means of escape measures in timber structures, and meet the same criteria that a concrete or steel building is required to meet. The material itself is not a major barrier to the use of timber framing from a fire viewpoint, nor from other design criteria (eg strength, earthquake resistance, etc).

However few timber framed buildings above 3 storeys exist in New Zealand. There is the Odlins four storey building in Petone, plus the Gulf View Towers Apartment (1995) and The Strand Apartment and Office complex (1999). The latter two are 5 and 6 storeys and were designed by Warwick Banks. Another of his projects, recently under construction in Wellington, is a 6 storey timber framed apartment building with plywood shear walls. It has a concrete framed ground floor to provide large spans required for the car parking. He advised that he is not aware of any other timber buildings that have been erected over 3 storeys since 2000. He has tried to interest owners to build in timber in subsequent projects, citing the cost advantages. However owners have proved reluctant because the estimated construction costs savings, though estimated at $100 to $200 per sqm, are theoretical, and their financial advisors (usually quantity surveyors) don't want to "go out on a limb" for what they see as non-guaranteed savings. Timber framed structures are quite feasible technically up to 6 storeys in New Zealand[4,5] using the traditional platform sawn timber framing and plywood shear walls to take lateral loads. The floors are the traditional particleboard on timber joists or they can have a concrete topping to improve acoustic performance. A different system has been proposed using timber poles as the

[4] Thomas G (1991) "The feasibility of multi-storey light timber framed buildings." Research Report 91-2 Department of Civil Engineering, University of Canterbury.

[5] Halliday M (1991) "Feasibility of using timber for medium rise office structures." Research Report 91-3 Department of Civil Engineering, University of Canterbury.

main columns and beams, with plywood shear walls, up to six storeys.[6] The study was in four parts:

- Radiata poles as columns,
- Comparing four types of timber floor structures for multi-story buildings,
- Large industrial truss structures using radiata poles,
- Six storey apartment building using radiata pole beams and columns.

The first study found radiata poles are feasible up to 14 storeys for gravity loads, however shear walls would be required for the lateral loads. The second study considered radiata poles as floor beams, timber trusses, glulam, and LVL as the main floor system, with spans up to 11 metres. The most economic was a system with pole floor beams in pairs as the primary structure, with smaller pole beams as the secondary beams at about 1.5 m centres, and then gauged timber joists (approx 200 mm deep) at 400 centres spanning between the secondary beams. The third project considered a truss with pole top and bottom chords, and pole web members in compression, inclined at 45 degrees, with steel rods as the tension web members. This system was cheaper than the equivalent glulam column-beam portal. The fourth project combined elements of the earlier projects in a six storey apartment building.

The fourth project has a low embodied energy content, but has not been built and while some thought has been given to the beam-column junctions, they may prove to be difficult to build in practise. Timber only floor systems tend to be acoustically less satisfactory than floors with several centimetres of concrete slab, so most projects have a thin concrete layer on a plywood floor. In contrast double stud timber walls with insulation have proved to perform well acoustically.

Another study indicated that hybrid structures in which a concrete core takes the lateral loads, and timber columns and beams take the vertical loads, are feasible up to 14 storeys in New Zealand. [7]

In summary some of the common themes coming through from New Zealand and overseas literature are that medium to high rise timber structures are technically feasible, but increased use of structural timber is being held back by conservatism of designers and cost consultants. The design professionals generally recognise that timber costs are similar or cheaper than the alternatives in many cases. Timber framed apartment buildings, up to six storeys have been built. Some innovative designs have been proved to be theoretically possible for other building types with larger floor spans than apartments, but until built their problems and potential remains undiscovered. Also there is a reluctance to use timber in major buildings due to durability and strength perceptions, and the general conservatism of owners and their advisors. Some specialist uses of structural timber is accepted but it is not a main stream use in commercial or institutional buildings.

5.2 Predictions of market penetration

The upper part of Table 2 shows the number of Government buildings that if utilising structural framing would have at least $50,000 of timber materials per building. How many of these predicted number over the threshold could reasonably be expected to use structural timber framing, assuming cost and design conditions allow ?

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[6] Chapman J (2004) "Timber, a truly sustainable resource, can be used to replace steel and concrete structures in multi-storey building." Proceedings International conference for sustainability, engineering, and science. Auckland July 2004.

[7] Banks W, (1999) "Multi-storey timber construction – A feasibility study." Proceedings Pacific Timber Engineering Conference, Rotorua, March 1999.

Prisons/ barracks.
An advantage of timber framing is that lightweight and low cost claddings and linings are readily fixed to the frame. However in prisons robustness of components is a major requirement and hence the linings and claddings tend to be made from strong materials, such as masonry block and tilt slab. These materials provide their own structural strength and there is a reduced role for a supporting frame. Timber based materials have been used in prisons and in secure mental patient units, including the use of plywood on timber frames as the finished lining surface. So timber framing, and wood based linings and claddings will be suitable in some prison buildings. A rough estimate is that about 20% of the single storey buildings would be suitable.

Education buildings.
In education approximately 47% of new building work has recently been for primary schools, 20% secondary schools and the remaining 33% are tertiary institutes. The percentages for primary and secondary are likely to reverse as the student bulge moves into the secondary sector over the next 3 to 5 years. Approximately 90% of new primary and secondary school buildings are one or two storeys in height, and most would be suitable for timber framing. Many are transportable since the Ministry of Education has a policy that as student rolls change classrooms are relocated to areas of need. This favours timber framed buildings and timber floors. Tertiary buildings tend to be larger in floor area and are more likely to be over one storey in construction than school buildings. Their suitability for structural timber is lower than for schools.

Health buildings
The modern practise in public health is for a hub and spoke arrangement for hospital services, with the specialist care in the main centres, routine surgical services in the secondary centres, and so-called "super clinics" in the suburbs of the main cities and rural towns. The latter tend to be moderately large (2000 sqm) low rise buildings, with a limited number of beds for in-patients as most operations are for ambulatory care procedures. They are suitable for timber structural framing.

The new specialist / surgical hospitals are more like the traditional hospital buildings, though not the high rise buildings of the past. Modern practise is for the physical layout to be designed to assist patient flow through the different specialities. Hence the new designs in Auckland and Wellington, replacing the old hospitals, are for large footprint, low to medium rise buildings. These buildings are designed for flexibility of use since medical technology, and available procedures are rapidly advancing, and the physical layouts required in the future are uncertain. Flexibility is assisted by large floor plates, minimal permanent partitions, and easily modified services (HVAC, cabling, etc). There is a challenge building timber floors over 10 m in span, but there is no reason why timber structural framing would not be suitable in some of these buildings. Engineered timber products are available that achieve quite high spans, facilitating the open floor plans required in modern hospitals. However, generally the depth to span ratio for beams is lower in steel and concrete, and headroom constraints may govern the material choice.

Health buildings are a specialist design area, usually headed up by overseas based specialist architectural firms. They tend to be conservative in their designs and the emphasis is on reducing running/maintenance costs, rather than minimising the initial first cost of the building. Penetration of timber framing into the main base hospitals will be difficult, and the greater scope would appear to be in buildings for the secondary centres, and for the low-rise super clinics in the suburbs.

