Tyfu Tŷ Unnos

The opportunity for home grown timber in the construction of affordable housing in Wales

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COED CYMRU

Cronfa Amaethyddol Ewrop ar gyfer Datblygu Gwledig: Ewrop yn Buddsoddi mewn Ardaloedd Gwledig
The European Agricultural Fund for Rural Development: Europe Investing in Rural Areas

Llywodraeth Cymru
Welsh Government

Preface

The Supply Chain Efficiencies Scheme of the Rural Development Plan for Wales 2007-2013 provides the context for this report.[1] Coed Cymru secured funding for the 'Low Value Timber' project to take forward research and innovation into the uses of Welsh timber, and seek to increase the use of home grown timber in different markets.

Wales relies heavily on timber imports and much of harvested Welsh timber doesn't find its way into local markets, despite demand for timber products in general and the presence of a vibrant timber manufacturing sector. The project aims to exploit the characteristics of available raw materials and ensure that more Welsh timber in used in Wales. This report describes the first steps in understanding the resource base, current practices and techniques for adding value, and the potential for providing affordable housing units from the softwood resource, using Tŷ Unnos system as a case study.

Photo Credits

[1] Rural Development Plan for Wales 2007-2013: Supply Chain Efficiencies Scheme. Funded by European Agricultural Fund for Rural Development. Welsh Government 2008.

Executive Summary

Timber is an important economic resource and demand is currently being met mainly by imported timber in a competitive market, only 40% by volume being met from the home grown UK market which provides less in terms of economic contribution as much of this goes into the lower value markets.[2] The role Welsh woods and forests have played in contributing to the economy of Wales has gradually eroded since the end of the Second World War. A combination of falling timber prices and the increasing availability and competitive pricing of timber imports have left the indigenous forest sector facing significant challenges.

Welsh Government expects a number of outcomes from a competitive and integrated forest sector; the key outcome relevant to this discussion being that more Welsh-grown timber is used in Wales. This includes timber used in all different aspects of the economy, but especially in high value end uses such as construction, and housing in particular.

This report has been produced as part of the Supply Chain Efficiencies Scheme 'Low Value timber' projects undertaken by Coed Cymru and funded by the Rural Development Plan for Wales 2007-2013. This initiative is supply chain-focussed and aims to provide capacity building support in the Welsh timber sector, from forest to finished product. Adding value is important in supporting the businesses involved at each stage, to enable a thriving, skilled workforce to be established and maintained in the sector.

A general description of the resource is followed by characteristics of the commonly used hardwood and softwood timbers. Techniques commonly used for adding value are briefly described, and an examination of current uses and the potential for adding value along the supply chain by using Welsh timber in construction is explained, with Tŷ Unnos as a case study. This is set against the background of acute housing need in rural Wales.

Specifying home grown timber has many advantages, in terms of carbon storage and the recent international recognition that identification of carbon at source, where the tree has grown, can now be included in greenhouse gas inventories at national levels. Coupled with the need to provide jobs and training for new skills in low carbon construction, and the need to satisfy the demand for affordable housing, using home grown timber in Tŷ Unnos has the potential to add value to an otherwise neglected resource, while bringing much needed benefit to the rural communities in Wales.

The new challenges of our age are moving towards a low carbon economy, securing jobs and training opportunities and providing sufficient affordable housing. The resource is readily available and could be put to good use, if sufficient interest and investment is directed into intervention techniques.

[2] http://wales.gov.uk/newsroom/businessandeconomy/2012/6758962/?lang=en [Accessed 040613]

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1. Introduction

Timber is one of the UK's most important raw materials. It is also one of its major imports. The aim of this paper is to assess the current status of the home grown timber resource in Wales, looking at the supply chain issues and the obstacles to its more widespread use. The overall objective of the Supply Efficiencies Scheme is to create added value to the existing resource and facilitate the uptake of new products and new markets for home grown timber. Similar supply chain issues exist in the food industry, where successful attempts have been made to raise interest in local food markets and encourage procurement of local produce. Wood, like food, is a key provisioning 'ecosystem service'[3] from land management in Wales. Developing a parallel supply chain for timber is an important part of the Supply Chain Efficiencies Scheme of the Rural Development Plan set up by the previous Welsh Assembly Government.[4]

In addition to examining and streamlining efficiencies in the existing supply chain, the objective is to make recommendations to bring about new and more effective use of the softwood resource, particularly Sitka spruce. The newly available larch resource, resulting from sanitation felling of plantations affected by the *Phytopthera ramorum* disease has recently attracted interest although larch is difficult to sawn and kiln to keep it straight. A report into the use of the timber concentrated on its structural applications but it has uses in joinery and potential to take Heat Treatment.[5] This is a relatively new departure for Coed Cymru, which previously focussed on promoting the more sustainable management of the hardwood resource.

The timber industry accounts for over 1200 businesses in Wales, employing 9500 people, (latest figures for 2008 from Office of National Statistics)[6] which are diverse,

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[3] Ecosystem services are the goods and services that the natural environment provide, such as food and building materials, sources of energy, clean air and water, wildlife and space for health and recreation

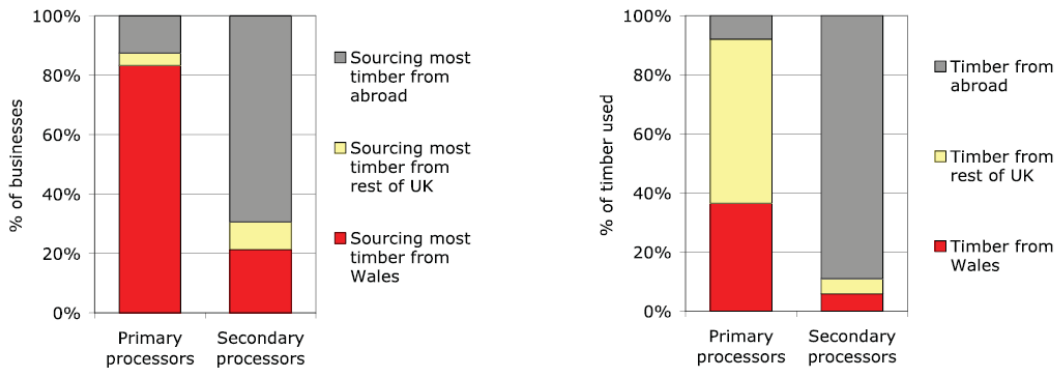
[4] The Rural Development Plan for Wales 2007-2013 Supply Chain Efficiencies Scheme

[5] Japanese larch in Wales: investigating the potential to grow market share of larch in Wales and the Marches with a view to utilising increased timber production due to Phytophthera ramorum sanitation fellings. Dainis Dauksta. Wales Forest Business Partnership April 2011

[6] Quoted in Woodlands for Wales Indicators Revised March 2011 at http://www.forestry.gov.uk/pdf/WoodlandsforWalesIndicatorsWAG2011.pdf/$FILE/WoodlandsforWalesIndicatorsWAG2011.pdf

often family-owned enterprises ranging from the small and medium scale manufacturers to large scale sawmills. Figures for numbers directly employed for 2007 indicate 8,900 generating regional Gross Value Added of £372 million. Most of these use only imported timber (Figure 1).

The reasons for the demise of the use of the home grown timber resource in Wales are many and varied but closely aligned to economic and environmental drivers. Ironically, it is likely to be economic and environmental drivers that will bring about the changes required to facilitate the use of the Welsh timber resource. A political aspiration to find employment opportunities, especially in rural Wales, coupled with carbon emission reductions and energy efficiency regulation, are in place to bring about benefits for the industry. A review by the Land Use and Climate Change Group set up by Elin Jones, then Minister for Rural Affairs[7] outlined the role of woodland in sequestering carbon, creating jobs and strengthening communities, social enterprise and Welsh culture. One of the key outcomes of a competitive and integrated forest sector stated in the Woodlands for Wales Strategy[8] is that more Welsh grown timber is used in Wales. This will be discussed in Section 5, following a more general discussion and reference to the resource and supply chains.



Source: FCW Survey of Woodland Enterprises 2010, based on sample of 24 Primary Processors and 75 Secondary Processors.

Figure 1: Source of timber inputs to primary and secondary timber processors

[7] Land Use Climate Change Report to the Welsh Assembly Government, LUCC Group, March 2010
[8] Woodlands for Wales: the Welsh Assembly Government's Strategy for Woodlands and Trees, 2009

2. Background

Trees have provided food, fuel, medicine and timber for fashioning weapons and building shelters for humans since humans first walked the earth. They still make a vital contribution to the survival of mankind and many other species by virtue of their biological functions and climate-tempering influence. Woods and trees are seen as a valuable resource in many primitive cultures and are now acknowledged by the world community to be one of the most important global habitats because of the biodiversity they support and the ecosystem services they provide. They are increasingly considered to be of value in the provision of important health and leisure opportunities, as well as being of intrinsic aesthetic value, particularly in the UK where forest cover is amongst the lowest in Europe (Figure 2).

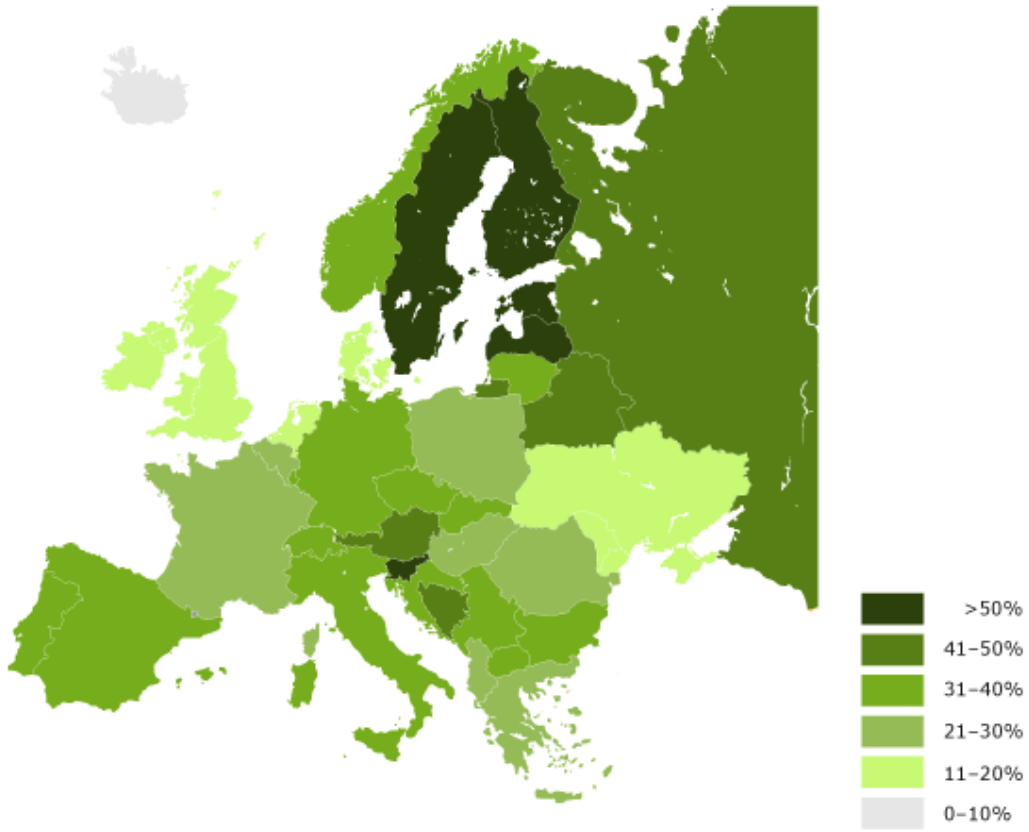


Figure 2.1: Areas of forest cover in Europe

Figure 2.2 Typical plantation forest on Berwyn mountain

Figure 2.3 Harvester at work in the forest

2.1 Historical Context

Since the development of settled communities, methods of managing the woodland resource for specific end uses have emerged, that could be relied upon to produce a renewable and sustainable volume of timber. This pattern of reliance on a local timber resource remained common practice in Wales until the 19th century, part of an ancient tradition of woodsmanship involving coppicing, pollarding and regeneration in the woodlands supporting a plethora of industries from shipbuilding to charcoal production.

Demand for timber of all sorts grew dramatically during the industrial revolution so that by 1880 nearly all of the timber used in the UK was imported. This included very large amounts of coniferous roundwood from Northern Europe and North America which was used in mining coal and iron ore. Naval blockades during the first World War led to shortages which threatened production from the mines, leading to the establishment of the Forestry Commission in 1919. Its task was to ensure a strategic supply of timber in the event of future conflicts. Ironically perhaps, it chose to do this through the use of plantation methods developed in Germany during the 19th Century, although these were already falling out of favour on the Continent. The expansion of largely single species stands of coniferous plantations in Wales continued for the next 70 years. The Commission purchased land, mainly poor agricultural upland and broadleaved woodland, which was planted and managed as the State Forest. It also provided grants and tax incentives to private landowners to encourage new planting and “coniferisation” of broadleaved woodland. Today Wales has 150,000 hectares of coniferous plantation and 153,000 ha of broadleaved woodland.

The year 1919 also saw the beginning of the process which led to the biggest upheaval in land ownership in Wales since the Dissolution of the Monasteries. Many of the larger estates were sold to existing farming tenants to pay death duties but standing timber was sold separately, usually to timber merchants who were given 6 or 12 months to remove any saleable timber. This had a devastating effect on the timber resources of Wales.

Meanwhile, in Scandinavia and the Baltic States, large tracts of land cleared in prehistoric times were re-afforested in the 18th and 19th centuries. This process continued in the 20th century with extensive "policy plantings" in many parts of Europe. As a result, and despite growing demand for softwood, supply has outstripped demand to the extent that the EU is currently harvesting only 60% of its sustainable cut.

In Sweden, the sawmill industry's future has better prospects than the pulp and paper markets, provided this industry sheds its commodity orientation and increases value-added by components in such areas as green building[9]. If this is true for countries rich in forest cover, it must be more than relevant to the use of woodlands in Wales.

2.2 Current Policy Context

Global, European, UK and Wales regulations to mitigate the impact of climate change have set high and challenging targets for greenhouse gas emission reductions between now and 2050. The timber industry is affected particularly in relation to construction, as buildings worldwide account for 50% of CO2 emissions when embodied and operational energy are taken into account.

The main driver from Europe is the Energy Performance of Buildings Directive that sets the carbon targets for all EU Member States and gives the context for the Building Regulations in the UK. These Regulations have been devolved to Wales and will offer an opportunity for the carbon reduction requirements in Part L Conservation of Fuel and Power[10] for new build dwellings to be addressed in appropriate ways, one aspect of which is the consideration of the embodied carbon in buildings.

The validation of the contribution to emissions abatement from forestry products and the energy and construction sectors is complex. The UK's land use, land use change and forestry greenhouse gas inventory is inadequately reflected in emission inventories, but a more holistic view of emission abatement would be supported by appropriate approaches to carbon accounting and a comprehensive evaluation of

[9] Swedish Forest Sector Outlook Study Jonsson et al United Nations Geneva 2011
[10] http://wales.gov.uk/consultations/planning/buildingregspartl/?lang=en
[Accessed 280513]

lifecycle analyses for a wide range of wood products, particularly the lifecycle of embodied timber in buildings.

As trees absorb substantial amounts of carbon dioxide and the wood products from forests store carbon, forests are unique in having this double benefit for climate change mitigation. Timber has a low embodied energy compared with steel or masonry, requiring little processing. It is a renewable resource, can be reused and is recyclable at the end of its useful life. When used in construction it locks in carbon over the lifecycle of the building. Timber stored in products is now accountable in terms of Kyoto Protocol targets, which is discussed later. Adding value to home grown timber by using it in construction and other long-lasting products locks up carbon for long-term use and is one of the Woodland for Wales priorities of the Welsh Government.

The Forestry Commission Wales Corporate Programme for Promotion of Timber and Development of the Forest Sector recognises a number of key **drivers** in respect to the role of timber in the Welsh economy:

- Timber is a renewable and flexible low carbon raw material and one of the main products arising from the active management of woodland
- Timber is an environmentally friendly and cost effective building material with the potential to displace high-embodied energy building materials such as concrete, steel, brick and plastic and high carbon emission fossil fuels such as coal and oil
- At almost any age and after almost any use, timber can be used as a renewable energy source, displacing fossil fuels in the generation of power and local heat. This use of timber in particular, is currently heavily influenced by government interventions such as the Renewable Obligation Certificates
- Woodland management has the potential to generate significant economic activity in rural areas. Activity which in part or in full, can fund the sustainable management of these woodlands
- By adding value to timber through primary, secondary and tertiary processing, it is possible to generate significant additional economic activity

- Despite the domestic demand for timber currently exceeding supply from Welsh woodlands, there is very poor performance in relation to the harvest of Welsh hardwood timber. In 2000, it was estimated that only 8% of potential increment was harvested in contrast to the conifer harvest where performance is at approximately 90%[11]

The use of timber as a substitute for high-embodied energy building materials in the construction industry (carbon substitution) is a key aspiration and gives the context for adding value to the Welsh softwood resource. Using wood as an alternative to other building materials saves an average of 0.9 tonnes of carbon dioxide per cubic metre.[12] On average, building a house in timber instead of brick reduces carbon emission by 10 tonnes.[13]

The many attributes of timber: structural expression, natural beauty, ease of use, thermal performance, strength, durability and provision of a wide range of engineered solutions, makes the use of wood attractive and beneficial in terms of economic, carbon saving and aesthetic value. Its use in buildings and construction make further contributions to the carbon store through their lifecycle: use, re-use, recycling and recovering by burning or decay. Therefore wood products are an efficient way of extending the storage of the forest carbon sink.

In recognition of the value of wood and paper products or Harvested Wood Products (HWP) in contributing to climate change, the UN Framework Convention on Climate Change decided at the Conference of the Parties at Durban in 2011 to include HWP in carbon accounting as mandatory. Locking carbon in long term products and adding value to Welsh-grown timber are two Welsh Government priorities which are addressed by the use of home grown timber in construction; in the case of buildings this carbon can be locked away for a very long time. Welsh Government could follow France's example of the 'Wood First Rule'[14] for procurement of public buildings, triple wins could be achieved in terms of mitigating climate change, providing much needed employment in the forest sector and supporting rural networks.