Market penetration
Based on the above considerations, an assessment was made on the possibility of converting the framing from concrete or steel to structural timber, for the three building types, by storey height. The assumed percentage of eligible buildings in each category is shown in Table 7 in the

Appendix. The range for education buildings was from 80% for one storey to 20% for over three storeys, smaller percentages were used for health and prison buildings. The results are in Table 3 which indicates, for example, that currently an additional 85 buildings could be constructed using timber framing. The additional number is derived from the total number suitable in Table 3, less the estimated number designed in timber in "business as usual" in Table 2.

Table 3 Timber framed building market potential

Projected potential timber framed buildings						
Buildings over the $750,000 threshold.						
Calender year	**04**	**05**	**06**	**07**	**08**	**09**
No. of Buildings suitable						
Prisons	1	2	2	2	1	1
Education	88	110	77	77	77	65
Health	16	20	20	23	23	20
Additional No. of Buildings.(1)						
Prisons	1	1	0	1	1	1
Education	72	91	63	63	63	53
Health	12	15	15	17	17	15
(1) Additional number of Government timber buildings, beyond those that are expected in the "Building as Usual" scenario.						

6. TIMBER POTENTIAL FOR NON-GOVERNMENT BUILDINGS

The brief was to assess the potential for timber in government buildings, rather than in private sector buildings. However, it is likely that should timber substitution occur in Government buildings there will be a flow-on effect to the private sector. Knowledge and experience obtained in the Government sector is expected to be transferred by designers and cost consultants into private sector timber buildings. This section provides a rough estimate of the number of private sector buildings that could be substituted and their associated carbon savings.

The main candidates are expected to be social/ cultural buildings, offices, and retail buildings. Other types such as industrial and farm buildings could be targets, but simple and cost effective steel systems are well established in these segments and market penetration would probably be quite difficult, thus these types have been ignored. Table 4 shows the potential in the private sector and the details are in the appendix. As a market it is at least equal in size to the Government sector, even allowing for a lower "take-up" rate.

Table 4 Private sector timber framing potential

Potential private sector timber framed buildings						
Buildings over the $750,000 threshold.						
Calender year	**04**	**05**	**06**	**07**	**08**	**09**
No. of Buildings suitable						
Social/cult	31	30	30	37	37	45
Retail	45	40	35	40	40	45
Office/admin	29	25	25	29	29	33
Additional No. of Buildings.(1)						
Social/cult	29	28	28	35	35	43
Retail	43	38	33	38	38	43
Office/admin	27	23	23	27	27	31
(1) Additional number of private sector timber buildings, beyond those that are expected in the "Building as Usual" scenario.						

7. COST SAVINGS AND CARBON RELEASE SAVINGS

There are limited studies available in New Zealand comparing timber framed non-residential buildings with other materials. Table 12 in the Appendix shows the comparisons for the only published NZ data that was found. Timber framing was found to be cheaper in all the projects in these reports, by between 3% and 22%. In most cases the comparison is between an actual structure built in concrete, and a theoretical timber alternative, designed using the same floor layouts to produce an equivalent building. Most of these comparisons appeared in timber industry journals and hence there may be an element of reporting only the results that are favourable to timber. However we are not aware of any refutations of the general finding that timber framing is usually cheaper than other materials in the low to medium rise (up to 5 storeys) residential and non-residential sectors, where the floor and roof spans are small to moderate (less than 10 metres). For large spans occurring in warehouses and some commercial buildings, steel framing is usually cheaper.

Table 12 also shows the estimated embodied energy, and the carbon release for the different designs. In some cases the timber buildings have a negative carbon release. This means that the carbon stored in the timber is greater than the carbon releases associated with the other materials in the building. The results are summarised in Table 5, including the volume of sawn timber.

Table 5 Estimated carbon emission savings from the use of structural timber framing

Embodied energy and CO2 savings - Government buildings
Calender year 2005

	Additional number of eligible projects	Average floor area (1) (sqm)	Embodied energy savings GJ/sqm	On eligible buildings, GJ	CO2 emission savings kg/sqm	On eligible buildings, tonnes
Prisons/ barracks	1	4214	0.31	1300	133	561
Education	91	1769	0.31	49670	133	21413
Health	15	5272	0.31	24401	133	10519
		Ratio		75372	Timber	32493
Timber volumes		(cum/sqm floor)			Volume (000cum)	
Prisons/ barracks		0.10			0.4	
Education		0.12			19.3	
Health		0.12			9.5	
(1) Last 5 years average floor area.					29.2	

Embodied energy and CO2 savings - Private sector buildings
Calender year 2005

	Additional number of eligible projects	Average floor area (1) (sqm)	Embodied energy savings GJ/sqm	On eligible buildings, GJ	CO2 emission savings kg/sqm	On eligible buildings, tonnes
Social/cultural	28	2570	0.31	22201	133	9571
Retail	38	2919	0.31	34226	133	14755
Office/ admin	23	2411	0.31	17110	133	7376
		Ratio		73538	Timber	31702
Timber volumes		(cum/sqm floor)			Volume (000cu	(000cum)
Social/cultural		0.12			8.6	
Retail		0.10			11.1	
Office/ admin		0.12			6.7	
(1) Last 5 years average floor area.					26.4	

Original signed by: ICP

Original signed by: EVZ

It should be noted that initial embodied energy is usually a small part of energy use in a non-residential building over its life time. A literature survey[8] indicates the structure embodied energy typical ranges from 2 to 4 GJ/sqm (concrete and steel), and 1 to 2 GJ/sqm (timber). We have conservatively used 0.31 GJ/sqm difference in Table 4. The non-structural items (i.e. fit-out and services) range from 2 GJ to 4 GJ/sqm. Recurring embodied energy is the periodic refurbishment of the building, and is typically about 7 GJ/sqm over a 50 year life span. However these numbers are quite small in comparison to the operating energy of a building, which is typically 0.3 to 1.0 GJ/sqm per year, or 30GJ/sqm over a 50 year period. According to the study the difference in operating energy between wood and other material framed buildings is negligible because:

- Offices and other commercial buildings tend to be internal load dominated, and their operating energy is less dependent on the thermal characteristics of the building envelop.
- Thermal mass could change the operating performance between the different structural types, but timber framed buildings tend to have concrete floor slabs which are the dominant factor affecting the thermal mass, rather than the underlying structure.
- All buildings have the same thermal resistance in the envelope because of code requirements.

Most work on energy efficiency is concentrated on reducing operating energy, but as improvements are continually made the embodied energy component becomes a larger percentage, and attention will focus more on initial and refurbishment embodied energy. Hence timber structures and timber based refurbishment options will have an increasing role to play.

8. OVERSEAS APPROACHES TO ENCOURAGE TIMBER SUBSTITUTION

The North Americans seem to be the people most advanced in promoting use of timber in buildings.

The WoodWorks project in Canada is an industry lead initiative to encourage greater use of timber in non-residential building. One main objective is to get designers to use wood and to this end they have several measures:

- A project tracking system using designer contacts to monitor upcoming projects.
- Publicity and media releases on timber structures of note.
- Lobbying of local government of the benefits of timber and requesting a commitment for equal treatment of timber in tender evaluation.
- Timber design tools developed and provided to designers and builders free of charge, plus information on proprietary products.
- Sponsors of the programme get display opportunities at WoodWorks events.
- A WoodWorks web site has extensive information on timber use, design aids, contacts, typical projects, etc.