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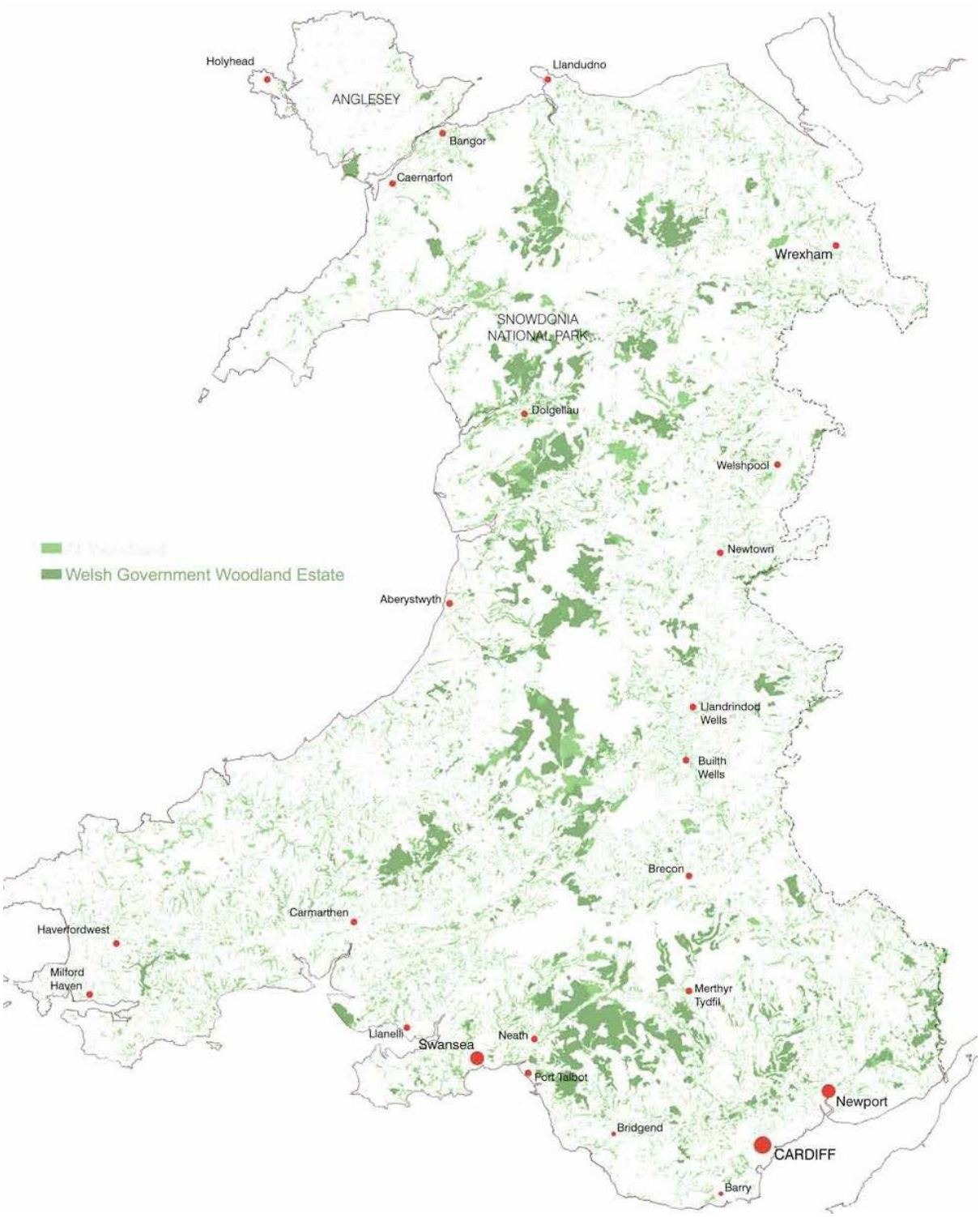
[11] Forestry Commission Wales Corporate Programmes and Guidance. Programme 8: Promotion of Timber and Development of the Forest Sector. Chris Edwards, 2009
[12] Timber Industry Manifesto
[13] The Miracle of the Carbon Cycle. Dr A. Frühwald, University of Hamburg, 2002. This refers to carbon dioxide emissions
[14] Timber Industry Manifesto



Map showing timber resource in Wales

Source Forestry Commission Wales

3. The Resource in Wales

Latest figures from the National Forest Inventory Woodland Area statistics indicate that 14.3 % of the total land area of Wales, 304,000 hectares, are under the cover of trees.[15] This estimate, using more accurate monitoring techniques, is around 20,000 ha more than the previously published data for 2010. Of this total growing resource, 151,000 ha are coniferous plantation of relatively recent planting with a rotation of 40-45 years and producing around 1 million m^3 of timber per annum[16]. Broadleaf woods account for 153,000 ha which are mostly privately owned, largely ancient and producing around 30,000 tonnes of timber every year.[17]

3.1 Hardwood Timber

Oak and ash dominate with oak much more prevalent (43,000 ha as compared to 19,000 ha of ash). Oak is usually harvested between 80 and 140 years old though there is a growing market for material from 35 years. The timber has variable grain which is hard and strong. It is used for joinery, veneers (which timber is sent abroad), furniture, structural timber, flooring and fencing. Ash is straight-grained, hard and strong and is usually harvested between 35 and 80 years old. It works easily to a good finish, takes stains, glues and varnishes well. It has a variety of uses including veneers, sports goods, tool-handles, furniture, joinery and flooring. Beech and sycamore are common and species present in lesser quantities such as birch, alder and sweet chestnut, may become viable for use in new applications (for example, chestnut used for exterior cladding).

Some specialist use of home grown hardwoods continued until the Second World War. Horsedrawn vehicles were still common on farms and wheels and frames were regularly repaired and replaced. Furniture making and joinery depended on imported timber with teak and mahogany the predominant tropical types and North American oak and maple species the main temperate timbers. The introduction of hydraulic

[15] National Forest Inventory Woodland Area Statistics Wales Forestry Commission March 2011

[16] 1 million tonnes of timber by weight approximates to 1 million cubic metres (m3) by volume

NB Tonnes normally used for unprocessed and unsawn timber but m3 normally used for sawn timber

[17] http://www.forestry.gov.uk/pdf/area2011.pdf/$FILE/area2011.pdf

mining after 1947 created a demand for hardwood blocks as the demand for wooden props declined. This continued until the 1990's.

The selective conversion of hardwood sites to coniferous plantation between 1945 and 1985 was a particularly effective programme. About 40% of the total area was converted during this period but this included only large, productive and accessible sites. The majority of these sites are still under conifers and those that are in conversion to broadleaf are in the early stages of the process. This had a huge impact on potential hardwood production as most remaining hardwood sites are on steep, unproductive and infertile land.

When Coed Cymru began to look at hardwood supplies in the 1980's there were 3 small mills processing hardwoods, one of whom was using a kiln and 3 mining timber mills. Larger parcels of hardwood were sold from time to time by the larger estates, (for example, during the Lloyds crisis) but these invariably left Wales as round timber. This coincided with the arrival of portable sawmills and a growing resistance to tropical timbers. Meanwhile, Coed Cymru campaigned for greater use of home grown hardwood and supported this with process and product development. As a result of all this coming together we now have over a hundred small mills in Wales and the mainstream hardwood markets rely largely on European hardwoods.

Demand for Welsh hardwoods is very species specific. Durable species such as oak and chestnut sell easily for high prices. Other species are more difficult to sell. The loss of furniture manufacture in the last 10 years has drastically reduced the use of whitewoods like beech and birch and thousands of jobs have been lost in the process.

3.2 Softwood Timber

Two principal species, Sitka spruce and larch, account for over 90% of the standing crop in Wales. Sitka spruce, a native of North America, is the most commonly planted timber tree in the UK. Planted from the end of World War II, it is the largest proportion by area and by volume (accounting for 70% of current sawmill production). Planted on wet infertile sites in Wales, it is fast growing, producing low density timber with heavy branching and large knots. It is very soft and difficult to finish, non durable and resistant to timber treatments. It saws and nails well. Harvested at 40 to 50 years, it is used in construction as carcassing timber machine graded to C16[18], packaging and fencing. It is widely used in the paper and particle board industry but the use for paper processing in Wales has ended with the setting up of the UPM-Kymmene paper recycling plant at Shotton on Deeside. Industry figures reflect this decline.

Larch, planted on sheltered fertile sites, is usually felled when about 55 years old. However, with the advent of the *Phytophthera* pathogen it is likely that a large proportion (estimated at 5M tonnes) will be prematurely available from sanitation felling. It is strong and straight-grained although strength and durability is very variable. Resin seep is a problem with joinery timber. Seasoned larch is susceptible to furniture beetle which requires its treatment for use in permanent structures.

Douglas fir and pine are present in smaller quantities than the two main species, and pine plantations are suffering badly from a complex of fungal diseases.

[18] C refers to Conifer and 16 the grading of the timber. This is discussed further in section *7*.

3.3 Plant Health, Pests and Diseases

The threat from pests and disease continues to plague many of Britain's trees. Chalara dieback of ash trees has been found in the wider environment for the first time[19], following its first discovery in October 2012 in Carmarthenshire. [20] It is a serious disease caused by Chalara fraxinea fungus causing leaf loss and crown dieback. The pathogen was first reported affecting trees in Poland in 1992.

Many tree diseases originate in imported species, and *Phytopthera ramorum* affecting larch is now widespread. The demise of the elm through Dutch elm disease was well know in the 1970s and wiped out between 25 and 30 million trees. This is a case for planting, growing and using more UK-grown plants which are known to be disease-free. With climate change comes more frequent outbreaks of pests and diseases, deterioration of condition of tree species and more storm damage. Other current disease outbreaks in Wales include red band needle blight affecting pine, acute oak decline, bleeding canker and horse chestnut leaf miner.[21]

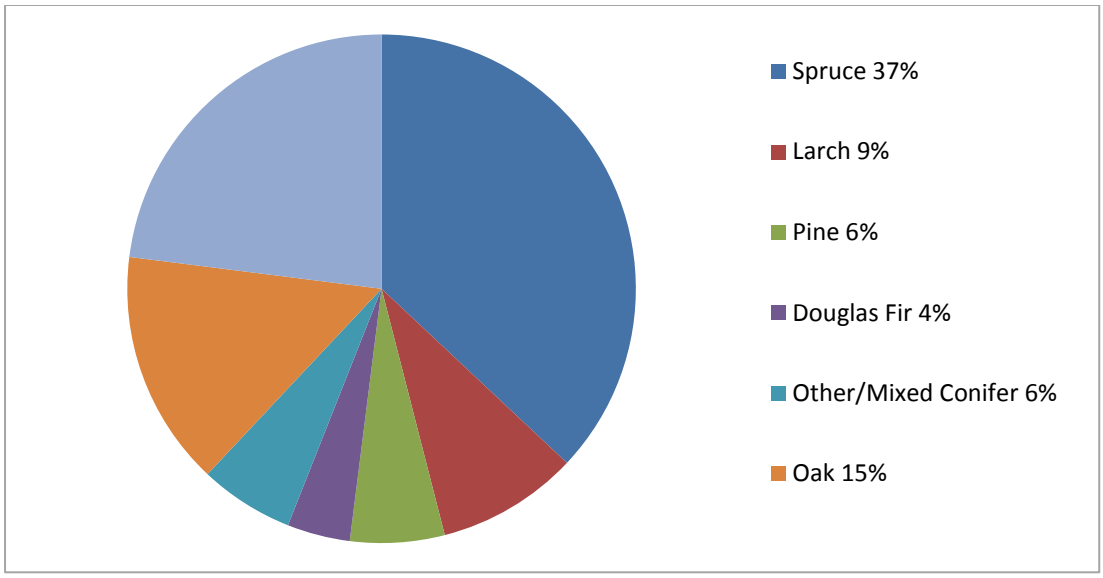


Figure 3.3 Species breakdown in 1998

Source: National Inventory of Woodland and Trees

[19] http://naturalresourceswales.gov.uk/our-work/news/chalara/?lang=en

[20] http://www.forestry.gov.uk/forestry/INFD-8Z6J87

[21] Woodlands for Wales Indicators Revised June 2012

Table 1: Uses for Timber grown in UK: Hardwoods

Common Name	Uses
Alder	Minor Utility Products, Plywood, Turnery,Veneers, Flooring
Ash	Joinery, Flooring, Furniture, Panelling, Tool Handles, Crafts, Veneer, Sports goods
Beech	Interior Joinery, Furniture, Flooring, Musical Instruments, Toys
Birch	Plywood, Turnery, Furniture, Toys
European Cherry	Flooring, Furniture, Musical Instruments
Sweet Chestnut	Joinery, Fencing, Furniture, Flooring, Exterior Joinery, and Cladding
Elm	Joinery, Furniture, Flooring, Crafts
Hazel	Woven Fencing/Hurdles
Holly	Craft Work, Inlays
Hornbeam	Minor Items, Musical Instruments
Lime	Furniture, Flooring, Turnery, Carving
Oak	Joinery, Fencing, Furniture, Flooring, Exterior Joinery, Structural Products, Tan bark
Poplar	Matches, Minor Craft Goods
Sycamore	Interior Joinery, Furniture, Flooring, Toys, Musical Instruments
Willow	Cricket Bats, Basket Work, Toys, Woven Fencing

Table 2: Uses for Timber grown in UK: Softwoods

Common Name	Uses
Western Red Cedar	Cladding, External Joinery
Douglas Fir	Exterior Joinery, Cladding, Structural Products, Sea defences
Western Hemlock	Packaging, Carcassing, Particle board
Larch	Cladding, Fencing, Particle board
Corsican and Scots Pine	Fencing, Packaging, Particle board
Spruce	Fencing, Packaging, Carcassing, Particle board
Yew	Interior Joinery, Veneer, Turnery, Furniture

***Source**:* Adapted from *TRADA Local timber species and their uses*

available at:

http://www.forestry.gov.uk/pdf/nf-awood-local-timber-species-and-their-uses.pdf/$FILE/nf-awood-local-timber-species-and-their-uses.pdf

4. The Timber Supply Chain in Wales

The timber supply chain is characterised by the raw material and the end product. All products require some form of treatment or processing, involving conversion from felled tree through various stages of sorting, seasoning and grading before manufacture and assembly into useful timber products. At every stage co-products arise. These may be used as fuel or undergo further processing.

Primary processing begins after the raw material is extracted from the forest. Conversion may involve de-barking, sawing and sorting of the timber. The sawing pattern for a softwood tree is shown below.

Larger dimension structural timber is cut from the centre of the log, containing the juvenile wood where quick growth occurs in the early stages, while the tree is in open canopy. Smaller dimension side or falling boards are cut from the outside of the log which develops at a slower growth rate once the tree is in competition with neighbouring trees.

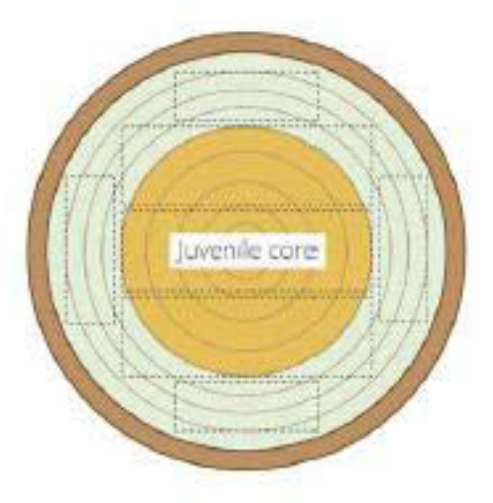


Figure 4.1 Cross section of softwood tree indicating cutting pattern: heartwood core surrounded by slower growing outer section

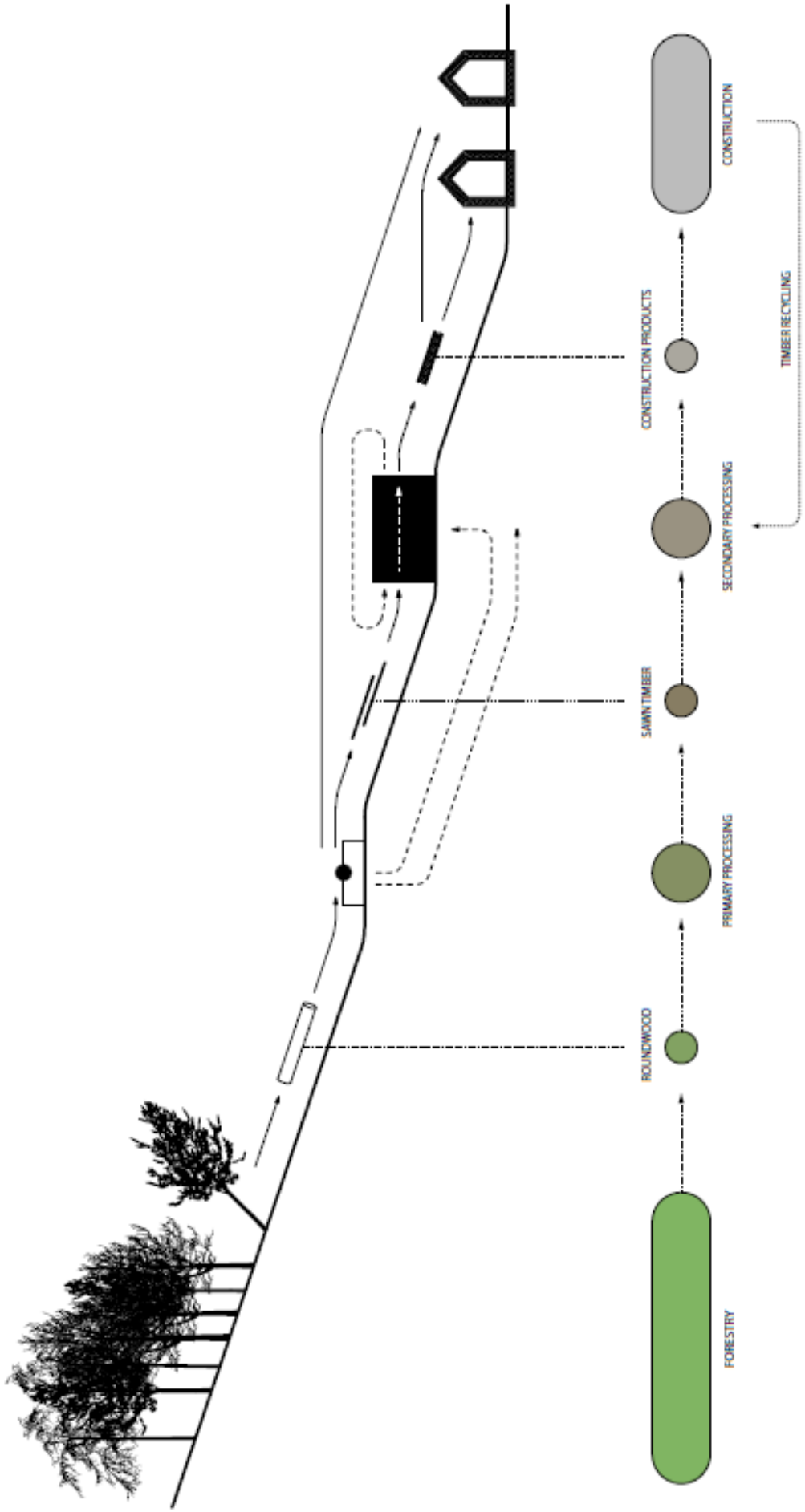


Figure 4.2 Typical supply chain from forest to end product

Source: Thomas Stoney Bryans

Sawmills may provide further processing such as air and kiln drying and stress rading. Products produced from the sawmill process include fencing and ungraded timber, graded timber for structural use and timber for joinery and carpentry. Primary processing also takes place in the Kronospan plant at Chirk where MDF and chipboard are produced. Secondary processing includes the manufacture of furniture, timber buildings, packaging and joinery components (Figure 4.2).

There is no single standard supply chain for wood and paper-based products. All supply chains are different but often interconnected through common co-products.

Solid wood, engineered wood and paper-based products are manufactured using different technologies, but they potentially originate from the same forest or even the same tree. Some forest-based industries use all parts of the tree for different products in a system of integrated processing facilities. Others specialise and use only the most appropriate portion of the tree.

Three large sawmills (>100k tonnes pa) operate on a significant industrial scale using timber of Welsh origin; BSW Timber at Newbridge on Wye, Pontrilas Timber at Pontrilas on the border near Hereford and Kronospan at Chirk. These rely heavily on coniferous timber with three-quarters of their requirements coming from Welsh forests.[22] A number of smaller mills in Wales and the Marches also process significant amounts of softwood for fencing and packaging.

Timber from the UK wood processing industry can be categorised as follows:

Sawnwood

The frequency, size and condition of knots are growth-related features that affect the suitability of timber for a number of end products, particularly sawnwood.

Softwood sawn timber is used for structural applications along with several other uses such as pallets, fencing and decking. Hardwood sawn timber is used in post and beam structures and products such as flooring and furniture.

[22] Woodlands for Wales ibid

Wood-based panels

Small diameter logs and recycled timber are frequently reduced to wood chips and sawdust that are then glued together to form large sheets with very uniform properties. Three types are currently made in the UK: particleboard, medium density fibreboard (MDF) and oriented strand board (OSB). These are large industries, and currently the UK imports the majority of the latter, although there are mills in Scotland involved in its manufacture.[23] Board materials such as OSB and MDF are available in various sizes for a wide range of structural, decorative and utility uses.

Engineered Wood Products (EWP)

Timber and wood-based panels are increasingly used in manufacturing large structural elements such as glue laminated timber beams (glulam, cross laminated panels (massive timber and brettstapel) and structurally insulated panels (SIPs). These are currently mostly imported, although I – joists are manufactured in Scotland using a combination of imported softwood and OSB. A small amount of glulam is made here on a bespoke basis. Further development is likely to include a move to factory produced structural panels and frames for housing, including insulated closed panels ready for assembly on site. This is in response to government initiatives to increase efficiencies and reduce waste in their Modern Methods of Construction programme (MMC).

Paper and board

Due to a low content of extraneous chemicals (extractives), home grown spruce is ideally suited to some types of paper and cardboard, as less bleaching is required than for the pulp of some imported timber. Since the conversion of the newsprint paper mill at Shotton to 100% recycled fibre, paper manufacture from Welsh spruce has ceased. Boards continue to be made in Kronospan.

[23] Sustainable Construction Timber: sourcing and specifying local timber. Ivor Davies, Forestry Commission Scotland, 2011.

Other Wood Products

Turnery, log buildings, garden sheds etc are produced from home grown timber. The fuelwood market is growing fast, with demand for a range of products from logs, chips and pellets on the increase due to the high cost of fossil fuel and atttractive subsidies to encourage the use of renewable fuels.

Co-Products

These include bark, wood shavings and sawdust. Wood chips are used for carton board, pulp and paper, chipboard, MDF and producing energy; sawdust in chipboard, agricultural bedding and energy generation; bark as horticultural composting material and shavings as agricultural and equestrian bedding. The processing and marketing of these co-products is often highly sophisticated and they provide a significant proportion of the sawmill's total revenue.

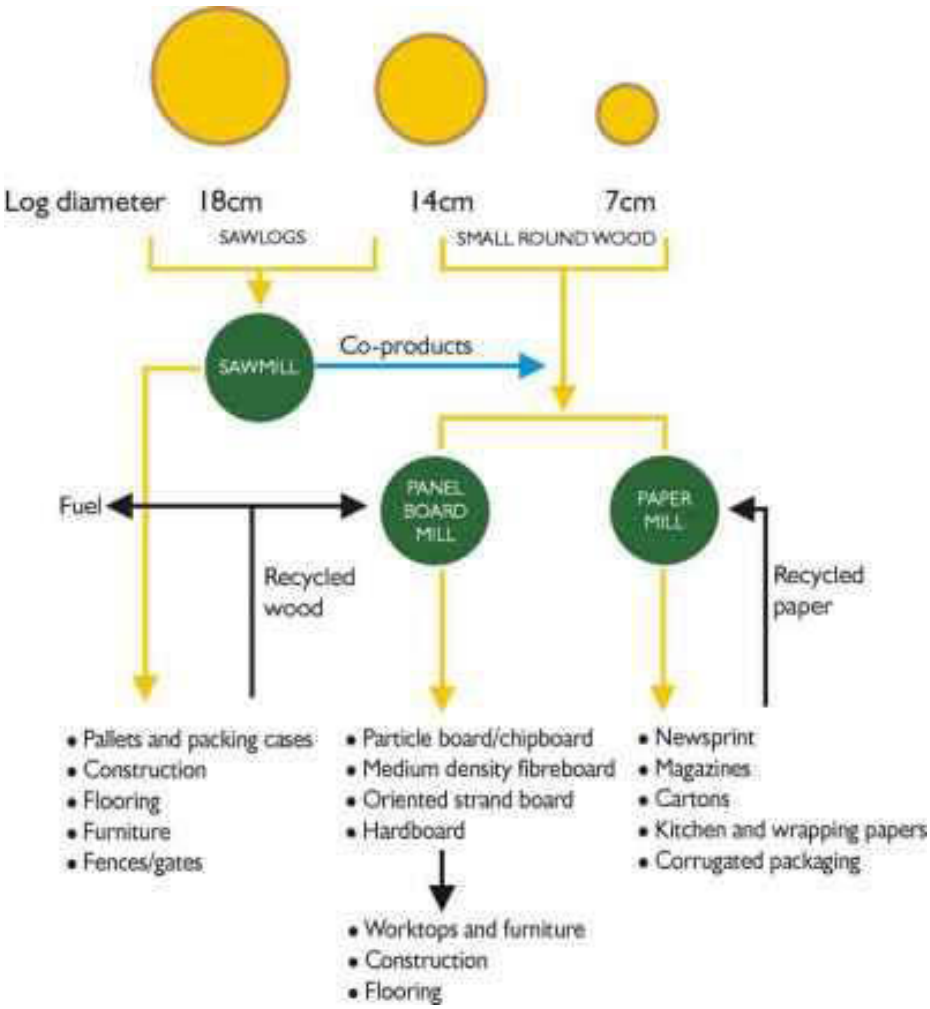


Figure 4.3 Timber Supply Chain in the UK

Source: TRADA

In Wales sawn softwood used in construction accounts for 25%, fencing 34% and packaging and pallet use 40%. In Scotland the use in construction is higher at 39%.

Welsh businesses produce a range of timber products including chipboard and MDF, sawn timber, cladding, pallets, packaging, and fencing from homegrown softwood.

The processing of home grown hardwoods involves much smaller volumes of timber. Pontrilas timber is the only major hardwood mill in the region cutting approximately 25,000m^3 of hardwood per annum. Many small mills, often based on mobile mills process hardwoods and softwoods for local use. None of these regularly kiln dry timber though a few have kilns which are used intermittently.

Hardwood products include joinery timber, furniture, flooring, windows, doors and craft items.

Added value can be generated by better integration of the supply chain from forest owners, growers, managers and contractors, primary, secondary and tertiary processors and the end user. The key challenge for the sector is the market dominated by imported timber. Timber and wood products have many advantages in locking up carbon in long-term uses such as buildings and the lifecycle benefits of timber as a renewable and unique resource that enables its reuse and recycling and also its use as a fuel.

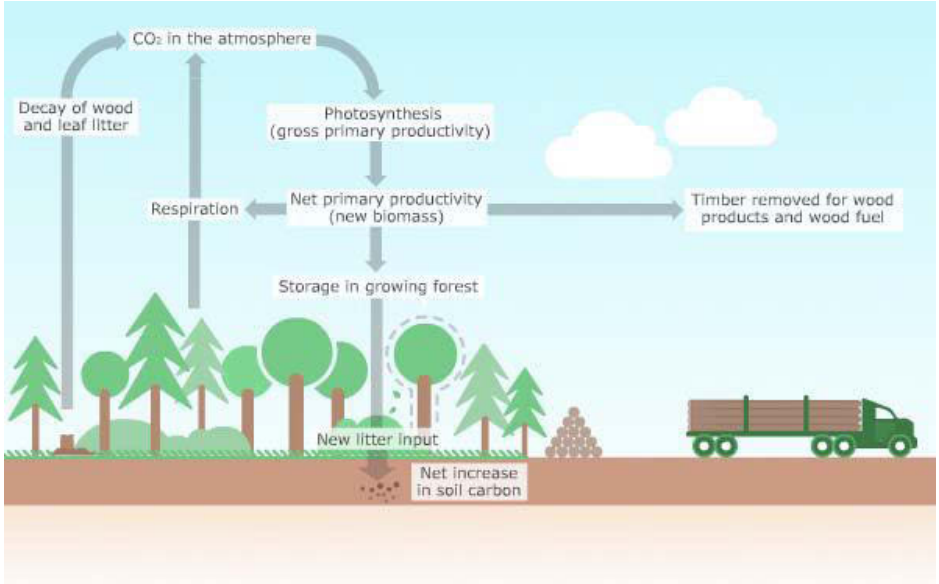


Figure 4.4 The Carbon Cycle

Source: CEI-Bois

5. Value of the Home grown Timber in the Welsh economy

5.1 Introduction

Timber and timber processing is of value because it produces a wide-range of products and services, including forestry, logging, manufacture of wood, wood products, paper and paperboard as well as derivative products of their manufacture, mostly fuel . The global market for forest products is governed by the demand for paper although growth in this sector has slowed down due to the arrival of electronic media.[24] Biofuels is also an emerging primary market operating at the scale of large power stations and small biomass plants and this is already having an impact on the ultimate fate of home grown timber.

Forestry products such as wood and paper are important inputs into other sectors of the economy for use in the production of their goods and services, as well as being sold directly to consumers for use in DIY and heating applications.

The economic contribution in terms of jobs and economic activity impacts directly and indirectly in the wider economy:

- Direct – goods and services produced from the forest industries
- Indirect – industries which supply goods to or use products from the forest industries

Forest industries' employee spending in the wider economy is also an indirect impact.

[24] State of the World's forests 2009. FAO, Rome 2009

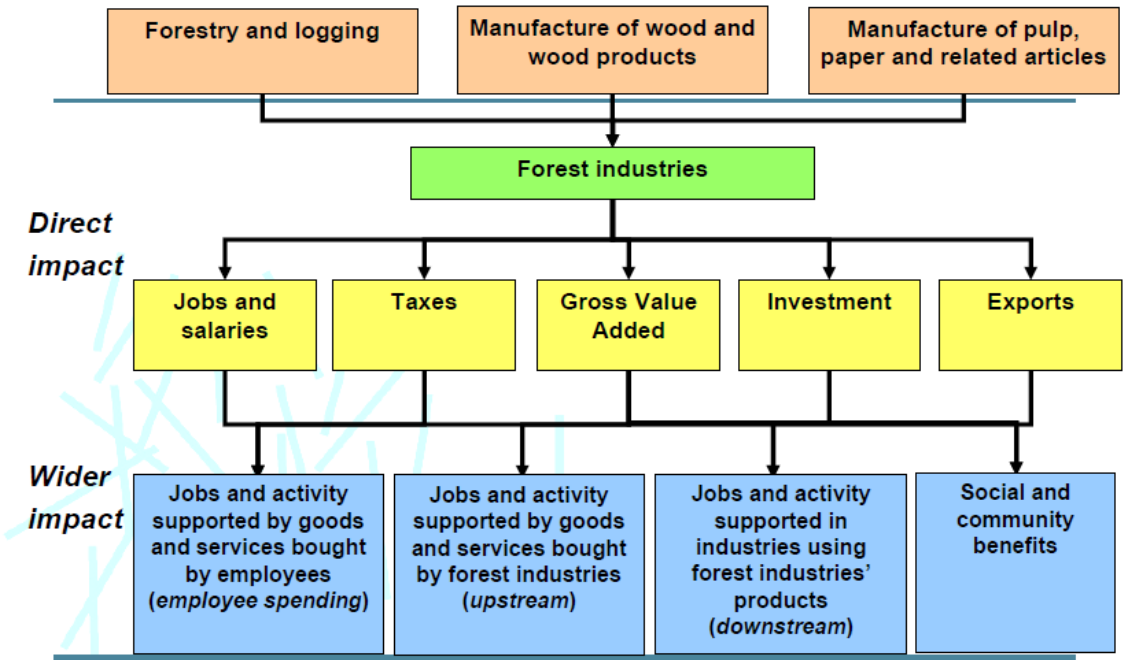


Figure 5.1 Economic Impact of forest activity

Source: Centre for Economics and Business Research Bath

The Annual Business Survey carried out by the Office for National Statistics includes statistics on employment according to the Standard Industrial Classification (SIC). There are some discrepancies in data making comparisons difficult, as forestry within SIC has a narrower scope than in the Forest Employment Survey, excluding certain activities such as timber haulage and government administration. The employment categories fall into three main areas: forestry, wood products (including sawmilling, panels and secondary products), and pulp and paper which are examined more fully later in this section.

Key activity sectors influenced by forest products are construction, printing and publishing and furniture. Their use of home grown timber is examined in the next section, following an initial discussion on trends in timber product prices as a background to the market for commodities.

5.2 Trends in Timber Product Prices

The price of timber is determined by two factors: the world market price determined by supply and demand and the strength of the pound relative to other currencies. There is also a distinction between standing timber and sawlogs.

Historically, there has been considerable fluctuation in global trends in wood product prices. In the early 1970s prices peaked, as did many other commodities, but have varied by region and product up until the 1990s. Figure 5.2 shows the falling trend in real prices for wood products in Europe, particularly for roundwood and sawnwood. Current prices are about one-third of 1970s prices in real terms and half of 1990s. The general decline for softwood is due to a number of factors including technological change and increases in plantation forestry making virgin wood fibre more abundant. Hardwood prices have generally risen, but the quantities harvested in Wales are small. The contribution from home grown softwood is confined to lower value products, the price of which fluctuate wildly but the long term trend shows falling prices.

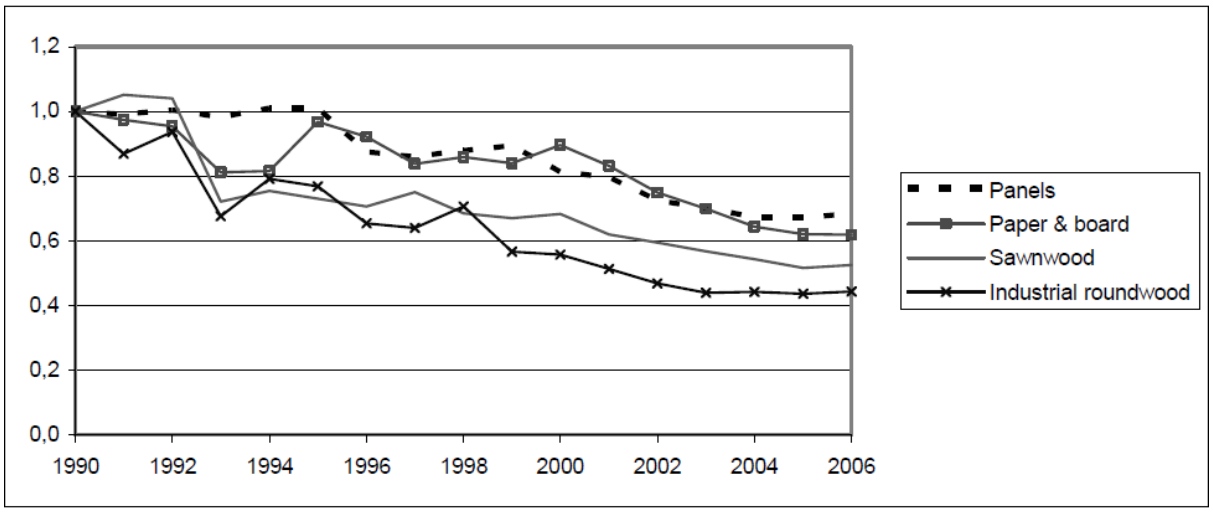


Figure 5.2 Relative real price developments in Europe

Source: FAOSTAT and FAO databases

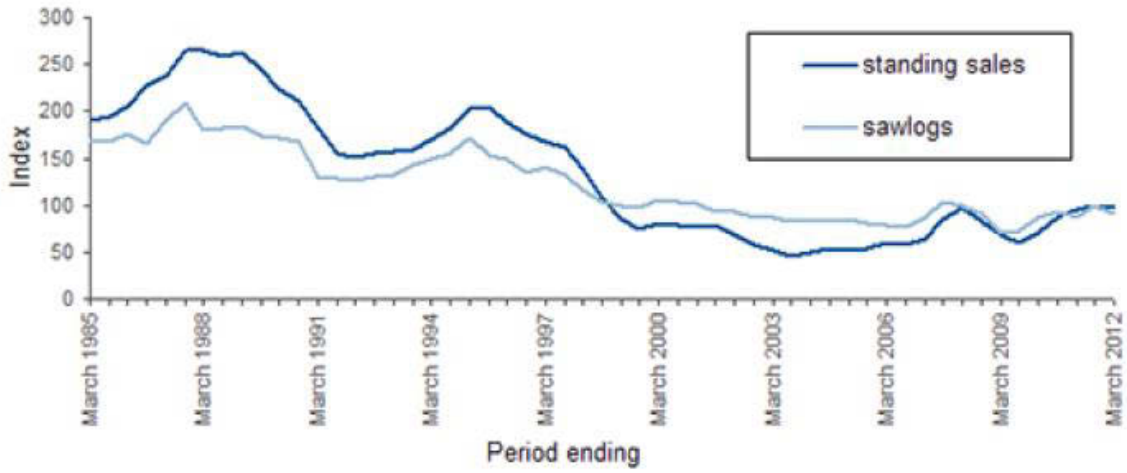


Figure 5.3 Coniferous standing sales and sawlog price indices in real terms 1985 – 2012

Source: Timber Price Indices

The role of the state forest is crucial in sustaining the supply chain for Welsh softwood. The Welsh Government Forest Estate provides 770,000 m3 pa to the market directly. This quantity does not increase or decrease significantly with fluctuating prices. This form of subsidy is crucial in sustaining the Welsh softwood processing industry and one of the main reasons for seeking to add value in order to see some return on the investment from the public purse.