The Forintek Canada Corporation is a major timber research organisation in Vancouver. One of their publications[9] addresses five action areas to increase market share for timber in commercial and institutional buildings. They are:

Fire safety – Measures to persuade authorities to move to performance orientated building codes. Unlike the NZ Building Code the North American building codes impose more restrictions on timber than other materials.

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[8] Cole R, Kernan P, (1996) "Life cycle energy use in office buildings." Building and Environment Vol 31, No 4.

[9] O'Conner et al, (2003) "Wood opportunities in non-residential buildings." No SP-46 Forintek Canada Corp.

Technical issues – Steel and concrete are easier to design because there are numerous systems, connection details, standards and design guides. Thus the structural engineer has all the tools at hand, which is not the case with wood. This applies to a large extent in NZ, though our design standards are comprehensive. Timber durability has become a recent issue in NZ.

Labour skills – lack of skills in working with timber on-site has affected the designer's confidence that the structure will be built as designed. Stick construction in housing is not of high quality, but this has not caused major problems because of the redundancy in domestic construction. (Note: Parts of North America have experienced weather-tightness problems in multi-unit housing, similar to those now becoming apparent in New Zealand). In non-residential design there is less leeway for on-site errors. In NZ a similar comment applies, however the proposed changes to the Building Act will require builders to be certified, and various enforcement provisions should ensure that the skill level and work quality on timber framing improves locally.

Designer support – specific guidelines are needed for buildings over two storeys. Develop more continuing education courses on timber. Develop a one-stop shop for all information on timber design. In New Zealand designers receive sufficient training in timber design and there is considerable research in the design schools into timber engineering. However we do not have a one-stop timber shop similar to the local focus points for steel and concrete, namely the Heavy Engineering Research Association (steel), and the Cement and Concrete Association.

Wood's Image – For many projects timber is never given fair consideration, not for code or cost reasons, but because of perceptions that it is OK for housing but not elsewhere, and because of entrenched attitudes. These include a low-tech image, poor quality, not strong, not appropriate in non-residential buildings, burns easily, rots, and is too hard to design with. Many of these attitudes apply in New Zealand, and in some cases with good reason. The solution locally is to provide credible performance data, and recent moves to tighten up the durability and weather-tightness provisions of the NZ building code will assist here. Note that the draft revision of the NZBC has as one of its prime purposes a requirement to consider sustainability when making regulations under the NZBC. What specific measures will be mandated to achieve this is yet to unfold. But it seems likely that this will favour timber use in buildings in preference to other materials. It is likely that the next major revision of the code clauses, to be carried out in 2008, will include specific sustainability requirements for all new construction.

9. DISCUSSION AND CONCLUSIONS

The summary in Table 1 indicates that timber framing could substitute for other materials in approximately 80 medium to large new Government buildings per year. How realistic is this? The main barriers, discussed in Section 5.1, are the conservatism of the costs consultants and designers. The evidence suggests that technically timber will perform satisfactorily for many larger Government buildings, and apart from the sustainability benefits, there may well be cost savings compared to concrete and steel alternatives. There is some expertise in large structure design in New Zealand and this would provide a base for expanding the capability of the cost and design professions to undertake more timber buildings. Provided timber structures are given the chance to tender on a similar basis to steel and concrete framed structures then there appears to be few barriers to an increased uptake of timber structures.

Assuming an increased incidence in Government buildings, what would be the flow-on to the private sector? There are potential more eligible buildings in the private sector but the substitution rates are likely to be lower, mainly because of the conservatism of owners and the pressures on designers to minimise their fees. Even when the take-up rates are reduced by 20%-

30% compared to Government buildings, the eligible number of buildings are similar to the Government sector.
The report notes that embodied energy savings are small compared to energy used throughout a building's life. However these savings are still significant, potentially amounting to about 150,000 GJ per year in the public and private sector, and about 60,000 tonnes of carbon emission savings per year.

The draft revision to the Building Act has a clause that includes a requirement to give consideration to sustainability impacts when making changes to the Building Regulations. There are approximately 30 performance clauses in the Regulations and these are each reviewed on a rolling basis every 5 years. The durability, plumbing and energy efficiency clauses have sustainability impacts and are due for revision by 2008, with work to start within a year or two. It is possible that specific performance criteria may be included that would favour timber in preference to other materials.

10. APPENDIX

This appendix contains details of the following:

- Recent trends in Government buildings.
- Government building activity forecasts.
- Eligible timber framed building model.
- Details of carbon sink of materials, and their embodied energy.
- Building industry structure and its ability to build more timber buildings.
- Heating plant fuel sources in Government buildings.

10.1 Recent trends in Government buildings

The number of building consents issued for central government building projects are shown in Table 6.

Table 6 Government consents by year and value group

Government Projects by Value range					
Calender yr	**1999**	**2000**	**2001**	**2002**	**2003**
Prisons	**Number of building consents**				
($000)					
<$200	108	89	74	83	67
200-499	12	9	16	5	8
500-999	9	5	7	1	2
1000-2499	4	3	5	5	0
>2499	9	4	8	3	3
	142	110	110	97	80
Education					
<$200	1409	1316	1216	1076	1041
200-499	205	215	203	205	239
500-999	55	40	64	86	84
1000-2499	26	37	38	45	48
>2499	14	13	12	19	18
	1709	1621	1533	1431	1430
Health					
<$200	101	94	79	84	64
200-499	14	20	22	11	18
500-999	9	15	4	4	8
1000-2499	14	18	13	6	9
>2499	5	13	14	8	8
	143	160	132	113	107
Other					
<$200	312	302	358	345	327
200-499	33	41	35	31	37
500-999	13	6	10	11	9
1000-2499	10	4	8	14	9
>2499	2	7	4	3	1

Other includes offices/admin, warehouses, farm bldgs, miscellaneous.
Source: Statistics New Zealand

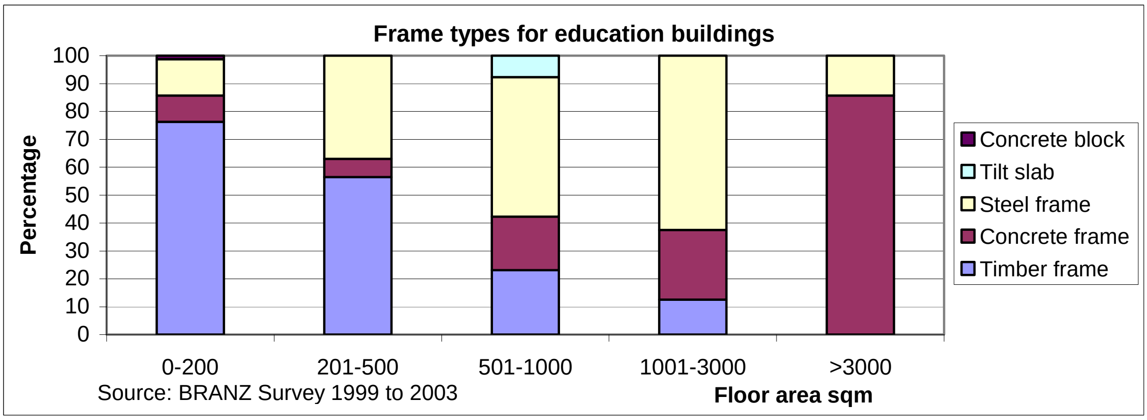
The office /administration category is mainly courts and police stations. Most Government Departments are housed in rental offices which have private ownership and are outside the scope of a Government promotion campaign.