Taking the example of the prospects for in Sweden, the sawmill industry looks brighter than for pulp and paper if the timber is treated less as a commodity and used more for innovative products. The growing demand for prefabricated factory assembled energy efficient construction components is recognised as a global market waiting to be exploited. Here in Wales, Tŷ Unnos has already made inroads into the area of factory controlled housing design with the development of the modular system. Value is added to the timber resource and employment opportunities offered in the processing and manufacturing of construction products from timber. This will be examined following a general discussion of the way the timber is sourced in Wales.

5.3 Sourcing Timber

The timber, board and paper industries and wood using power stations in Wales derive their raw materials for a number of sources. Once the raw material has left the forest gate, it is difficult to track the route taken by the timber through the supply chain from sawmill to primary producer.

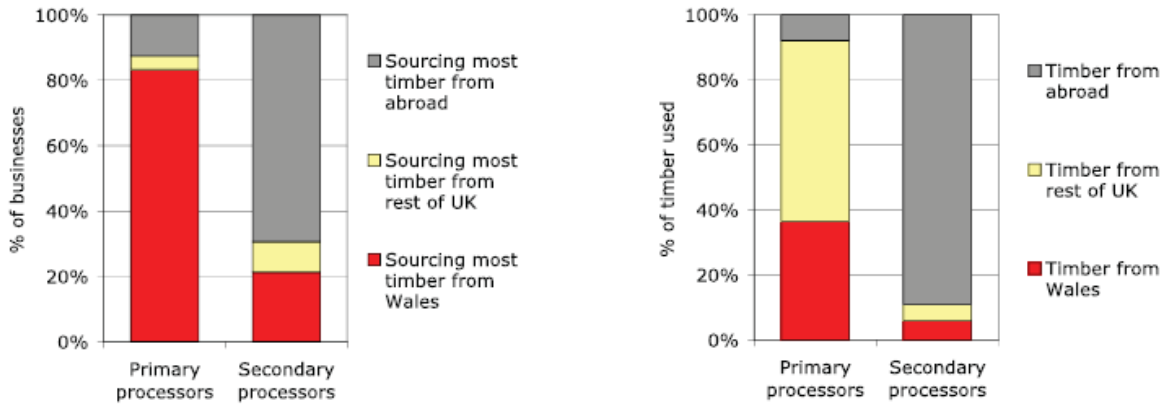


Figure 5.4 Source of timber inputs to primary and secondary processors

Source: FCW Survey of Woodland Enterprises 2010

Establishing how these are derived and their relative importance can be very difficult. Most of the timber used in Wales is grown outside the UK but the proportion varies according to the state of the economy and the end product. Home grown hardwood is used in a variety of products ranging from wood fuel to fine art and furniture but the quantities traded are small and the measurement of quantities traded are considered too unreliable for further analysis. The remainder of this section will attempt to evaluate the home grown Welsh softwood industry.

The feedstock derived from Welsh forests is mainly spruce with lesser quantities of larch, pine and Douglas fir. The majority of this is derived from the Welsh Government Estate which produces 770,000 m3 per annum (with small variations). The private sector contribution is less clearly defined and is subject to significant fluctuations according to current prices. The picture is further confused because a significant proportion of the timber harvested passes from growers to contractors,

merchants and hauliers on its way to the mills so there is a high likelihood of double counting. Many of the mills are in England and timber grown in England and Scotland is processed in Welsh mills.

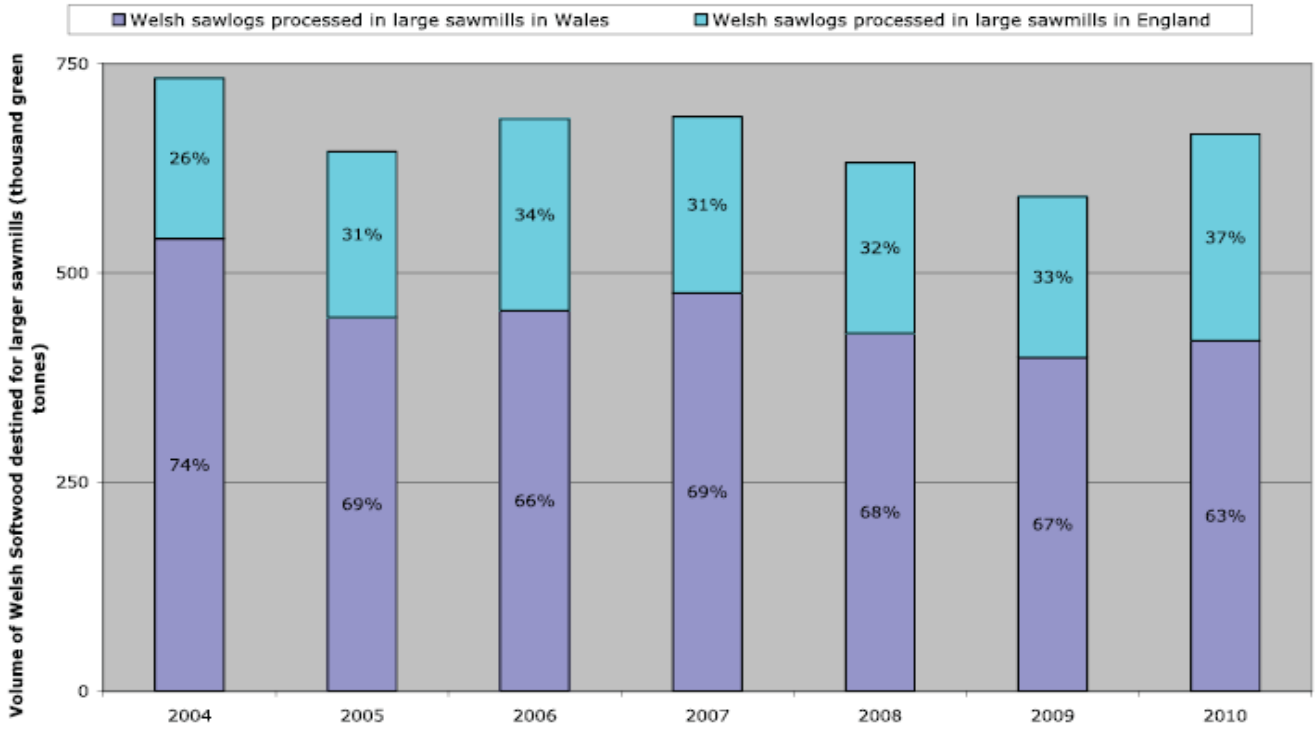


Figure 5.5 Proportion of Welsh sawlogs processed in Wales 2004-2010

Source: Sawmill Survey

New data from 2010 shows more than 80% of primary processing businesses, including woodfuel ones, sourcing most of their timber from Wales. However, less than 40% of the volume of timber consumed by these businesses comes from Wales. This is because a few big businesses consuming 10,000 to more than 100,000 tonnes annually mainly source from the rest of the UK (Figure 5.5).[25]

The role of recycled wood and fibre is also a major factor. Neither of the remaining paper mills at Maesteg and Shotton use UK grown fibre. Chipboard produced at Chirk includes recycled wood residues from Wales, UK and other origins and wood fired power stations and coal fired power stations which co-fire with wood also use material of mixed and indeterminate origin.

[25] Woodland for Wales Indicators Revised June 2012

Further analysis will assume an average production of 1 million m^3 over bark of softwood per annum in Wales. Based on FCW figures the value of this as a standing crop is £12m. The notional cost of harvesting this crop to roadside is £14m and the cost of transport to the mill £8m. The value of the crop at the mill or power station is £25-30m. (The standing value of the crop given here does not take account of the need to restock). The net annual revenue cost of growing 1M m^3 to the taxpayer is circa £20m. This figure does not include any notional return on past investment, procuring land and establishing the crop or the cost of maintaining the environmental value of the forest estate or grants made to harvesting companies[26]. Various estimates of the scale of the forest/paper/timber/wood fuel industry in Wales exist. These have attempted to quantify the gross value of the industry in monetary terms and the size of the workforce. The results vary considerably (from £400M, and 4,000 jobs to £1.6bn and 16,000 jobs).

This variation probably reflects the lines drawn by different authors between Welsh, UK, imported and recycled timber and pulp, though the ratio of 10 jobs per 1m turnover seems to be consistent throughout.

More recent analysis and indicators from WG have looked at the contribution forestry makes in the Welsh economy.[27] Estimates of Gross Value Added from the Regional Accounts published by the Office of National Statistics gives an overall figure of £340M per annum with 9,141 employed in 860 business units for all forest services and timber and paper sectors.

	2000	2001	2002	2003	2004	2005	2006	2007	2008
SIC 02: Forestry, logging & related services (£million)[1]	18	18	18	19	19	20	20	21	25
SIC DD: Manufacture of Wood and Wood Products (£million)[1]	125	122	130	140	145	145	139	146	150
SIC 21: Manufacture of pulp, paper & paper products from ABI national accounts (£million)[2] Not directly comparable to Regional GVA figures above	283	274	283	257	214	218	164	180	166

Table 5.6 Regional GVA for Welsh forestry, timber and pulp and paper

[26] Forestry Commission Annual Report 2012
[27] Woodlands for Wales Indicators Revised June 2012 WG
http://www.forestry.gov.uk/pdf/WfWIndicatorsENGLISH2012.pdf/$file/WfWIndicatorsENGLISH2012.pdf
[Accessed 070513]

Source: Office of National Statistics

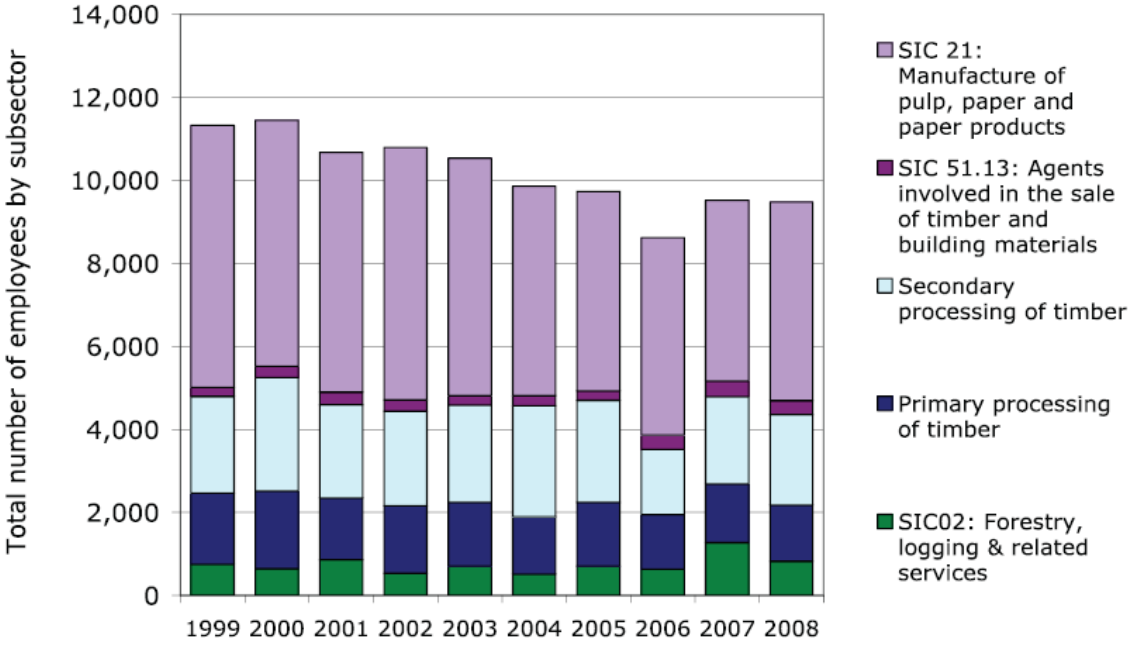


Figure 5.7 Current estimates of employment in the forestry sector

Source: Office of National Statistics

The 1M m3 of timber harvested each year generates some £175M of revenue. Some 43% of this is home grown timber supporting about 2000 jobs.

An alternative approach might better identify the scale of the industry specifically linked to the crop grown in Wales.

The bulk of the softwood crop leaves Wales as a small number of basic products: Construction 17%, fencing 34%, packaging/pallets 46% and other products accounting for 3%[28]. Construction products include kiln dried timber for carcassing, chipboard and MDF, woodfuel and bark typify other products.

The current value of these products ranges from £140 m^3 for carcassing timber to £20 m^3 for woodfuel.

The average out turn price will be of the order of £100 m^3 suggesting a gross value of the softwood crop of £100M and 1000 jobs. As timber is a widely traded

[28] Sawmill Survey 2011

commodity and home grown timber a small part of the trade it is not realistic to expect to influence the traded price. That means finding other ways of adding value to the crop. One way of achieving this is to add value through construction of affordable housing units. This is discussed in more detail in Section 9.

The Supply Chain in Adding Value

The correct conversion, seasoning and subsequent storage of timber during initial processing is a critical phase of the supply chain, where the eventual end use of the timber is determined. That determines whether the timber is of sufficiently high quality after seasoning and storage for its intended use appropriate to species and quality. The first important stage for adding value to the timber is its proper conversion and storage. In terms of securing supplies in this critical first stage, it is necessary to have access to companies that store timber in appropriate quantities for the intended end use. This currently includes privately-owned sawmills and supplier companies, but additional supplies exist in some local authorities.

6. Technologies for Adding Value

Understanding the timber resource and the strengths and weaknesses of the material for its intended use is an important prerequisite of realising the potential added value of timber for use in a particular product.

For a timber to be widely used the different properties need to be matched to its end use; that is, it must be 'fit for purpose'. Wood for the construction and wood working industry needs to meet many different requirements, depending on the application. Higher quality wood uses include: window frames, exterior doors, timber facades, furniture and parquet flooring; waterfront constructions and other exposed applications, and timber in structural construction.

Lower value uses are pallets, fencing, packaging and many board materials.

There is also a growing demand for wood as fuel by industrial and domestic users. Opportunities to produce new and different products based on enhancement of certain timber properties gives greater potential in higher value markets.

Timber can be classified according to strength, dimensional stability, glueability, machinability, appearance, natural durability, treatability, coating adhesion and paintability.[29]

For use in construction, different qualities are required for timber depending on end use, but dimensional stability, strength and stiffness, resistance to wood-destroying organisms and fire performance are minimum requirements. These characteristics are measured against British (BS) and European Standards (EN) for use and durability of the timber in its service life. A comparative list of the bodies charged with the British and European technical standards is given in Figure 6.1 and a comprehensive list is given in the Appendix I.

BSI Committee	CEN Committee
B/515 Wood Preservation	CEN/TC 38 Durability of Wood
B/518 Structural Timber	CEN/TC 124 Timber Structures
B/525/05 Design Codes/Structural Use of Timber	CEN/TC 250 Structural Eurocodes SC5
B/541 Wood Based Panels	CEN/TC 112 Wood-Based Panels
B/543 Round and Sawn Timber	CEN/TC 175 Round & Sawn Timber

Table 6.1 Comparative remits of BSI and EN Standards Committees

[29] Adding Value to Home-grown timber. Scottish Forest Industries Cluster, Forestry Commission, 2007.

Species	Characteristics	1	2	3	4	5	6	7	End Uses
Sitka spruce *(Picea sitchensis)*	White, straight grain fine texture, good paint performance. Live and dead knot problems	34 67	5900 8100	384	16.1 36.1	M	N	R	Construction, sheds, pallets
Scots pine *(Pinus sylvestris)*	Pale yellow brown, medium texture. Good joinery and good paint performance.	46 89	7300 10 000	513	21.9 47.4	M	N	MR	Construction, joinery
Douglas fir *(Pseudotsuga menziesii)*	Light reddish brown heart-wood, prominent growth rings, moderately resinous.	53 91	8300 10 500	497	24.6 48.3	S	M	R	Fencing, joinery, structures
Larch, European *(Larix decidua)*	Straight grained, knot free pale reddish brown heartwood, hard and tough.	53 92	7900 9900	545	24.3 46.7	S	M	R	Poles, fencing
Oak, European *(Quercus robur)*	Yellow brown, large pored early-wood, acidic and durable timber.	59 97	8300 10 100	689	27.6 51.6	M	D	R	Furniture, joinery, structures
Beech, European *(Fagus sylvatica)*	Whitish to pale brown, fine and even textured, strong.	65 118	9800 12 600	689	27.6 56.3	L	N	P	Furniture, good gluing properties
Ash *(Fraxinus excelsior)*	White to light brown, straight grained, coarse textured and tough	66 116	9500 11 900	689	27.2 53.3	L	N	MR	Sports items, tools, furniture
Birch, European *(Betula spp.)*	White to light brown, bright timber, fine textured and tough. Good gluing properties.	63 123	9900 13 300	673	26.3 59.9	L	N	P	Plywood, furniture

1: Bending Strength MOR N/mm2 green & 12% air dry

2: Stiffness MOE N/mm2 green & 12% air dry

3: Density kg/m3 12% air dry

4: Compression parallel to grain N/mm2 green & 12 % air dry

5: Dimensional movement Small Medium Large

6: Biological durability of heartwood Non-durable Moderately durable Durable

7: Permeability Permeable Moderately resistant Resistant

Table 6.2 Selected UK timber species and their properties

Source: Scottish Forest Industries Cluster

6.1 Wood Modification

"Wood modification involves the action of a chemical, biological or physical agent upon the material resulting in a permanent change to the chemical composition; with such a change leading to a desired property enhancement. The modified wood should itself be non-toxic under service conditions and furthermore, there should be no release of any toxic substances during service, or at end of life following disposal or recycling of the modified wood."

This precludes wood preservation techniques, where toxic substances tend to be used. Increased environmental awareness and recent stringent legislation has led to restricted use of wood preservation systems, such as Chromated Copper Arsenate (CCA) and the less highly toxic biocides.

Timber, by its nature is degradable, and the rate of degradation is dependent on species and end use. Many European species, particularly the softwoods, are classed as slightly durable or non-durable, making their use for in-ground contact (Service Class 4) limited.

Some of the processes used to modify wood are not new but the scaling up of the processes to cater for mainstream markets has only taken place in the last decade.

The main categories of modification are thermal and chemical modification and properties of modified timber vary according to the modification process, and the timber species.

Modified wood can enhance properties such as hardness, dimensional stability and resistance to decay, fire, weathering and moisture. Resistance to acids and bases, ultraviolet radiation, biodeterioration and thermal degradation can be achieved by different processes, making wood more appropriate for use in special applications, for example, in items requiring hard, impervious and decorative surfaces. Timber colour can be affected, so that darker timbers resembling tropical hardwoods can be achieved by modifying softwood and hardwood species. This adds value by varying colour to satisfy preference in interior design, for high-end flooring, joinery and other products.

Heat Treatment

Heating changes the properties of wood: it can reduce the hygroscopicity and improve the dimensional stability and decay resistance. However, this is accompanied by increased brittleness and loss of some strength properties (impact toughness, modulus of rupture and work to failure). Darkening of the wood usually occurs, and there is a tendency to crack and split.[30]

Thermal modification of the timber takes place in a controlled heating environment alongside steam or oil, depending on the specific product manufacturing process. In all cases, wood is heated to temperatures of 160 - 230ºC for the duration of several hours. One of the benefits is reduction in resin seep particularly for species such as larch. Different results emanate from heating dry and wet wood.

High temperature modification of timber has been exploited for millennia. Over the last fifty years a variety of processes have been developed and patented in Europe to produce more dimensionally stable timber, less prone to expansion and contraction in changing humidity, and more resistant to rot and insect attack, a particularly useful property for upgrading normally non-durable softwoods and hardwoods without the use of chemicals.

[30] Wood Handbook: wood as an engineering material. USDA Forest Products Laboratory, 2010.

Chemical modification Permeable timber species can be modified by chemical impregnation of the wood which react with water-binding sites present in the cell wall.[31] Using pressure impregnation techniques, a good level of penetration of modification chemicals is achieved throughout the wood structure. Followed by heat, the water-binding sites are permanently substituted by chemicals, thus preventing the binding of water, which is the cause of wood movement such as shrinkage and swelling in service. Products such as Kebony and Accoya, which have excellent durability and stability, are now becoming more widely used for external joinery. Accoya was used by Gwalia in a housing scheme at Parc Pendre, Cydweli in 2008. The products differ in colour attributes, according to the chemical modification process adopted but all depend on a sufficiently permeable timber for the chemical to penetrate through the wood section, which limits the range of species applicable. In the case of Accoya, radiata pine originating from New Zealand, was used. No Welsh grown softwoods are suitable for chemical modification because of limited permeability but hardwood species like birch, alder, lime, sycamore and poplar are very good. Alder is likely to supersede Radiata pine because pine knots and heartwood are impervious so only clear grade or defect cut sapwood can be used.

[31] Modified Wood Products. TRADA Information Sheet 63. 2010.

6.2 Engineered Timber

Engineered Wood Products (EWP) can be produced by re-engineering solid wood to upgrade and add value to traditional sawn timber products. Techniques such as defect-cutting, finger-jointing and laminating of timber increases its potential use and may include heat treatment. More recent lamination and engineering techniques have enabled many innovative designs to be pioneered, especially in terms of construction of longer spans in buildings.

Engineered timber is a generic term used to describe a wide range of wood-based products that have been designed to provide enhanced performance making the engineered wood behave differently to timber that has not undergone these techniques. This improves the suitability for particular end uses, especially in demanding structural situations, but may also be designed to improve other characteristics such as durability. Usually these products are composites that combine wood or wood fibre with adhesives and possibly other materials. Some reasons for engineering solid timber into such composites include:

- to overcome the dimensional limitations of sawn timber
- to improve performance; structural properties and stability
- to transform the natural orthotropic product into one with more homogenous properties
- to optimise the use of a valuable resource and minimise waste.

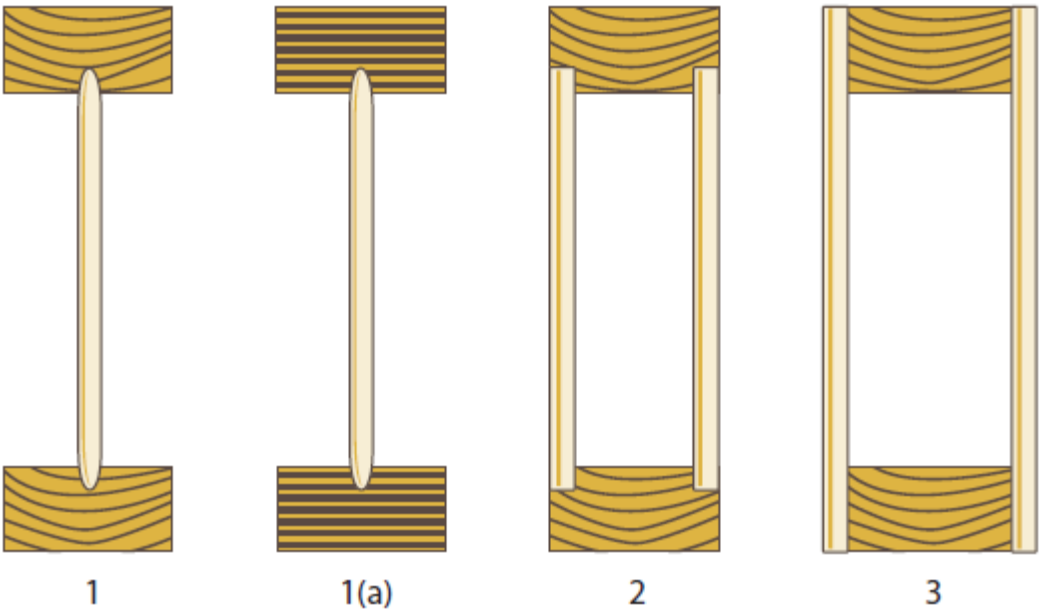
Engineered timber in the form of Engineered Wood Products (EWP) can take several forms:

Structural timber composites produced in large sections for use as beams, columns and other structural components. Products include glued laminated timber (glulam), parallel strand lumber (PSL), laminated veneered lumber (LVL) and cross laminated timber (CLT). Massive timber or Brettstapel (literally ‘stacked planks’) is a solid timber construction system fabricated from softwood timber posts connected with hardwood timber dowels.

Timber I-joists comprise a timber flange, typically solid timber or LVL (laminated veneer lumber) and a panel product web, usually OSB (oriented strand board). They offer a number of benefits over traditional sawn joists, including low weight, no moisture movement and greatly reduced risk of squeaks. They are also more easily

adapted to take the increased depth required of natural insulation materials in high thermal performance walls.

Vernacular timber buildings in Britian used hardwood in their construction, and green oak is still used in the traditional way for certain types of build (solid timber portal frames). However, softwood is a more readily available and cheaper resource, and was formerly the most frequently used timber in load-bearing situations. I joists have largely replaced solid timber in new buildings.



Beams with timber flanges:
(1) I-beam (2) Recessed beam (3) Box beam

Beams with LVL flanges:
1(a) LVL I-beam

Figure 6.2 Types of engineered beams

Source: Forestry Commission

Engineered wood flooring provides a durable and stable decorative floor that is less prone to moisture movement than traditional solid timber flooring. It comprises a solid timber walking surface bonded to an engineered timber substrate for strength and stability.

A range of products can be made using solid timber, falling boards and co-products.

6.3 Wood-based Panels

Small logs and recycled timber are reduced to wafers, woodchip fibre or sawdust then glued together to form large sheets. The main types of wood-based panels used in the UK are particleboard, medium-density fibreboard (MDF), oriented strand board (OSB) and plywood. These panel products can be used in a range of applications, including construction, interior joinery and furniture making. Loose-fill material is now also becoming popular, made from a variety of cellulose-based material and wood fibres. The use of recycled newspaper insulation manufactured in Wales by Excel Industries and marketed as Warmcel has been used in the Tŷ Unnos buildings. Other natural insulation materials made from wood-fibre are mainly imported from Austria, Switzerland and Estonia (Gutex, Pavadex, Steico, Isoplat etc).

Particles are held together by adhesives and compressed resulting in a denser product than the wood density of timber particles. MDF has the highest bending strength, followed by OSB and particleboard.

All wood-based structural panels can be cut and installed with the same ease and types of equipment used with solid wood.

Particleboard

Particleboard is made from residues such as sawdust, shavings and bark. Particles are bonded together with synthetic (phenolic) resins and are pressed to form panels of different thicknesses and grades. The grades vary according to end use and whether load bearing or non-load bearing. It is also available with decorative facing such as melamine or wood veneer.

MDF

MDF is manufactured from individual fibres and fibre bundles. It is made from sawmill residues and chips from roundwood. The fibres are prepared from a pulp which are then combined with an adhesive and pressed to form boards of various thicknesses and densities. Most of the wood used in making MDF in Britain is Sitka spruce, its natural colour producing light coloured boards and its low density wood of relatively thin-walled fibres does not require large amounts of pressing force to create good bond strength.[32] Thus it is possible to produce lightweight panels with the desired strength properties.

Globally, MDF has filled the market segment between solid wood and particleboard, widely used in furniture and joinery industries, due to its ability to create a profiled edge and better ability to hold fastenings than particleboard.

OSB

Originally developed as an alternative to plywood, which uses large diameter (peeler) logs in its manufacture, OSB (also known as Sterling board) has the advantage of using the small diameter logs typically produced in forests in the UK. It consists of small thin flakes (strands), compressed into layers; the surface layers generally laid parallel with the long edges of the panel ('oriented') while core layers are laid at right angles to the surface strands, so providing directional properties. These are bonded with synthetic resins and pressed to form different thicknesses and grades of panels.

While OSB does not have a continuous grain like a natural wood, it does have a specific axis of strength. This can be seen by observing the alignment of the surface wood chips. The most accurate method for determining the axis of strength is to examine the ink stamps placed on the wood by the manufacturer.

The two grades manufactured in the UK are OSB" and OSB3, load-bearing for use in dry and humid conditions, respectively. Heavy duty OSB (OSB4) is not made in the UK. It is widely used as site hoardings, sheathing material for walls, floors and roofs in closed-panel timber-framed houses and as the web material in I-joists. It is also

[32] Wood Properties and Uses o Sitka spruce iin Britain. John Moore, Forestry Commission 2011

the main component of Structural Insulated Panels (SIPs), a sandwich of OSB and a rigid insulation core, usually foam products. Although manufactured in this country, demand is so high that most OSB is imported from the USA and Canada and Europe.

Plywood

Plywood is a type of manufactured timber made from thin sheets of wood veneer. It is one of the most widely used wood products, although recent advances in panel technology are rapidly replacing its use. It is used instead of plain wood because of its resistance to cracking, shrinkage, and twisting/warping, and its general high degree of strength.

Plywood layers (called veneers) are glued together with adjacent plies with their grain at right angles to each other for greater strength. There are usually an odd number of plies so that the sheet is balanced—this reduces warping. Because of the way plywood is bonded (with grains running against one another and with an odd number of composite parts) it is very hard to bend it perpendicular to the grain direction. A staple of the construction industry, it is used in floors and roofing.

7. Timber for Use in Construction

7.1 Introduction

The construction industry offers high value markets for a variety of timber products. Timber is a versatile material that can be used in solid form or as a composite material. Because of the ease of cutting and fixing it is preferable in many cases to steel and concrete, but where the last two are manufactured to meet specific product requirements and are quality controlled, timber is a natural material and variable in characteristic. It therefore requires a degree of selection and sorting, a rather different approach to manufacturing using man-made materials.

Timber is used extensively in various applications in the construction industry:

- Structural frames – post and beam, open and closed panels
- Interior joinery – doors, windows, skirtings, architrave, stairs
- Interior lining – solid timber profiles, boards, panels
- Furniture and fittings – kitchens, shelves, cupboards, furniture
- Exterior cladding – walls, roofs, sarking
- Sheathing – OSB, MDF, SIPs
- Flooring
- Outbuildings and landscaping - fences, gates, decking
- Whole and machined logs

The type of characteristics required will vary according to end use and whether the timber is for internal or external use with corresponding service and movement classes. Structural components additionally require the timber to be strength graded. Historically, the demand for timber for local construction was met locally mainly by hardwood species. Vernacular buildings in Britain typically used hardwood for construction, and this is still the traditional method of building using solid timber framing members (posts, beams, studs, rails, plates and rafters), mainly

characterised by oak framed structures. As markets progressed from local to international supply and demand, many of the local timbers were superseded by imports. The need for mass housing signalled the advent of a modern platform frame variety of timber construction using softwood for storey height timber wall panels for the inner leaf, timber floor panels and an outer leaf. The timber frame market grew to one third of the housing market before an early 1980 television broadcast adversely affected the uptake.[33] This broadcast claimed that timber-frame could not produce houses that would last, citing rot in the frames of nine-year old houses on an estate in Cornwall, caused by defects in workmanship.

The market for timber frame recovered as using timber has many advantages in terms of pre-assembly, speed of erection, dry construction and compliance with thermal regulations. Modern construction has resulted in a factory manufacture of 'closed' panels, consisting of a panel 'sandwich' with insulation filling. The benefits of prefabricating offsite include quality control, shorter build times, and less time and disruption onsite, and less weather dependency. The type of load bearing panel known as SIPs (Structural Insulated Panels) are now universally popular, and comprise a rigid insulation core bonded between two sheets of material such as plywood or plaster board. They differ from ordinary construction panels in that they do not rely on studs within the panel to bear vertical loads.

7.2 Specifying for construction use

Specification forms part of the building contract describing the nature and quality of materials and components to be used. A specifier (architect or engineer) defines the performance or product; a typical timber specification might include the species, moisture content, grade, BS classification or fitness for purpose. Up until recently, this would have been without specifying the country of origin but project briefs are now coming through specifying the use of local timber and products, promoting their use in the same way as specifying the use of local food or local skills. The lead in time for sourcing, drying and conversion of local timber is also perceived as more problematic than sourcing cheaper, better grade, dried and off the shelf imports, which are more readily available and predictable, reliable supply chains. Countering

[33] World In Action: 1983

this trend are a small but growing number of specifiers and end-users that seek the environmental benefit of using home grown material. In terms of the low carbon agenda, timber is very competitive in terms of its carbon emission, compared with other building materials like steel, aluminium, brick and concrete (Figure 7.1, 7.2)

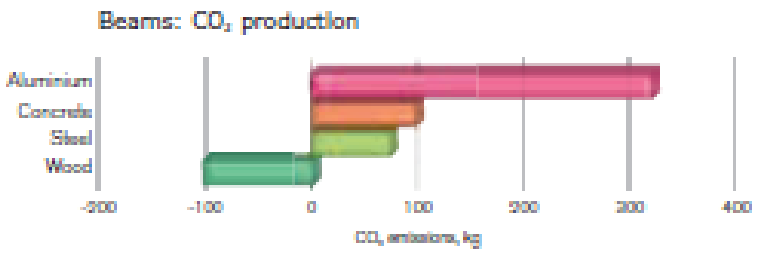


Figure 7.1 Carbon dioxide emissions for beams of different materials

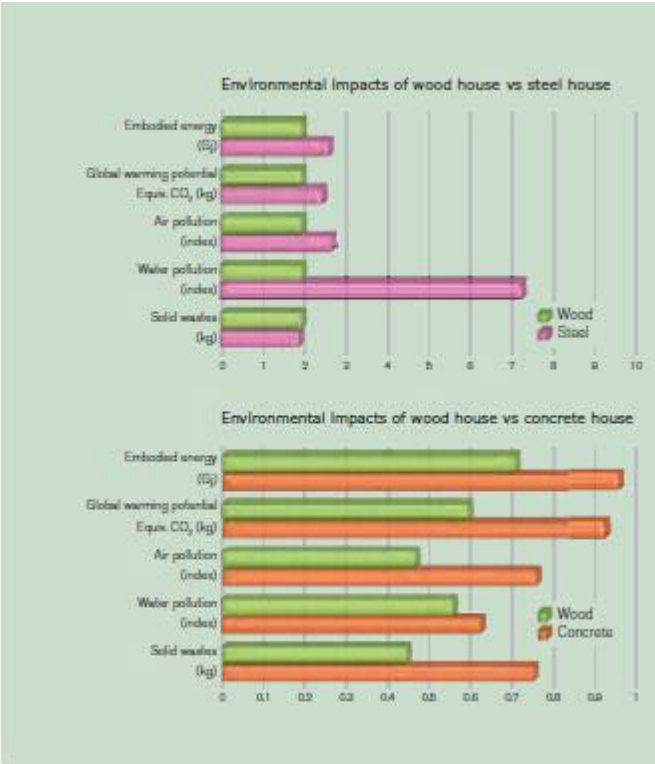


Figure 7.2 Comparing environmental impact of timber with steel and concrete house

Source: CEI-Bois

Products used in construction have a finite service life that varies according to their overall performance. This is affected by several factors: material used, design, quality of manufacture, climatic conditions in use, user behaviour and maintenance regime.

Natural materials such as timber are at particular risk of degradation because of the effects of climate and natural biological processes such as attack by wood-destroying organisms.

Timber for use in construction is defined by

- Strength and Stiffness
- Dimensional stability
- Durability

Others that need consideration are

- Fire Performance
- Hardness
- Appearance
- Machinability
- Permeability and Treatability
- Gluability
- the ability to take nails and other fixings

The first three deserve closer examination as they relate to the specific characteristics required of timber intended for construction to ensure it is 'fit for purpose'.

7.2.1 Strength and Stiffness

Strength is a loosely defined property that depends on multiple parameters such as the structure of the wood, mode of application of the stress and environmental conditions. It is closely linked to the intended end use which is affected by density, hardness, impact resistance, stiffness (modulus of elasticity or MOE) and maximum bending strength (modulus of rupture MOR). The presence of water affects the movement and mechanical properties of timber dramatically, which is why timber

needs to be dried before use. Generally, freshly felled timber has lower strength than dried timber; in some cases affecting strength and stiffness by as much as a third.[34]

Non-uniform properties and inconsistencies in drying characterise some species; drying regimes for Sitka spruce, for example, need to consider the effect of twist or 'propellering' in drying the timber which results from characteristic spiral grain.

Structural timber at a sawmill varies greatly and some pieces can be eight or more times stronger than others of the same size and species, owing to differences in density of the material and the presence of defects such as knots and sloping grain. This strength variability poses the biggest challenge to the efficient use of timber as a structural material.[35] Although timber has been used successfully in buildings for thousands of years, and many ancient structures are still standing[36], it is only in the last 60 years or so that accurate assessments has been possible for selecting suitable timber for structural applications.

Strength Grading

In order to comply with Building Regulations, timber for structural use must always be strength graded. Two methods of strength grading are in use: one a visual inspection and the other using a machine to grade.

Timber grading is not tied to specific timber species but uses grading categories according to strength, based on mechanical performance. Engineers are therefore free to design using these strength classes without the need to specify a particular timber species.