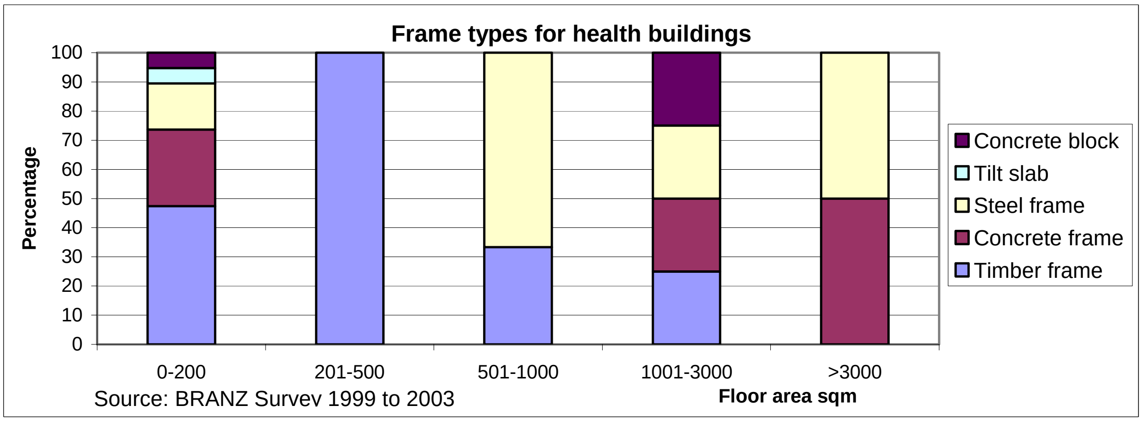
The best Official source of building activity is the building consent data collected by Statistics New Zealand, which is a 100% record of new construction plus alterations and additions work. The only data collected are floor areas, contract values, and type of building. All building work that has safety or health implications is required to obtain a consent, including new buildings, additions and alterations. Major replacements, such as claddings, windows, repiling, relocating bathrooms, wall partitions, and replacement ceilings also require a consent. So the consent series covers most work that uses timber or timber based materials in buildings. The main exception is furniture which is not covered by the consent process, though built-in fittings such as cupboards and storage areas are included.

The consent series does not provide data on materials used in buildings, so BRANZ started a quarterly survey to quantify material use several years ago. The BRANZ Materials Survey covers approximately 350 non-residential buildings per year, and includes questions about materials types (frame, claddings, etc), and the floor areas by storey level. This data has been used for several of the charts and tables in this report. The sample size for education buildings is fairly large (334 returns), but lower for health building (34), and very low for prisons/ barracks (2) .

Additional information from the survey is shown below in Figure 6.

Figure 6 Government building frame types by floor group





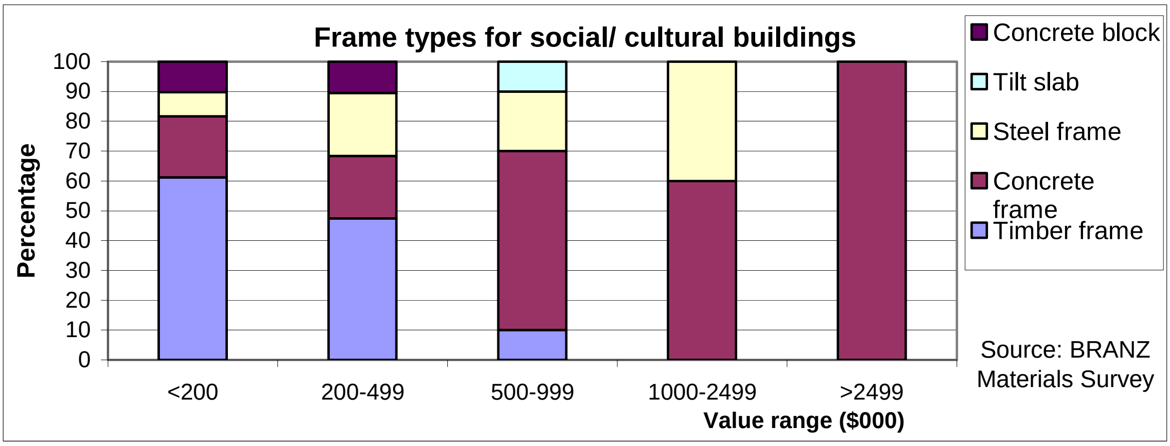
10.2 Recent trends in private sector buildings

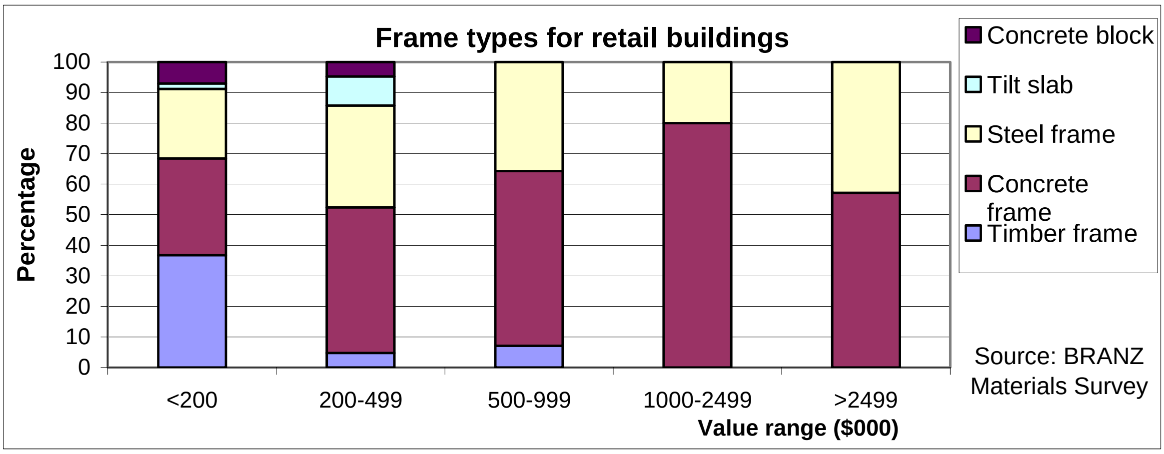
The number of building consents issued for selected building types in the private sector are shown in Table 7.

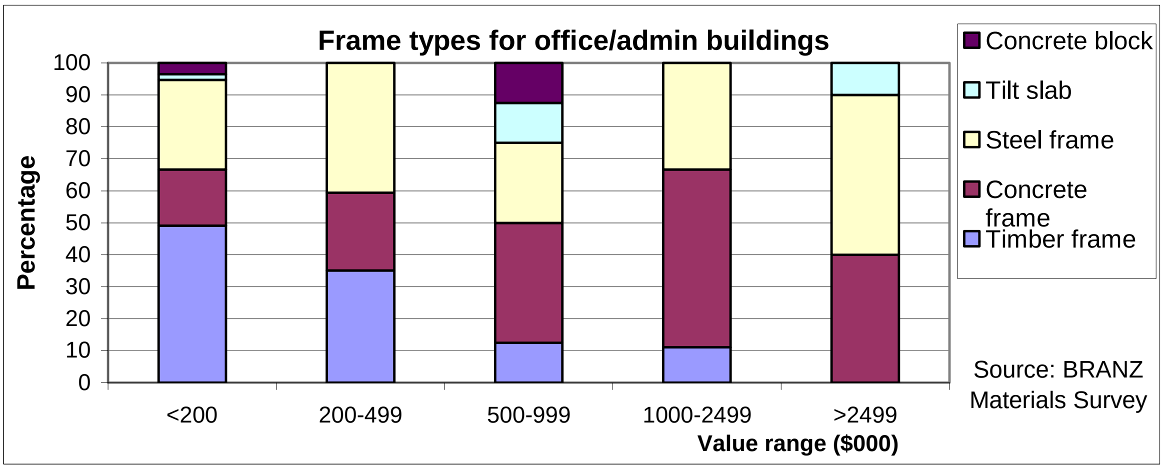
Table 7 Private sector consents for selected building types by year and value group

Private sector projects by Value range					
Calender yr	**1999**	**2000**	**2001**	**2002**	**2003**
Social/cultural		**Number of building consents**			
($000)					
<$200	818	798	799	849	675
200-499	109	108	132	127	92
500-999	44	42	37	31	38
1000-2499	19	18	23	20	28
>2499	6	15	22	13	15
	996	981	1013	1040	848
Retail					
<$200	2214	2241	2470	2366	2094
200-499	195	169	173	224	235
500-999	58	63	74	82	90
1000-2499	33	31	37	47	62
>2499	15	31	18	26	28
	2515	2535	2772	2745	2509
Office/admin					
<$200	2073	1964	1981	1988	1970
200-499	231	240	205	179	224
500-999	75	64	75	69	74
1000-2499	33	50	41	45	34
>2499	16	18	17	13	24
	2428	2336	2319	2294	2326

Figure 7 Building frames for selected private sector building types







10.3 Government building activity forecasts

Forecasts for the main sectors are shown in Figure 1, and in Table 8 below.

Table 8 Government building consent forecasts

Government buildings consent forecasts											
	actual $ of day	-----------------------	--------	--------	------->|	< ------------------	--------	--------	-forecasts, 2003 $		
	$M	$M	$M	$M	$M	$M	$M	$M	$M	$M	$M
Calender yr	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Prisons/barracks	93	29	54	32	68	60	120	160	110	40	60
Education	278	300	289	342	360	400	500	350	350	350	300
Health	93	121	186	174	106	200	250	250	300	300	250
Office/Admin	13	10	24	9	15	15	15	15	15	15	15
Other	55	72	46	53	34	34	34	34	34	34	34
	531	533	598	610	583	708	918	808	808	738	658

Forecast details for prisons, education and health buildings are discussed below:

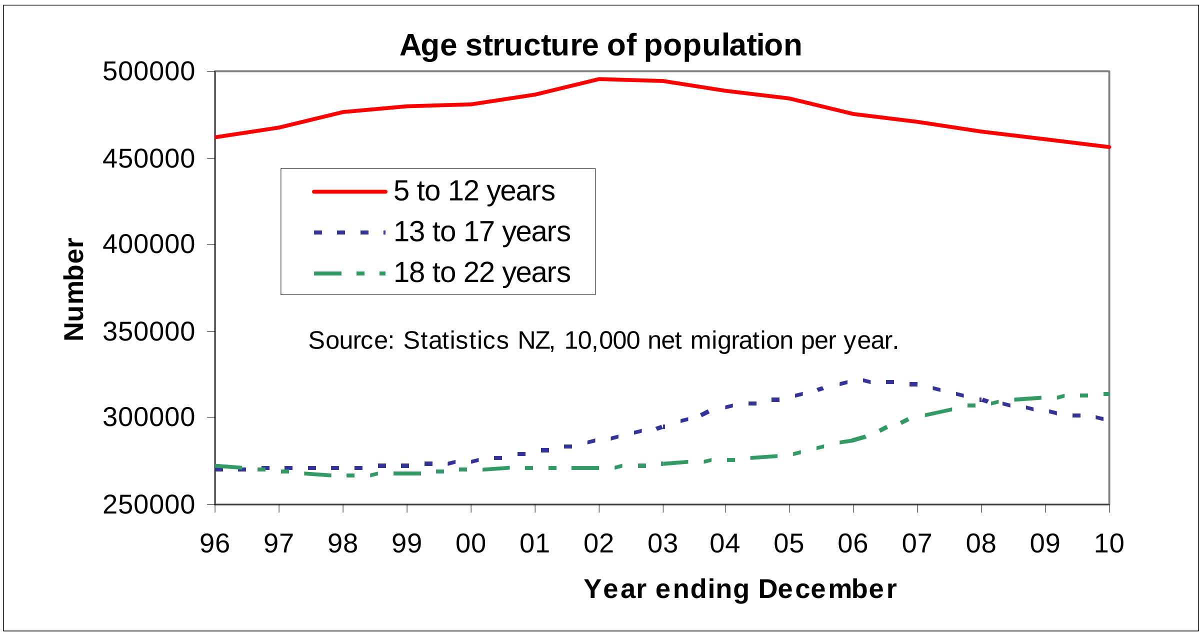
Prisons
The latest forecast for the prison population[10] indicates a 25% rise in the roll numbers by 2010. A major construction programme to house these inmates is now underway. Five new regional prisons are planned over the next 7 years, namely Northland Corrections Facility ($130M), Auckland Women's Correction Facility ($60M), Spring Hill Corrections Facility ($250M, South Auckland), Otago Corrections Facility ($120M), and Hawkes Bay Corrections Facility ($100M). The costs include all fit-outs and the actual building consent values are likely to be about 20% lower than these costs.

Education buildings
The main features of the education forecast are:

- The primary schools building programme peaked nationally in 2003, although activity still remains strong in Auckland. There was a "crash" building programme to add new classrooms, including the establishment of seven new primary schools in the Auckland region since 1997. Primary roll numbers are expected to slowly decline nationally over the next few years. See Figure 8 which shows age cohorts that approximately correspond to the primary, secondary and tertiary student groups.
- In the secondary sector roll numbers do not peak until 2006 and there is a steady rise in new building starts to that time.
- In the tertiary sector, increases in enrolments have been on-going for several years, primarily due to increased participation, rather than an increase in the numbers in the main enrolment age group. At the same time growth in overseas student numbers has been dramatic, though numbers are down this year. Much of the latter demand is met by the private sector in converted office buildings, rather than in Government facilities. Tertiary roll growth is expected to be slow for 1-2 years then pick up again as the secondary cohort bulge enters the tertiary system in significant numbers.

[10] Clark, C (2003) "Annual update of forecasts of the prison population ." Ministry of Justice.