British C16 timber is graded by machine to European Standard EN 14081: 2005 and is the only commonly available type of construction timber grown in the UK.[37] Strength grading is undertaken primarily to provide timber of sufficient stength for a particular construction function, such as a floor joist. At the same time, strength grading helps to ensure that both the design and the timber sizes specified are economical. Evidence of the strength class has to be provided either with a stamp or a separate certificate, if the timber appearance is not to be marked (figure 7.3).

[34] Adding Value to Home-Grown Timber, Scottish Forest Industries Cluster Forestry Commission 2007
[35] Guide to machine strength grading of timber. Benham, Holand and Enjily. BRE Digest 476
[36] Greenstead Church in Essex is the oldest wooden building still standing in Europe, dated 9th Century
[37] British grown C16 timber. BSW Timber Presentation 2010

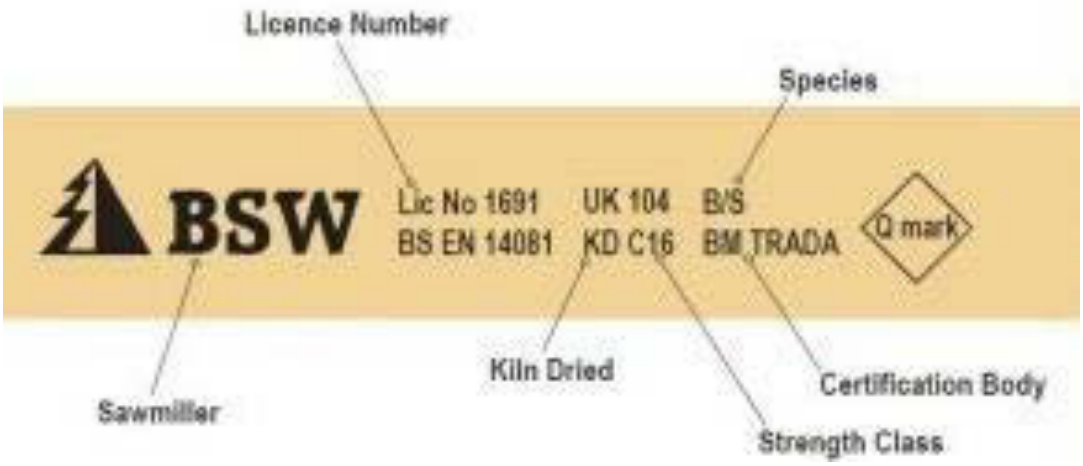


Figure 7.3 Machine grading stamp

Source: BSW Timber

The most common types of strength graded timber used in the UK are **C16, C24** and **TR26**. C16 is a strength classification of structural timber that allows for a number of strength-reducing defects (knots, grain deviation, wane) and also permits **unlimited** amounts of defects that do not affect strength, such as blue sapstain and pinworm holes. Some British timber can grade to C24 but is not considered economical to do so due to the high number of rejects, even though the price differential is minimal, public perception has a large role to play. C24 is a higher grade of structural timber. TR26 is a higher grade used in trussed rafters. Both C24 and TR26 are imported. The sawn timber grading process is shown in Figure 7.4.

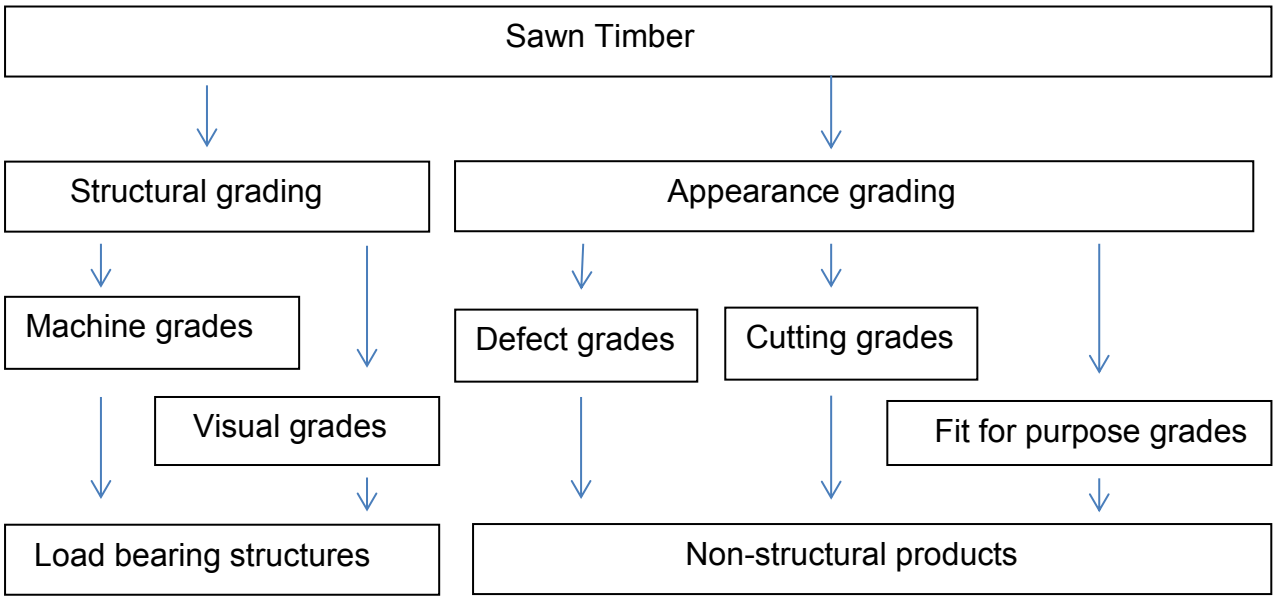


Figure 7.4 Summary of the different types of sawn timber grading

Source: TRADA

Two sawmills currently machine grade timber to C16. BSW Timber at Newbridge on Wye and Pontrilas Timber near Hereford. Material is sorted by trunk diameter and not species. Up to 20% of a batch of C16 spruce may be other species – usually Douglas Fir or hemlock. Customer research carried out by BSW Timber confirms that architects over-specify to C24 when in reality this strength is not required. C24 may be used for longer spans or to increase the load bearing capacity of particular member in non-domestic use. If C24 is specified, this excludes British spruce; C16 is a viable, cost-effective option for most construction projects, used in new build housing, stud walls, floor joists and carcassing for fitted units in bathrooms and kitchens. Stability and poor management of drying are the main reasons given by manufacturers for not using home grown timber.

The timber frame industry standard is C24 softwood kiln dried to about 14%. From relatively slow growing forests this is very stable, mainly because it has a small proportion of juvenile wood. Some C16 is also used but the same comments apply. Swapping C16 for C24 is often straightforward in standard design packages.

Plantation softwoods grown in short rotation in a mild wet climate produce logs with a high proportion of juvenile wood which is of low density and durability and is prone to twist in drying. Of the options available in Wales, spruce, larch and Douglas fir, spruce is by far the most important. It makes up more than 70% of the sawlogs available. Home grown spruce can achieve C16 by machine grading or C14 by visual grading but this may become more difficult as the practice of low density planting and fast growing clones employed in the last 20 or 30 years begin to impinge on the market. This is likely to achieve C14 based on current evidence. We could grow spruce to C24 by changing our silviculture to reduce growth rates in the early years and extend rotation length. This could also be achieved by a switch to continuous systems. Sitka will grow happily under parent trees and respond as they are removed. The result in either case is fine branched trees with a small proportion of juvenile growth producing strong, stable timber with small knots but to do this would require a long term vision and a long wait for trees to mature. Changing the settings on grading machines at this stage will produce a high proportion of rejects which cannot be regraded at a lower grade, because of the rules of the grading system.

Due to the way that logs are sorted at sawmills, a significant proportion of Douglas fir finds its way into C16 as “spruce” It can be visually graded to C24 but only in cross sections over 20,000 mm2 (8 x 4 inches). None of the sizes used in modern timber frame qualify. Larch can be visually graded to C24 provided it is kiln dried. At present the carcassing mills are not doing this, preferring to sell the glut of larch resulting from Phytophthera into fencing and garden products. Larch is difficult to saw and kiln to keep it straight. With high temperature kilning there may be potential to use it but mainly for specialist uses in joinery. It is likely to be too expensive for structural timber.

7.2.2 Dimensional stability

Dimensional movement or shrinkage and swelling is an important property of timber species. The natural water level in freshly felled timber is contained within the cell cavities and is easily removed without affecting timber dimension, up to the fibre saturation point at about 27% moisture level. Below this, drying removes water from the cell walls and causes shrinkage. This reversible process means variation in size of dried timber, unless ‘conditioned’ to the temperature and humidity conditions of the environment in which it is used.

To satisfy British Standard Building Regulations, structural timber must be kiln dried to an average of approximately 20% or less and be marked DRY or KD. The grade stamp must also contain information on the species - the strength class - the graders’ licence number - the BS number and the certification body logo or mark. (Figure 7.3)

Timber is a hygroscopic material: it absorbs moisture if the timber is drier than its surroundings; conversely if it is wetter it will tend to dry out. In stable conditions it will eventually settle down to equilibrium with the relative humidity of the surrounding air. This is known as the equilibrium moisture content (EMC). The amount of water in a piece of timber is termed its moisture content (MC) and is usually expressed as a percentage of the dry weight of the timber. The glossary explains this further.

When drying timber, the aim is to reduce the moisture content (MC) to the anticipated EMC of its end location, which can be predicted according to Service Classes in Eurocode 5. This feature is an extremely important consideration when

specifying timbers for use in buildings, because many timber properties change in response to fluctuations in the EMC, the most important being shrinkage, swelling and decay risk.[38] However, dimensional changes in timber are often difficult to predict in indoor climates, particularly the dry, airtight conditions experienced in thermally efficient homes associated with higher levels of the Code for Sustainable Homes, and the PassivHaus standards.

7.2.3 Durability

Natural durability is defined as 'the inherent resistance of wood to attack by wood-destroying organisms'[39], with biological attack from fungi and insects being the most important, with the former being of greater threat than the latter in the case of wet timber and the latter a greater threat to dry timber[40].

The amount of decay which occurs in timber in service will depend on not only the moisture content in the timber, but also on surrounding temperature and relative humidity, and the availability of oxygen.

The natural durability of UK timbers are regarded as being well established[41] but softwood timbers grown in Wales may be less durable than others because of the warmer wetter growing conditions here. The threshold point for fungal activity in wood is quoted as 22% moisture content[42].

European Standards EN 335-1 and 335-2 describe Use Classes to allocate risks of different exposure to timber, dependent on whether it is used internally or externally. The sapwood of all species is not durable. Susceptibility to insect attack does not correlate to durability in all cases (Handbook of Softwoods, 1986).

[38] Sustainable Construction Timber: sourcing and specifying local timber Ivor Davies Forestry Commission 2011
[39] European Committee for Standardization Brussels 1994
[40] Wood Properties and uses of Sitka spruce in Britain John Moore Forestry Commission 2011
[41] Review of the Welsh Timber Resource Low Carbon Built Environment Report Cardiff University 2011
[42] Public Perceptions of Timber LCBE Report 2011

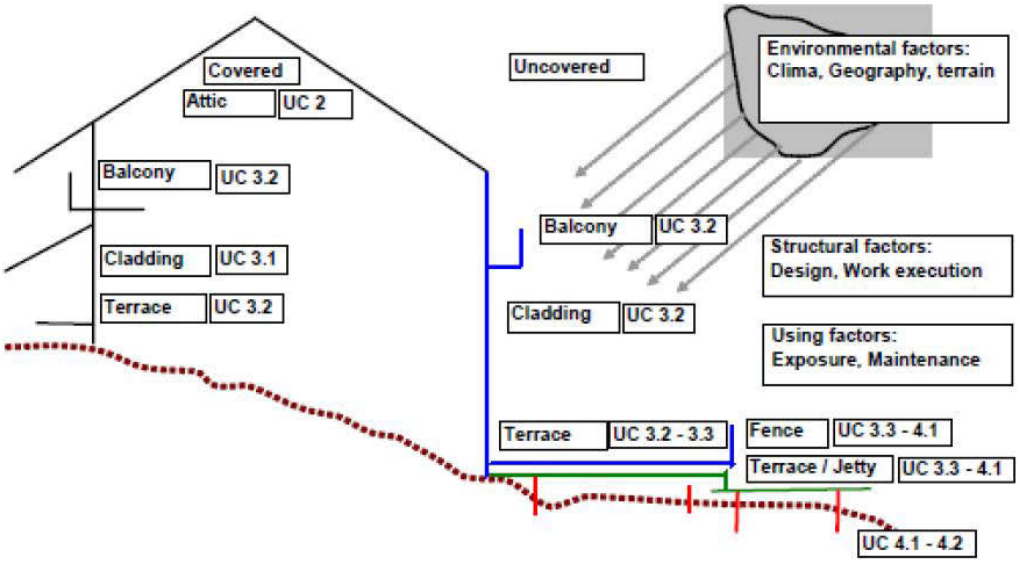


Figure 7.5 Schematic of Use Classes of timber products used in construction

Source: Forestry Commission

UC 1:	internal flooring: parquet, strip boards, end grain
UC 2:	roof timbers not exposed
UC 3:	cladding or window frame exposed
UC 3.2	decking board
UC 4:	pole in ground contact

Table 7.6 Typical products matched to Use classes from Figure 7.5

Use Class	Description	Typical Moisture Content
1	Under cover, fully protected from the weather and not exposed to wetting (interior), predominantly RH < 65 %	<20%
2	Under cover, fully protected from the weather but where high environmental humidity can lead to occasional but not persistent wetting interior, occasionally wet, RH 80 -90 %	<20%
3	Exterior, not covered and not in contact with the ground	
3.1	Above ground, protected, exterior, occasionally wet	20 -25 %
3.2	Above ground, unprotected, exterior, frequently wet	>25%
3.3	Above ground, unprotected, exterior, high risk for elevated moisture content. However there need to be considerations over climatic and geographical differences	25-30%
4	In contact with the ground or fresh water; permanently exposed to wetting	
4.1	In ground contact, exterior, predominantly wet	>30%
4.2	In ground contact (severe exposure), in contact with fresh water, permanently wet	>30%
5	Permanently exposed to salt water, permanently wet	>30%

Table 7.7 Use Class and corresponding Moisture Content

Durability Class	Description	Expected Life (Yrs)
1.	Very Durable	30 – 60 >
2.	Durable	15 - 60
3.	Moderately Durable	< 15 - 30
4.	Slightly Durable	5 - 15
5.	Not Durable	< 5

Table 7.8 Durability Class and Expected Life Service of timbers in construction

7.3 Impact of Legislation

Higher thermal and airtight performance required of current modern buildings are providing new opportunities for the construction of buildings incorporating timber in some form or other. This will become increasingly so if carbon stored in buildings is to be accounted by carbon reduction methodologies for national greenhouse gas inventories, enabling home grown timber used in buildings to be viewed favourably as it is counted as carbon storage.[43] Because sequestered and biogenic[44] carbon is now currently accounted for, the contribution of timber used in construction offers an opportunity for the Welsh Government to adopt a radically different approach although there are considerable challenges in its more widespread use. How architects specify the use of timber in construction must be examined more thoroughly as despite the desire to use timber derived from the local environment there are considerable obstacles in obtaining the quantities of kiln dried material required for large scale construction projects, or a tendency to overspecify grading requirements.

Most of these requirements will be overcome with sufficient attention to detail in specification clauses. There is also a widespread misperception of the value of timber in different forms of construction. The Code for Sustainable Homes account for timber used in buildings by way of material credits, but linked to ensuring sustainable sourcing of timber, rather than evaluation of its embodied energy. Experts agree that embodied energy is likely to become a more important part of the energy equation as operational energy decreases with increasing thermal standards. Timber is renewable, of low embodied energy, and is recyclable; an ideal material for use in low carbon construction.

[43] http://www.unece.org/fileadmin/DAM/timber/publications/03.pdf Agreed at UN Climate Change Conference at Durban 2011

[44] Biogenic carbon is recycled naturally in the carbon cycle.

8: Housing in Wales

Building new affordable[45] homes is one of the stated aims of the Welsh Government (WG)[46], alongside its commitment to ensuring everyone has access to a decent home. The recent announcement of an ambitious target of providing 12,500 homes over the next four years includes the building of 7,500 affordable homes and bringing 5,000 empty properties back into use.[47] To put these targets into perspective, Shelter says there are 90,000 households currently on waiting lists for council or social housing in Wales[48] with 9,000 households classed as homeless in 2010.[49] Wales is now the least affordable area in the UK outside London and south of England for younger working households.[50] The impact of UK government welfare reform also threatens to increase these numbers.

A number of factors currently affect the housing supply crisis: economic influences, affecting affordability, land and planning, and demographic influences.

Affordability

The current economic climate adversely influences job availability, house price and income ratios, availability of mortgage finance, food and fuel prices. The impact of welfare reform is also feared to jeopardise any recovery. Accessing affordable housing is increasingly problematic for younger working households, throughout Wales with an average price to income ratio of 4 to 1.[51] There is a growing affordability gap for people aged between 20 and 39 across Wales, making home ownership out of reach for many young, dual income families. In rural areas the situation is far worse: with some areas with house price ratios of 5 to 1.[52]

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[45] Defined as housing where there are secure mechanisms in place to ensure that it is accessible to those who cannot afford market housing, both on first occupation and for subsequent occupiers. Planning Policy Wales Edition 5 Welsh Government November 2012

[46] Meeting the Housing Challenge; building a consensus for action consultation, Welsh Government, December 2011

[47] http://wales.gov.uk/newsroom/housingandcommunity/2012/6063562/?lang=en [Accessed 140512]

[48] http://www.bbc.co.uk/news/uk-wales-politics-18057200

[49] www.poverty.org.uk

[50] Young, working and STILL homeless CIH 2006

[51] Young Working and Homeless: Younger Working Households in Wales and the Affordability Crisis in 2005 CIH Cymru 2005.

[52] Young Working and STILL Homeless: Housing market affordability in Wales in 2005. CIH 2006.

Average house price in Wales is now £150,808[53] and a generation are locked out of the housing market as saving for a deposit for a home triples in a decade.[54]

The issue of affordability is defined by various indicators that give some insight to how housing market developments affect both the financial position of households and the future direction of house prices. House price to income ratios, interest rates, arrears and repossessions and the first time buy and buy to let market all affect a household's ability to access housing. Increasing the supply of affordable housing is one of the key strategic themes of several Welsh Government strategy documents.