Figure 8 Age structure of the student age population



It is quite difficult to predict tertiary student numbers beyond 3 or 4 years because changes in migration, overseas student numbers, and participation rates can alter the student rolls dramatically. The forecasts assume:

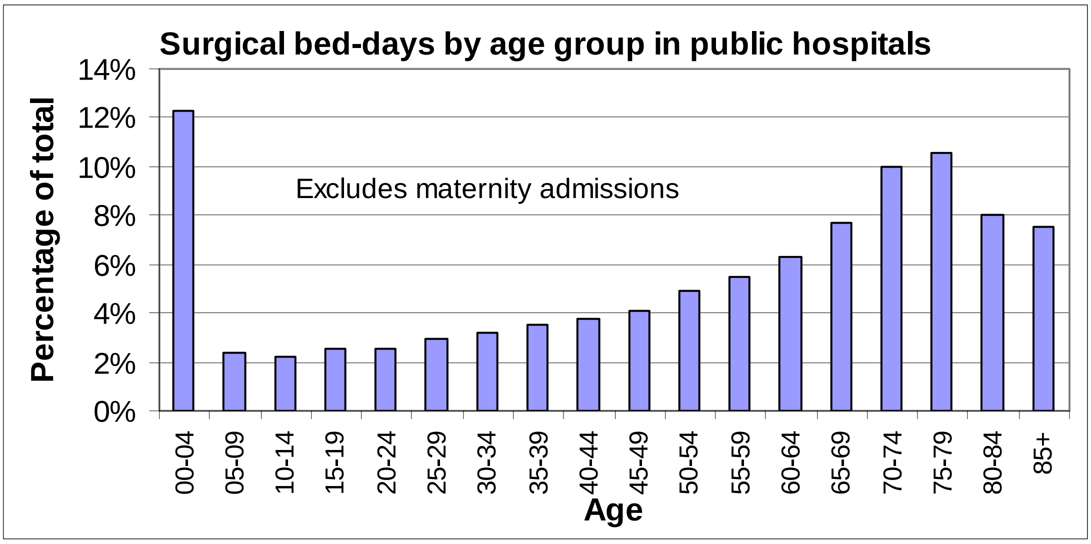
- Net migration levels out at about 10,000 net inflows per year.
- Overseas student numbers recover from the current downturn but growth rates are lower than in the past.
- Participation rates of the 18 to 22 year age group remains at current levels of about 60%.
- Mature student numbers do not change radically from current levels.
- Government funding per student, and the student loan scheme remains unchanged.

Health buildings

The elderly, defined as those aged 64 years and older, are significantly more likely to use hospital beds and services than other age groups, see Figure 9. For example in the June 2003 year approximately 45% of all bed-days in the public sector, excluding maternity, were taken by people aged over 64 years, while in comparison they are only 12% of the general population. It is not until about 2015 that numbers in the over 64 years age group start to rise significantly, so in the medium term bed capacity is probably adequate. Authorities are now designing the new generation of health buildings as the existing stock is quite unsuitable for modern health care management.

In the long-term the forecasts produced by Ministry of Health indicate an increasing share of GDP to go toward health care. Currently Government health expenditure is 6.0% of GDP and it is forecast to rise to 8.4% of GDP in 2051. This equates to approximately three times current health expenditure, and some of the increase will need to be in infrastructure, including buildings. This is a long-term picture but the current infrastructure development has this picture of an aging population, and rising health care expenditure as part of its planning. There is now an on-going programme of new construction over the next ten years, ending the hiatus we have had since the last major building programme of the 1960s and early 1970s.

Figure 9 Hospital use by age group



10.4 Eligible buildings timber frame model

Tables 9 and 10 are the detailed models summarised in Tables 3 and 4, showing how the number of buildings that are potential candidates for timber framing is derived. The percentage distribution by storey is from the BRANZ survey, and the same distributions are assumed to apply in the future. The main assumptions are within the heavy box outline. They are a “guesstimate” of eligible percentages based on BRANZ knowledge of building and design practises, and what is achievable given the constraints of floor span size, and the uses within the building. Prisons have a quite low potential due to the need for robust surfaces and the tendency to build in tilt slab and concrete masonry. Education buildings, particularly in the primary and secondary sectors are usually small to medium scale buildings and are ideally suited to timber framing. Health buildings tend to have large footprints but there is a trend to medium rise , rather than high rise of the 1970s era. Hence there is some potential for timber framing, though the large flexible open spaces required for flexibility of space management pose a challenge for timber framing.

Table 9 Eligible Government timber framed buildings model

Number of candidate buildings for structural timber frame
Buildings over the $750,000 threshold.

Calender year			**04**	**05**	**06**	**07**	**08**	**09**	Assumed % suitable for timber frame (2)	**04**	**05**	**06**	**07**	**08**	**09**
Prisons			**No. of buildings over the threshold**							**No. of buildings suitable for timber frame (3)**					
	Storeys (1)	%													
	1	90	4	6	8	5	2	4	30	1	2	2	2	1	1
	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	5	0	0	0	0	0	0	0	0	0	0	0	0	0
	>3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		100	4	7	9	6	2	4		1	2	2	2	1	1
Education															
	Storeys (1)	%													
	1	59	71	89	62	62	62	53	80	57	71	50	50	50	42
	2	32	38	48	33	33	33	29	70	27	34	23	23	23	20
	3	5	5	7	5	5	5	4	50	3	4	3	3	3	2
	>3	5	5	7	5	5	5	4	20	1	1	1	1	1	1
		100	120	150	105	105	105	90		88	110	77	77	77	65
Health															
	Storeys (1)	%													
	1	41	16	20	20	24	24	20	50	8	10	10	12	12	10
	2	24	9	12	12	14	14	12	40	4	5	5	6	6	5
	3	24	9	12	12	14	14	12	30	3	4	4	4	4	4
	>3	12	5	6	6	7	7	6	20	1	1	1	1	1	1
			40	49	49	59	59	49		16	20	20	23	23	20

(1) Storey number distribution from BRANZ Materials Survey
(2) Percentage of buildings in each storey group assumed to be suitable for timber structural framing. See text for discussion.
(3) Number of buildings over the threshold x % suitable.

In the private sector social/cultural buildings includes religious, sports, cultural, social, ethnic and recreational buildings. These are generally small to medium scale in size and the appearance of timber framing is considered to be aesthetically pleasing in these types of buildings, and hence their potential for timber framing is high. Retail construction is increasing using industrial building structural systems, namely steel framing to provide large open spaces. Hence the potential in retail is constrained to some extent. However appearance is important in retail buildings and some medium sized developments make a feature of timber framing. The office category includes a wide range of office and administration building types, ranging from small timber framed single storey buildings, medium and high rise offices, and prestigious administration buildings (including local authority admin, town halls, courts, police stations, parliament). The potential is overall fairly restricted as many of these buildings need to display a solid, establishment presence. However there are a large number of utilitarian buildings in this category in which the main criteria is to provide floor space cheaply for white collar workers. As the cost advantages of timber become more apparent there will be potential in the private office sector.