Affordable housing is not just social housing for rent; low cost home ownership (such as WG Homebuy scheme), shared ownership and intermediate rents, where rents are set at 80% of market value, are among other mechanisms. This broader definition gives providers more opportunities to come up with solutions for the long term. However, UK Government initiatives such as Help to Buy have overshadowed a similar scheme in Wales even before its launch.[55] A NewBuy Cymru Mortgage Guarantee Scheme is to be set up by WG to support 3,000 home buyers with a 5% deposit, due in September 2013 and available for 3 years.[56]

Land and Planning

Research indicates that over 14,000 new homes are needed every year in Wales for the next 15 years.[57] This would mean providing over 5,000 affordable units annually alone to satisfy current needs.[58]

The number of homes completed in more prosperous pre-crunch years still fall below the estimated number required to satisfy demand (Figure 8.2).

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[53] http://news.bbc.co.uk/1/shared/spl/hi/in_depth/uk_house_prices/regions/html/region4.stm

[54] http://www.hbf.co.uk/media-centre/news/view/the-locked-out-generation-time-to-save-a-deposit-for-a-home-triples-in-a-decade/

[55] http://www.bbc.co.uk/news/uk-wales-22189232 [Accessed 170513]

[56] WLGA E-Bulletin March 2013

[57] Housing Need and Demand in Wales 2006-2026. Holmans and Monk, 2010 [accessed 25 July 2011]

[58] Inquiry into the provision of affordable housing in Wales. Communities, Equality and Local Government Committee, National Assembly for Wales April 2012

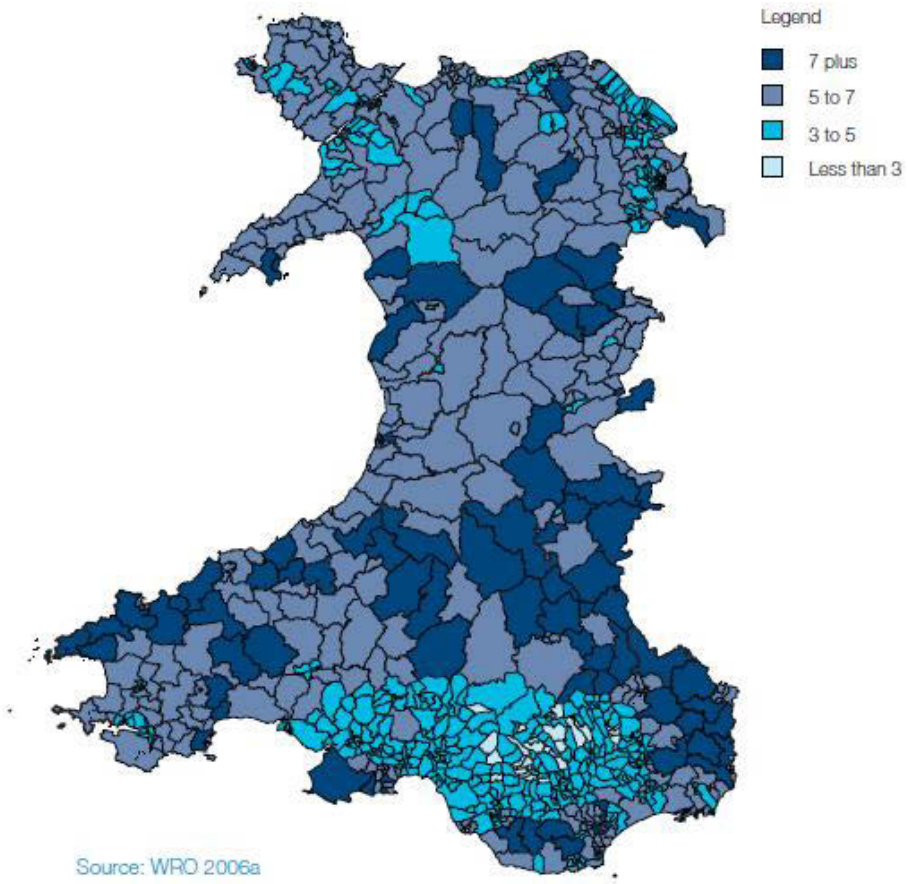

Figure 8.1 Average house price to average household earned income ratio by ward in Wales 2005

Source: Wales Rural Observatory

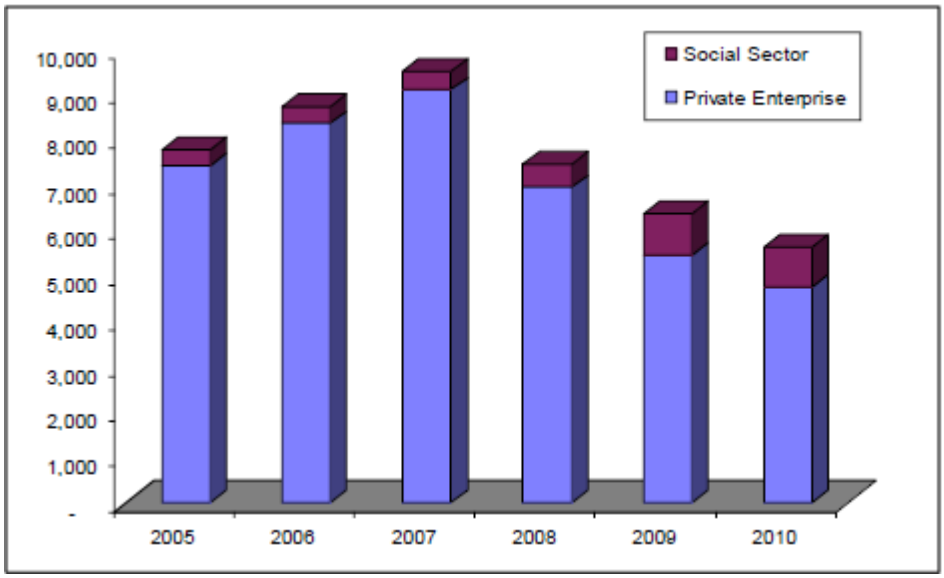

Figure 8.2 Annual house completions in Wales since 2005

Source: Chartered Institute of Housing

Making land available for building is a cornerstone of any policy aimed at alleviating the housing crisis. Government intervention in bringing forward land that it owns, for example, the Forestry Commission donated land at Dolwyddelan (discussed later in the Tŷ Unnos section) are providing some sites for affordable homes, but these and Section 106 agreements are insufficient to tackle the task. [59] A Task and Finish group appointed to look at affordable housing, led by former AM Sue Essex, made 43 recommendations on the issue. The Essex Review, as it became known, played a major role in shaping the new regulatory regime for RSLs, within which much of affordable housing is delivered in Wales.

In terms of planning, this is often a blunt tool when the consequences are viewed by opposite sides of the argument: decision makers, very often local councillors with little or no experience of what constitutes 'appropriate' development, are left to balance the NIMBY stance of those opposed to social housing or any development, versus the housing developers who can provide much needed construction jobs.

Very often, the choices are made for political expediency and not on the merits or otherwise of any development. Higher building performance standards in terms of Code for Sustainable Homes and devolved Building Regulations are also seen by some as obstacles due to higher compliance costs. [60] But as Sue Essex stated:

"…there is a need for a greater emphasis on innovative construction and processes to meet not just climate change targets but at reducing overall building costs."[61]

This is an invitation for high thermal performance innovative housing solutions to be provided by those responsible for delivering affordable housing in Wales decision-makers, RSLs, local authorities and housing developers, alike need to embrace this

[59] Section 106 agreements - The legal basis of planning obligations is set out in Section 106 of the Town & Country Planning Act 1990 (TCPA 1990). A Section 106 agreement is a legally binding private contract between a developer (or a number of interested parties) and a Local Planning Authority and operates alongside a statutory planning permission. They are a legal charge on the land, so they transfer automatically with any change in ownership. Such agreements require developers to carry out specified planning obligations when implementing planning permissions and are the result of negotiations on these matters between the two parties. Obligations may be entered into to prescribe the nature of development, to secure a contribution from a developer to compensate for any loss or damage caused by a development, or to mitigate a development's wider impact. Obligations can be carried out either by providing what is needed to a standard specified in the agreement (such as affordable housing) or by paying a sum to the planning authority which will then itself provide the facility.

[60] House Builders' Federation in The provision of affordable housing in Wales Report by LGE Committee

[61] CELG Committee National Assembly for Wales: HSG 31, p3 2011

opportunity for taking the first step in building sustainable communities with the provision of affordable housing for local people.

Demographic Influences

Two critical factors drive the need for more housing: an increasing population due to various factors, and the need for more single and two person accommodation, with the increase in life expectancy and the breakup of the nuclear family.

Issues of affordability, homelessness and the need for social housing have been acute in rural areas of Wales.[62] In rural Wales[63] the population has seen a net increase mostly resulting from in-migration of older people and out-migration of younger people.[64] The latest census figures states that 29% of the rural population in Wales is 60 or over.[65] The effect this has on housing exacerbates the availability and affordability of housing for young people. Home ownership amongst under 35s has fallen by a third in 10 years.[66] There is a cultural cost in terms of the out migration of the young and in migration of an older population, as the low numbers of Welsh speakers in the latest Census attest.[67] Rural areas of Wales, like Cornwall, are also popular holiday home destinations. House prices are subject to local conditions and factors considered endemic to rural Wales, the beauty and appeal of the landscape, is attractive to wealthy in-migrants, retirees, tourists and holiday and second home owners and investors in buy to let. An increasingly economically inactive population due to unemployment among the general population and the young in particular, and an ageing population, exacerbates the market needs. Although the overall number of second homes remains relatively small, unlike Cornwall, the numbers in the predominantly Welsh – speaking areas impact not only on the economic and social fabric of local communities but also in terms of cultural impact and the decline in use of the native language.

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[62] Rural Housing in Wales Joseph Rowntree Foundation Commission Report June 2008

[63] Welsh Government uses the local authority classification, as distinct from the one used by the ONS

[64] JRF Commission on Rural Housing in Wales 2008

[65] Census 2011 quoted in http://www.walesruralobservatory.org.uk/latest-figures-2011-census-reveal-29-rural-population-wales-aged-60-or-over [Accessed 050613]

[66] Savills Seconds out on second homes http://www.savills.co.uk/research_articles/141280/146154-0 [Accessed 040613]

[67] http://www.bbc.co.uk/news/uk-wales-21259079 [Accessed 130313]

Building Homes and Communities

The significance of housing in delivering wider benefits has never been more relevant. The capacity for spending on housing to add value across many agendas is well documented[68]: in terms of jobs, training, regeneration, improved health and well-being. It presents a huge opportunity to develop local manufacturers, service providers and a local skilled workforce. This is explored further in the next Section.

Construction represents around 20% of the overall public procurement spend of £4.3 billion and presents many opportunities for Wales-based suppliers to compete for and win business while also acting as a vehicle to achieve social and environmental benefits for local communities.[69] Maximising the returns from social housing investment is a key government priority, and a recent Value Wales evaluation of the 'multiplier' outcomes for public investment recognised the key role for housing.[70]

The CHC report points to evidence that a greater number of jobs and apprenticeships are created through housing than other forms of construction such as transport, where a higher proportion of the spend goes on plant and material and less on employment. A wider assessment of the value of public investment in housing is needed to reflect the positive economic, social and environmental impacts. Value Wales has developed a 'community benefits' measurement tool to assess outcomes and measure the success of implementing procurement policies: using monies from the £4bn public sector spend to seek local training, employment and supply chain opportunities. The evidence points to 30% greater local multiplier effect when this policy is applied.[71]

As well as the current WG commitment to building 12,500 new homes, 7,500 of these to be affordable units, [72] an additional £30M package to increase the housing supply has been made available, £20M of which is earmarked for Social Housing Grant specifically to target investment for homes for those affected by welfare reforms. This is against a background of falling government - backed grants[73] and

[68] The cost of poor housing in Wales. BRE and Shelter Cymru, 2011
[69] Housing and regeneration sustainable community investment report, Housing Directorate, WAG, 2010
[70] CHC Evidence to Communities, Equality and Local Government Committee inquiry into provision of affordable housing, 2011
[71] Maximising the impact of Welsh procurement policy. McClelland Report 2012
[72] http://wales.gov.uk/newsroom/housingandcommunity/2012/6063562/?lang=en [Accessed 280513]
[73] Social Housing Grant budget for 2013-14 is £53M; compared to £75M 2011-12 and £60M in 2012-13

the need to secure alternative methods of funding, pursued by newly formed companies such as the Ely Bridge Development Group and Community Development Capital.[74] These new funding models eliminate the need for grant and government procurement restrictions, and are more likely to give priority to innovative solutions, Modern Methods of Construction (MMC), higher build performance and targeted build costs (£1050/m2). Innovative solutions are being used by West Midlands based Accord Group to build their own Low Carbon Living (LoCaL) energy efficient timber panel homes, the first housing association in the UK to do so.[75]

Housing is central to a low carbon economy and limiting its environmental impact through higher thermal performance is a consideration in the proposed targets of Part L of the devolved Building Regulations in Wales. There is scope in addressing not just the operational energy of a building, but its embodied energy[76]and Wales could take the lead in specifying timber first for use in public buildings in a similar way to France.[77] As any intervention seen to threaten economic recovery may be viewed with caution, WG may need persuasive arguments to pursue the more stringent options in devolving Building Regulations for Wales.

Although WG is one of only a handful of administrations in the world to make sustainable development a statutory obligation, one of its priorities is to find new ways of building low carbon, energy-efficient and affordable homes.

A new opportunity has arisen with the increased powers of the Government in Wales, and the acquisition of powers over the Building Regulations in Wales represent a once in a lifetime opportunity to make a difference stance to standards set in the rest of the UK. The Environment Minister at the time, Jane Davidson, provided an impetus for higher construction standards using the planning system to promote improved building performance via BREEAM and DCLG's Code for

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[74] http://www.socinvest.co.uk/news/2811/Welsh-government-backs-new-housing-delivery-vehicle [Accessed 270613]
http://www.insidehousing.co.uk/finance/social-homes-plan-revealed/6527319.article [Accessed 140613]

[75] http://accordgroup.org.uk/articles/106-First-factory-homes-set-for-Walsall-housing-development--

[76] Operational energy is energy used by occupants of a building over its lifetime; embodied energy refers to the energy used in extraction, manufacture and transport processes of materials used in its construction

[77] http://woodforgood.com/blog/press-releases/sustainability-campaign-calls-for-a-%E2%80%98wood-first%E2%80%99-rule-for-all-public-buildings

Sustainable Homes. Setting the minimum requirement at Code level 3+ for new build social housing was a first step toward the European Performance of Buildings Directive (EPBD) and the zero carbon target for all buildings. A focus on improving the fabric and energy efficiency of building envelopes is likely to continue with succeeding Ministers in an attempt to eradicate fuel poverty, the effects of climate change and increased flooding, and alleviate the effects of a triple dip in the economy. This scenario is currently set against a background of economic recession and a stagnant construction sector, particularly in speculative housing.

One way to provide much needed new homes, alleviate fuel poverty, revive employment, and bridge the skills and training gap in construction is to build more affordable units; the readily available resource from plantation forests the basis for that revival.

An Ipsos MORI survey found that around 6M Britons would like to build their own home and over 1M would like to do so in the next 12 months. [78] The same report quotes National House Building Council figures that say the number of small builders constructing 30 or less units a year has declined by 55% between 1991 and 2011. The opportunity for self build and custom build homes is significantly greater than the number of units completed. The demand for studio/workshop type structures is indicated by the number of queries on the potential of Tŷ Unnos for self build received by Coed Cymru annually at the Smallholders and Royal Welsh Show.

The Caban Unnos and Woods of Wales studio buildings attract self builders wishing to use Tŷ Unnos, its portability and buildability being well suited for this purpose.

A standardised kit form for those wishing to erect their own dwelling could fill a niche in the market, as families now try to accommodate new homes on garden plots.

Building for social rental is done by Registered Social Landlords (RSLs) and some local authorities who have not opted for Large Scale Voluntary Transfers (LCVTs) of their stock to an independent housing company or RSL. Costs for new housing developments can be classified into four areas: land acquisition, planning, site development and marketing, build costs and gross profit. The decision to build is

[78] A 10 - point plan to boost Self-Build Homebuilding & Renovating magazine May 2013

illustrated below. Adopting offsite methods of construction can help meet demands for higher performance. Offsite is defined as a process where 40% of the construction value of the finished building is delivered on site.[79]

Figure 8.3 The decision to build formula

Source: Construction Industry Council

Advantages of offsite are predictable quality and performance, low waste, fast construction, control of health and safety and work conditions, thermal performance and sustainability control, adaptability. Of these, one of the more important factors is the ability to be independent of weather conditions, and the element of prefabrication protects building components from poor weather, and less construction time spent onsite. The offsite industry has an exciting future ahead with the prospects of a market that is likely to grow and likely to demand products it can provide. The complex routes to market is a challenge to the supply chain but it is possible to target the possible customer segments of the future illustrated in Figure 8.4:

[79] Offsite Housing Review Construction Industry Council February 2013

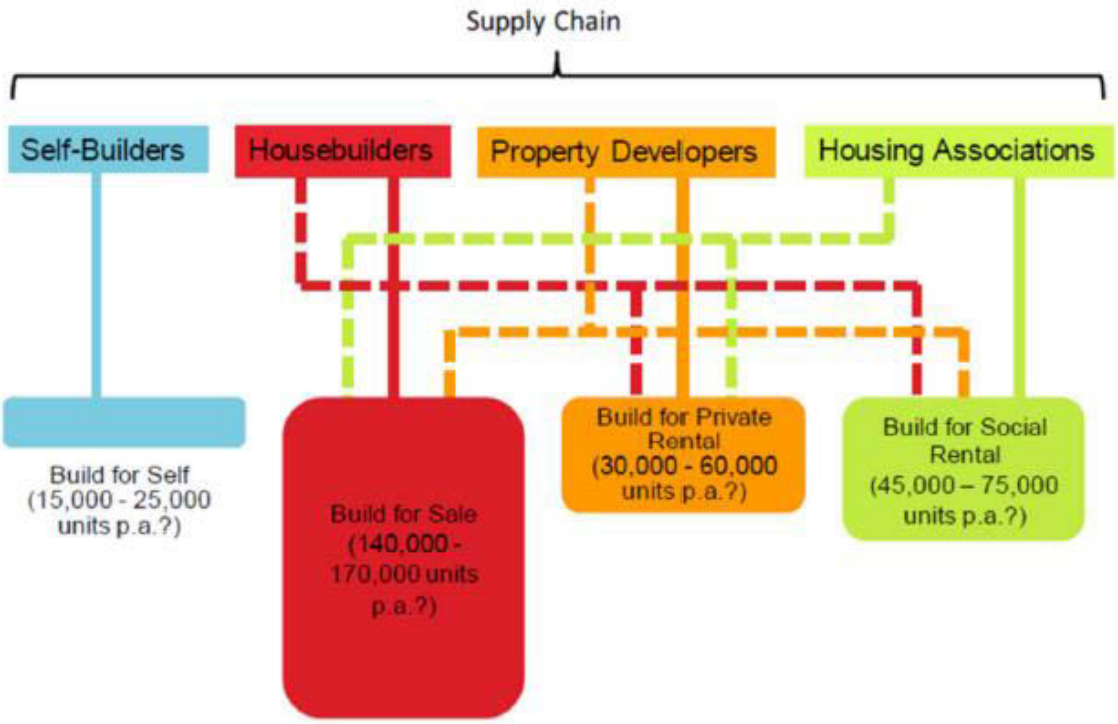


Figure 8.4 Potential future shape of the market – indicative figures for England

Construction Industry Council

9. Tŷ Unnos Case Study

The idea of creating houses from home-grown timber started from a small feasibility study carried out by Coed Cymru which looked into whether it was possible to produce low-carbon, affordable housing from Wales' own forests. It had not been done before as, although the main softwood species Sitka spruce grows well in the Welsh climate, it is fast growing and matures in 30 to 40 years resulting in a reduced density of timber compared to growth in its native climate. It also has heavier branching and bears larger knots in the finished timber than its North American counterpart. One of the challenges faced by the consortium led by Coed Cymru was to find ways to engineer the traditionally weak and previously, largely unusable timber in terms of construction, home grown plantation Sitka spruce now readily available from harvesting. Engineering solutions were found to strengthen it and make it more stable, approaching the quality of other imported construction materials.