Table 10 Eligible private sector timber framed building model

Number of candidate private sector buildings for structural timber frame Buildings over the $750,000 threshold.														
Calender year		**04**	**05**	**06**	**07**	**08**	**09**	Assumed % suitable for timber frame (2)	**04**	**05**	**06**	**07**	**08**	**09**
Social cultural		**No. of buildings over the threshold**							**No. of buildings suitable for timber frame (3)**					
Storeys (1)	%													
1	35	25	23	23	29	29	35	60	15	14	14	17	17	21
2	54.5	38	37	37	46	46	55	40	15	15	15	18	18	22
3	10	7	7	7	8	8	10	20	1	1	1	2	2	2
>3	0	0	0	0	0	0	0	5	0	0	0	0	0	0
	99.5	70	67	67	84	84	101		31	30	30	37	37	45
Retail														
Storeys (1)	%													
1	80	136	122	107	122	122	138	30	41	37	32	37	37	41
2	10	17	15	13	15	15	17	15	3	2	2	2	2	3
3	10	17	15	13	15	15	17	5	1	1	1	1	1	1
>3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	100	170	153	134	153	153	172		45	40	35	40	40	45
Office														
Storeys (1)	%													
1	40	55	49	49	56	56	63	40	22	20	20	22	22	25
2	10	14	12	12	14	14	16	20	3	2	2	3	3	3
3	10	14	12	12	14	14	16	10	1	1	1	1	1	2
>3	40	55	49	49	56	56	63	5	3	2	2	3	3	3
		137	122	122	139	139	157		29	25	25	29	29	33

(1) Storey number distribution from BRANZ Materials Survey
(2) Percentage of buildings in each storey group assumed to be suitable for timber structural framing. See text for discussion.
(3) Number of buildings over the threshold x % suitable.

10.5 Carbon emissions and embodied energy coefficients for materials and buildings

Table 11 shows embodied energy and carbon release for selected common building materials[11]. Embodied energy is the energy required to make the material, and includes transport of the raw feedstock, the capital equipment energy (the energy used to make the plant, that is used to make the building material product), and all energy used in the manufacturing process. There is a close relationship between embodied energy and carbon releases for most materials, except for timber because it stores carbon. To obtain the carbon release factors the fuel type at each stage of the production process is identified, and the carbon release associated with that fuel is used to arrive at the aggregated amount for the finished product.

Timber products are calculated in the normal manner for energy embodied up to the factory gate and for the carbon emitted in the production process. Then there is a calculation to account for the carbon sequestered by the growing tree. Timber products usually have a net negative carbon emission, as the sequestration is greater than the release during manufacturing.

[11] Alcorn A (2003) "Embodied energy and carbon dioxide coefficients for New Zealand building materials." Centre for Building Performance Research, Victoria University of Wellington.

Table 11 Carbon and embodied energy coefficients

Material	MJ / kg	g CO_2 / kg	Imported	
			MJ / kg	g CO_2 / kg
Aggregate, general	.04	2.3		
, river	.03	1.6		
, virgin rock	.06	3.1		
Aluminium, virgin	192	8000	57.9	4292
, extruded	202	8354	57.9	4292
, extruded, anodised	226	9359	57.9	4292
Extruded, powder coated	218	9205	57.9	4292
Cement, average	6.2	994	0.2	14.5
dry	5.8	967	.2	10.9
wet	6.5	1021	.3	17.9
Cement fibre board	9.4	629		
Ceramic brick, new technology	2.7	138		
, old technology, average	6.7	518		
Concrete block 200 mm	0.9	106		
Block concrete fill	1.2	156		
17.5 MPa concrete	.9	114		
30 MPa concrete	1.2	159		
40 MPa concrete	1.4	189		
Glass, float/ tint	15.9	1735	12.7	1500
Gypsum plasterboard	7.4	421	3.6	218
Insulation, fibreglass	32.1	770		
, polystyrene	58.4	2495	52.9	2495
PVC, extruded	60.9	4349	60.9	4349
Sand	0.1	6.9		
Steel virgin, structural	31.3	1242	30	1148
Recycled, reinf, sections	8.6	352	1.6	87.5
Timber, radiata, rough sawn, air dried	2.8	-1665	0.6	43.5
r.sawn, air dried, treated	3	-1657	62.5	3288
dressed, air dried, untreat	3	-1662	0.6	43.5
dressed, gas dried, untreat	9.5	-1349	0.6	43.5
dressed, bio dried, untreat	4.1	-1644	0.6	43.5
dressed, gas dried, treated	9.7	-1342	62.5	3288
Glulam	13.6	-1141	955	50042

Table 12 has a summary of a variety of studies on embodied energy and carbon releases associated with typical buildings in New Zealand. In some cases the timber buildings have a negative carbon release. This means that the carbon stored in the timber is greater than the carbon releases associated with the other materials in the building.

Table 12 Costs and carbon emission comparisons

Cost, embodied energy and carbon emission comparisons

Project	Reference		Cost $/sqm (03/04$)	Difference %	Embodied Energy GJ/sqm	C02 released kg/sqm (1)	Difference kg/sqm
6 storey apartments (1), (2)	J Chapman 2002	Timber	198	-22	1.0	-2	
4000sqm		Concrete	241		2.4	55	57
Industrial building - 1 storey (2)	Buchanan &	Timber	na		na	117	
1000 sqm	Honey (1993)	Steel	na		na	250	133
Education bldg - 4 storey (2)	Buchanan &	Concrete	na		na	496	
8568 sqm	Honey (1993)	Steel	na		na	549	
Office building - 5 storey (2)	Buchanan &	Timber	na		na	132	
2400 sqm	Honey (1993)	Concrete	na		na	349	217
YMCA hostel 6 storey (3)	G Thomas 1991	Timber	1259	-4	0.93	-53	
4190 sqm		Concrete	1314		1.24	80	133
Office building 5 storeys (3), (4)	M Halliday 1991	Timber	873	-3	na	na	
2460sqm		Concrete	904		na	na	
3 storey Apartment complex (3), (5)	W Banks 2000	Timber	1160	-22	na	na	
5500 sqm		Concrete	1416		1.86	157	

na = not available.
(1) Frame and floor only, excludes foundations, claddings, linings, fittings.
(2) Uses "old" embodied energy, carbon release factors, from Buchanan and Honey (1991).
(2) Uses updated embodied energy, and carbon release factors, from Alcorn (2003).
(3) Whole building including services and decorating, concrete costs are as built cost, timber costs are estimated.
(4) Costs are abased on an existing 3 storey concrete building with two storeys added.
(5) Timber buldings costs are as built. Concrete costs are estimates for same layout, and same non-structural components.

Updated factors (Alcorn)	Embodied energy GJ/cum	CO2 emissions kg/cum	
Sawn timber	1.25	-696	
Plywood	5.7	-480	
Concrete	2.8	376	
Steel	67.1	2766	recycled reinforcing steel
Plasterboard	7.08	404	
Particleboard	5.7	-200	

The embodied energy and carbon releases per sqm of floor area vary somewhat between buildings. The first four projects used "old" factors based on an 1990 analysis of building materials. This work was updated in 2003, as shown in the tables above, and some of the coefficients changed markedly. For example, the concrete factors dropped significantly reflecting a change in the manufacturing process in the interim, toward much more energy efficient production processes in the cement industry. At the same time the sawn timber industry had improvements in efficiency of production, though not to the same extent as the concrete industry. The results of the savings in carbon emissions, from an increased use of structural timber, are summarised in Table 5. They assume that savings will average about 133 kg CO_2 per sqm of floor area, as per Table 12.

10.6 Building industry structure and its ability to build more timber buildings.

The predominant structural system in the residential sector is timber framing, comprising about 92% of all new stand-alone houses, and about 80% of multi-unit construction. In 2005 the forecast value of timber framed housing is $3.9 billion, and for timber framed non-residential buildings about $200 million in the "business as usual" scenario, giving a total of $4,100 million of timber framed buildings. The estimated value of additional potential timber framed buildings, numbered in Tables 3 and 4, for government and private sectors is estimated at about $580 million, an increase of 14% in timber framed buildings. This implies a shift in skills in the building sector from steel and concrete structures to timber, consisting of about 14% of the workforce. This is a significant shift but is well within the ability of the industry to manage. Currently the industry workloads are at an all-time high mainly due to new housing demand, but a drop of about 16% in work is expected over the next 18 months from about 31,000 new dwelling units per year to about 26,000 per year. These skills presently employed in housing would be readily transferable to non-residential timber buildings. The main constraint could be in design skills and resources for designers, as discussed in Section 5.1, and reliable data on timber properties and design aids would assist the take up of timber framing in non-residential buildings.

10.7 Heating plant fuel sources in Government buildings.

This section investigates the potential of wood fuelled heating plants in Government buildings. Currently all plants surveyed use either coal or natural gas for central heat plants. The younger plants in the North Island tend to use gas, while the older plants, over 20 years, are mainly coal fired.

In a sample of education and health buildings the following fuel types were found:

- Auckland University – Distributed natural gas, 200-300 kW plants, plus some coal fired steam from Auckland Hospital. Previous the boilers were mainly oil fired, in a large central plant.
- Auckland University of Technology – 2 campus, and 7 boilers in total 600kW to 1900 kW each. All fired by natural gas.
- Waikato University – decentralised natural gas boilers. No coal.
- Otago Polytech – central coal fired boiler supplying about 10 buildings.
- Mid Central DHB – using natural gas in a central boiler for Palmerston North Hospital. Coal is used as a back up. The new building nearing completion will use gas and has extra capacity so that the existing gas/ coal unit will be closed.
- Wairarapa DHB – current site is using 2/1.2 MW coal fired boilers. Current operations will move to new buildings ($30M) on a new adjacent site and probably a new heat plant will be built. About 1500 kW, either LPG or electricity, and yet to be decided.
- Nelson/ Marlborough DHB – 5 sites. Nelson, 290 and 450 kW coal fired boilers. Murchison and Wairau hospitals, small coal fired boilers. Motueka hospital, diesel, and Golden Bay hospital, electric.
- Christchurch DHB - 5 sites. Christchurch hospital 3 coal fired boilers 600- 800 kW each. Princess Margaret Hospital, electric. Hillmorton distributed LPG boilers (very expensive to run). Burwood, 2 coal fired boilers. Ashburton 2 coal fired boilers. The Resource Consent for the Christchurch Hospital boilers expires in 2011 and the plant manager doubts the consent will be renewed without major expenditure on scrubbers. The Christchurch boilers will need replacing before then and alternative fuels are to be seriously considered.

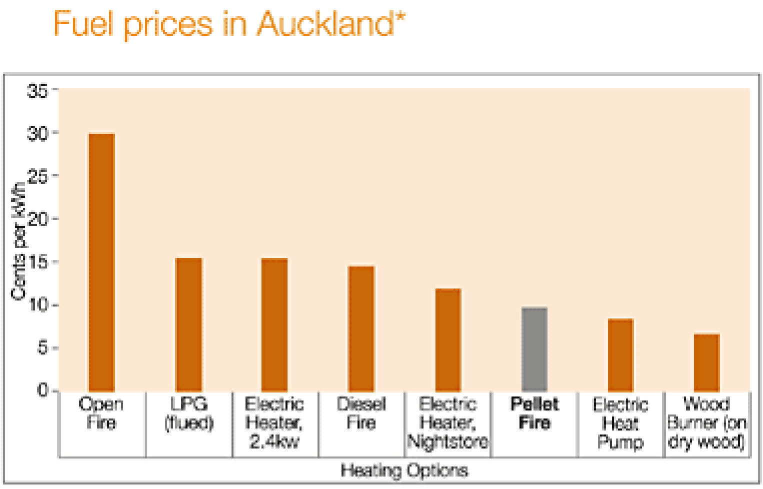
Substitution of coal and gas fuel with wood fuel could use either wood chip or wood pellets. In a paper on bioenergy[12] a Forest Research scientist investigates three scenarios in which 25%, 60% and 100% of total organic waste in New Zealand (forest residuals, wood processing residuals, paper, demolition waste, firewood, etc) is used as fuel. In the first scenario 20% of industrial, 2% of institutional and 3% of domestic space and water heating energy use would be supplied from organic waste. This saves about 0.73 million tonnes CO_2/year and 12 PJ/ year of energy, because of efficiency savings from using wood fuel directly in place of electricity generated from natural gas and coal fire power stations. The reduction in carbon releases from decaying organic waste is also included. In the second scenario 20% of institutional space and water heating energy use (and 10% residential, 20% industrial) is supplied by organic waste, with carbon reductions of 1.95 MtCO2/yr and energy savings of 29PJ/yr.

The paper suggests a combination of wood chip, solid wood, and wood pellet as the fuel type. In the first scenario the volumes are 1.1 million tonnes of chip and solid wood fuel, and 110,000 tonnes of wood pellet per year. In the second scenario the volumes are 2.1 million tonnes of chip and solid wood fuel, and 540,000 tonnes of wood pellet per year. Wood pellet is preferred to the other wood fuels because its energy content per unit weight is approximately double solid wood, and it can be automatically fed through thermostatically controlled hoppers.

The current production of wood pellets in New Zealand is only 3000 tonnes per years, almost all for residential use, so that manufacturing operations would need to be scaled up by 40 times in the first scenario, and 180 times in the second scenario. Domestic wood pellet stoves with and without wetbacks are made in New Zealand, with a capacity of about 12 kW. The only commercial wood pellet boiler currently manufactured locally is a 25kW unit with auto ignition and auto feed. In most institutions (schools, hospitals, etc) the usual boiler size is about 500 to 800kW for centrally located plant, but may be 100 to 200kW if the plant is distributed among buildings or servicing groups of small buildings. So suitable pellet fired boilers are not available locally for most institutional buildings, though manufacturers advise it would be fairly easy to scale up the current wood pellet heat plant designs. The fuel cost is competitive with other fuels according to the suppliers, see www.naturesflame.co.nz, from which Figure 10 was obtained. Note that the company manufacturing the pellets, Pellet Fuels NZ Ltd, has been recently purchased by Solid Energy New Zealand Ltd, the Government owned coal producer.

[12] Nielsen Per, 2004 "The role of bioenergy to meet the renewable energy target for New Zealand." Proceedings International conference for sustainability, engineering, and science. Auckland July 2004.

Figure 10 Heating energy fuel prices



Source: Naturesflame website.

Discussions with Dr Pers Neilson of Forest Research revealed the following:

- The maximum wood pellet design heat plant in New Zealand is 25kW.
- A pair of these furnaces would service a building up to about 800 sqm, which covers a significant number of Government buildings, see Table 6 (and use a conversion of $1600/ sqm).
- A 175 kW wood pellet furnace is currently being designed by furnace designers, A Estcourt Ltd, phone 07 347 7261.
- In addition to the Solid Energy wood pellet manufacturer there is an Auckland company Golden Strand Wood Fibres Ltd. A Hasting company, Inset Firelogs Ltd, is expected to start wood pellet manufacturing next year.
- Currently pellets are bagged but in Europe they are mainly bulk supplied, at a unit cost about 50% below the bagged price. They can be handled by pump systems, similar to coal slurry pump systems.

Dr Neilson is hoping to get Government funding to install a large demonstration wood pellet furnace in a Rotorua school.