The use of a local and inherently low cost material gives the Tŷ Unnos system an opportunity to add value at each stage of the supply chain. The project was conceived in order to provide an innovative response to the step change required in the cost of low impact solutions for rural housing, specifically:

"to take forward the results of previous basic research and overcome the technical barriers and economic challenges in the development of Sitka spruce in an integrated whole house system for low carbon affordable housing."[80]

The study therefore proposed a radical departure from current practice in the form of a whole house construction system of engineered home grown timber components.

The proposal attracted great interest from all aspects of the industry and a multi disciplinary team of experts formed to prototype, test and develop the timber components in combination with a number of commercial partners.

[80] Tŷ Unnos Sitka spruce housing: Feasibility study 2007

9.1 System Components

The system uses two principal innovative structural components: a box beam and a ladder beam illustrated (Figure 9.1). Typical Tŷ Unnos structures incorporate a post and beam construction although other variations can be built.

The Tŷ Unnos post and beam structural solution using box sections for both beams and columns and ladder 'I' beams for infilling floor and wall panels. The timber for both is dried to 14% MC but only the structural box section are strength graded. The box sections are constructed using glued tongue and groove connections at the corners to form standard timber sizes into a hollow member. Box sections of 220 x 220mm have been produced but also rectangular sections can be built up using narrower boards along the length. The sections are strong in orthogonal directions and have flat surfaces on all sides for fixing. The box beam has the same properties and capacity in both vertical and horizontal directions, unlike solid sections.

Solid timber joists are typically used in construction, usually to depths of 100mm and 175mm for domestic floors. Again an engineered 220mm deep section can be made using smaller, less expensive timber. These span horizontally between box beams to form walls, roofs and floors. The advantage of the system is lower structural self weight. Engineered timber sections in proprietary systems are available as 'Posi Joist' beams with open web arrangements to allow services to be installed without cutting or notching the joist.

Both components can be used together in an integrated build system or independently in new build and refurbishment projects. To date, they have been used in building over 20 complete units and the individual box beams are being used in innovative development around the UK. The design team followed the Eurocodes convention in prototyping and testing and European certification is currently being sought for quality and performance.

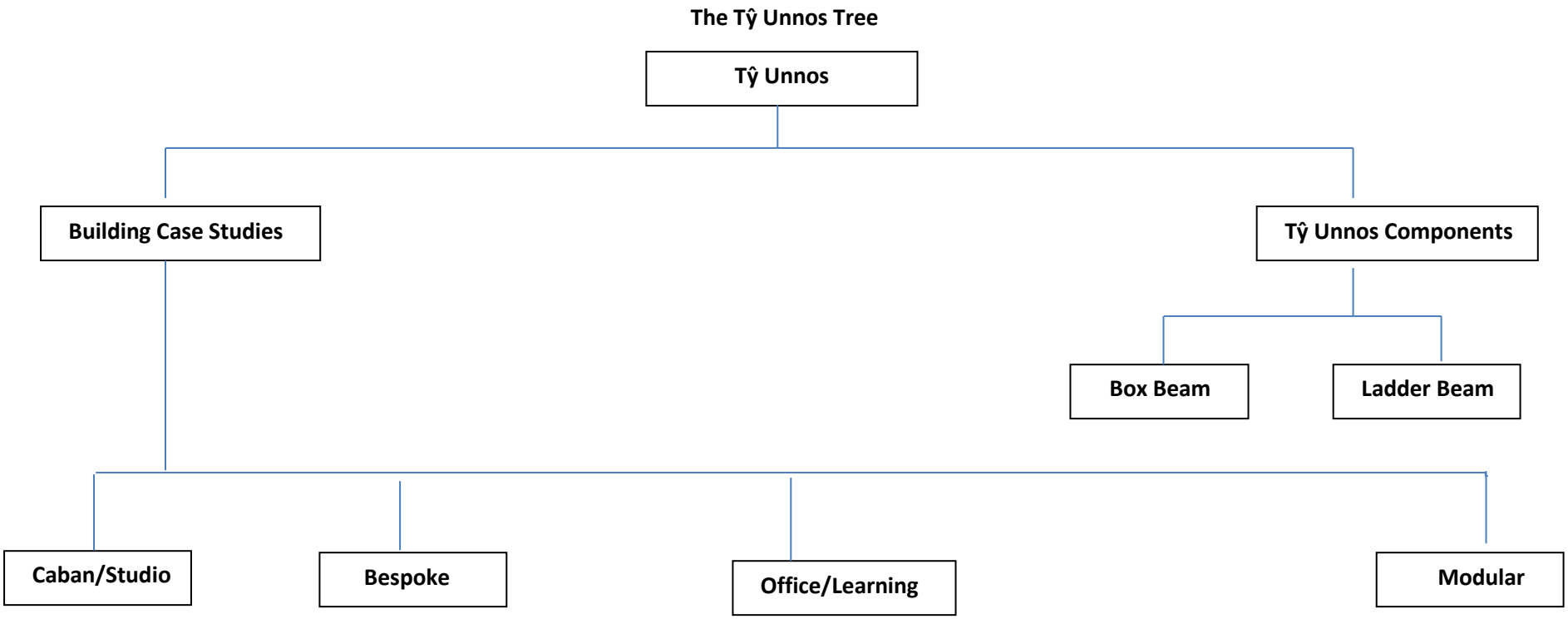
The box beam can be used in load bearing situations with a span of up to 4.8 metres. The ladder beam can be used as a floor joist with a span of up to 3 metres and as a non-load bearing wall stud. (see Appendices for Technical details).

Connections to the portal frame can either be resin fixed bolts or a solid ‘L’ piece. These main connections allow a great deal of variation in different building types. The remaining structural joints use simple shear connections.

The system offers an adaptable method of building using these basic elements and is suitable for a variety of development opportunities, from affordable housing in its modular form, to a near PassivHaus exemplar and smaller sized one off studio or cabin suited for smaller plots.

The various forms of Tŷ Unnos, from the basic pavilion and caban style, to the more sophisticated Passive House, non-domestic buildings and proposed domestic buildings, show that the system and its components are flexible and adaptable to a range of build types (Figure 9.2). Two types discussed in more detail are Tŷ Unnos Modular ™ suitable for affordable housing and the smaller sized studio or Caban Unnos suited for self-build or community projects as small homes, studio or workshop environments (Figure 9.3, 9.4).

Figure 9.1 Box beam manufacture (left) Installing ladder beams in wall studs (right)



Smithsonian Pavilion	Ebbw Vale Passive House	Environmental Research Centre	Glan Gors Dolwyddelan
Pembrokeshire	Swallow Hill	Rosliston Forestry Centre	Leighton Arches
Tregynon Rural Studio	*Blaengors Farm Rhydargaeau*	Cowdenbeath	
Woods of Wales Studio		Tŷ Tyfu	
		Canolfan Tyfu	

Figure 9.2 Tŷ Unnos Hierarchy: buildings constructed to date *Italics are proposed builds*

Figure 9.3 Tŷ Unnos Modular™ at Glan y Gors Dolwyddelan showing solar thermal panels

Figure 9.4 Woods of Wales Studio at Royal Society of Architects Wales conference

9.2 Home grown homes and timber buildings

Increasing the net value of the crop by adding value to the timber is feasible provided the technology exists which is compatible with the starting material. Sitka spruce is too soft and unstable for general use in conventional timber frame and joinery but the components of Tŷ Unnos are specifically designed to use this material.

Using home grown timber for housing is a way of adding value to the resource while contributing to social and environmental goals. The building of energy efficient housing using a readily available local resource offers a practical solution to future challenges of climate change, fuel poverty, homelessness and unemployment. Opportunities exist for innovative solutions that are needed to achieve WG aspirations for a new low carbon future. The provision of affordable homes answers a pressing social need while offering new job and training opportunities. There follows an explanation of how value can be added to the timber resource by way of building with Tŷ Unnos Modular™.

Tŷ Unnos Modular™

This system is a factory manufactured modular unit constructed from the simple box and ladder beam system created by the Tŷ Unnos team. The units are prefabricated, quality controlled units that arrive by truck and each floor unit is positioned onsite, making delivery and construction easier, faster and less weather dependent. There is also inherently less waste in this method of assembly than in traditional timber frame onsite assembly.

The modular units fit together and can be erected in one day, as per the tradition of Tŷ Unnos. They meet Code for Sustainable Homes level 4 and can achieve hoigher thermal efficiencies and airtightness, making them ideal energy efficient homes, cost effective to heat. Internal kitchen and bathroom fittings are preinstalled ready for simple plumbing connections, reducing time onsite involving wet trades.

Table 9.5 Tŷ Unnos price guide for semi-detached houses*

2/3 bed 76m2	£	£/m2	£/ft2
Frame: sub and superstructure, watertight shell & insulation, exterior doors & windows	28,120.00	370.00	34.42
Kitchen	5,000.00	65.79	6.12
Bathroom & WC	3,000.00	39.47	3.67
Cladding	3,500.00	46.05	4.28
Roof, coverings, facias, soffits, barges gutters & downpipes	3,500.00	46.05	4.28
Internal finishes (wall & ceiling linings, door & furniture, skirtings, architraves, stairs & balustrades)	7,610.00	100.13	9.31
M & E	6,175.00	81.25	7.56
Fees	1,500.00	19.74	1.84
Prelims	2,875.00	37.83	3.52
TOTAL COST	**61,280.00**	**806.32**	**75.01**

***These prices are indicative at cost without profit margin - only to be used as a guide**

Source: Elements Europe part of Pickstock Group

Assumptions made in illustrative example in Table 9.5:

Basic 2/3 bed house frame uses about 6 m^3 of sawn timber derived from 12 m^3 of round wood

Based on Kiln dried C16 sawn timber £140/m^3 and £46/m^3 for felled and sorted round wood [81]

Delivered as kiln dried timber for a modular build it costs £840. The timber components assembled on site is valued at £28,120 which provides an **uplift figure of over 33 times the original value**

The completed house £61,280 does not include site costs and revenue from sales

Based on a realistic 10% from the Welsh Government target of 7,500 affordable homes announced on 12 May 2012[82] for building houses using Tŷ Unnos Modular™ units we have:

	GVA	Proportion of Wales Output
9,000 m^3 Roundwood	£414,000	0.75 % total softwood*
4,500 m^3 Sawn	£630,000	1.42 % total sawn
750 frames	£21M	
750 homes	£46M	

Alternatively, using 0.75% of the current sawlog harvest would produce 10% of the current WG target of affordable housing.

* 1,193,000 total roundwood harvest for softwoods in green tonnes; 316,000 m^3 sawn softwood production

[81] Prices current May 2013

[82] http://wales.gov.uk/newsroom/housingandcommunity/2012/6063562/?lang=en [accessed 090513]

Caban Unnos

These structures, exemplified by Caban Unnos and Studio or workshop type buildings, are characterised by their portability and buildability and therefore suit self-build and community projects.

Several of these have been manufactured by Woods of Wales for different project requirements since the Tŷ Unnos partnership was formed: the Smithsonian pavilion that travelled to Washington DC, Caban Unnos which toured Pembrokeshire, Tregynon rural studio and Woods of Wales studio, that recently appeared at the Royal Society of Architects in Wales (RSAW) spring conference in Aberystwyth (Figure 9.4).[83]

Whereas all of these require transport to site, some can be assembled onsite and if components were available in kit form and provided with the necessary certification (fire, health and safety in assembly, thermal performance). However, standardisation and simplification would require adequate professional indemnity cover, from either the manufacturer or designer. The forthcoming Construction Products Regulation comes into force in July for the CE marking of manufactured products and their characteristics under different uses may also affect future trade and profitability.[84]

Options for using Tŷ Unnos in the future are many and varied, not just in terms of the current products available. The development of the box beam as a substitute for structural solid beams in house conversions and refurbishments, as well as new builds; beams used as 'posijoists', open and closed (insulation and service channels included) ladder beam cassettes and the potential to remove the box beams in the post and beam from the current building system offer new and exciting opportunities for designers in the future.

A detailed examination of the potential for self build with Tŷ Unnos is examined in a recently published Doctoral thesis by Robert Huw Thomas for Cardiff University

[83] See video at http://www.coedcymru.org.uk/news-article.html?id=24

[84] http://www.planningportal.gov.uk/buildingregulations/buildingpolicyandlegislation/cpr [Accessed 240613]

entitled ‘An Innovative Timber Construction System: building affordable housing using homegrown Welsh softwood.’

10. Conclusions and Recommendations

The plantation forests of Wales were established as a strategic timber reserve in the middle of the last century for the mining industry. They were never called upon to fulfil that original purpose. The resource, however, was put to use and is currently producing close to its production potential but this requires significant subsidy from the public purse. Despite the high level of investment in harvesting and processing plant, falling commodity prices, exposure to global competition and the threat from disease and climate change, suggest a very uncertain future. There is ample milling capacity but no incentive or aspiration for the industry to kiln to the higher consistency required for providing timber for construction. All this could change if the political will is demonstrated.

When the National Assembly for Wales was established with the devolution package the forest was transferred to the Welsh nation. The current severe housing shortage and the lack of training and employment opportunities, especially for young people in rural areas, presents an opportunity to meet a pressing social need.

Construction is one of our few remaining labour intensive industries. It supports a large and diverse workforce including professional, skilled and semi-skilled personnel, of both genders and across the age range in both urban and rural areas.

The skills and disciplines required are widely transferable and the industry provides opportunities for self-employment and part time working, which can be particularly important for rural areas. The modern industry makes high demands of its workforce; an apprenticeship can be challenging and rewarding. Where local materials are deployed, jobs and training opportunities are also created in the supply chain. This is particularly true with timber where all aspects of the industry are becoming more sophisticated and regulated. Tŷ Unnos was conceived around an engineering formula which is ready to use and teach. It can adapt to a wide variety of modern and traditional architecture, materials and trades.

The benefits of using timber are significant in the move to a low carbon society: it is a renewable, carbon neutral raw material of low embodied energy. Timber construction

can lock up carbon during the lifetime of the building: a typical 3 bedroomed semi-detached timber framed house uses around 6m3 of timber and timber-based products, able to store over 4 tonnes of atmospheric carbon dioxide. This in turn promotes the sustainable management and use of our forest resource, while providing much needed training and employment opportunities.

Tŷ Unnos has the capacity to add value to the widely available resource currently coming out of the forest: diverting use from low value products to provide quality, affordable and energy efficient homes. This could, with careful management, bring social and environmental benefits back to the people who fund it.

Recommendations

The original *raison d'etre* for the plantation forests in Wales has disappeared: there is not now a threat of warfare disrupting our supplies of mining timber.

The major challenge of our time is to create a prosperous economy in Wales which is capable of supporting and retaining its population, particularly young people. Of necessity it must be a low carbon economy, securing jobs and training opportunities and providing sufficient affordable homes for all the people of Wales.

The Welsh Government's timber resource is readily available and currently under-utilised. It should be harnessed to deal with our current crisis.

In summary, the Tŷ Unnos system allows Welsh timber to be diverted into higher value uses, particularly building houses of exceptional quality and performance. This can bring benefits to rural and urban communities of Wales and create export opportunities for Welsh businesses. This opportunity should be seized upon as a matter of national priority.

APPENDICES

Appendix I

British (BSI) and European (EN) Standards

BS 4978: Specification for visual strength grading of softwood. BSI London, 2007.

BS 5756: Specification for visual strength grading of hardwood. BSI London, 2007.

BS DD ENV Eurocode 5: Design of timber structures – Part 1.1 General rules and rules for buildings. BSI **1995-1-1:** London, 1994.

BS EN 336: Structural timber – Sizes, permitted deviations. BSI London, 2003.

BS EN 338: Structural timber – Strength classes, BSI London, 2003.

BS EN 350-2: Durability of wood and wood-based products – Natural durability of solid wood. Part 2: Guide to natural durability and treatability of selected wood species of importance in Europe. BSI London, 1994.

BS 373: Methods of testing small clear specimens of timber. BSI London, 1957.

BS EN 384: Structural timber – Determination of characteristic values of mechanical properties and density. BSI London, 2004.

BS EN 385: Finger jointed structural timber. Performance requirements and minimum production requirements. BSI London, 2001.

BS EN 386: Glued laminated timber – performance requirements and minimum production requirements. BSI London, 2001.

BS EN 387: Glued laminated timber – Production requirements for large finger joints. Performance requirements and minimum production requirements. BSI London, 1999.

BS EN 390: Glued laminated timber – sizes – permissible deviations. BSI London, 1995.

BS EN 408: Timber structures – Structural timber and glued laminated timber – Determination of some physical and mechanical properties. BSI London, 2003.

BS EN 1194: Glued laminated timber - strength classes and determination of characteristic values. BSI London,1999.

BS EN 1912: Structural timber – Strength classes – Assignment of visual grades and species. BSI London, 2004.

BS EN 14080: Timber structures – Glued laminated timber – Requirements. BSI London, 2005.

BS EN 14081-1: Timber structures – Strength graded structural timber with rectangular cross-section – Part 1, general requirements., BSI London, 2005.

BS 14081-2: Timber structures – Strength graded structural timber with rectangular cross-section – Part 2: Machine grading; additional requirements for initial type testing. BSI London, 2005.

BS EN 14081-1: Timber structures – Strength graded structural timber with rectangular cross-section – Part 1, general requirements., BSI London, 2005.

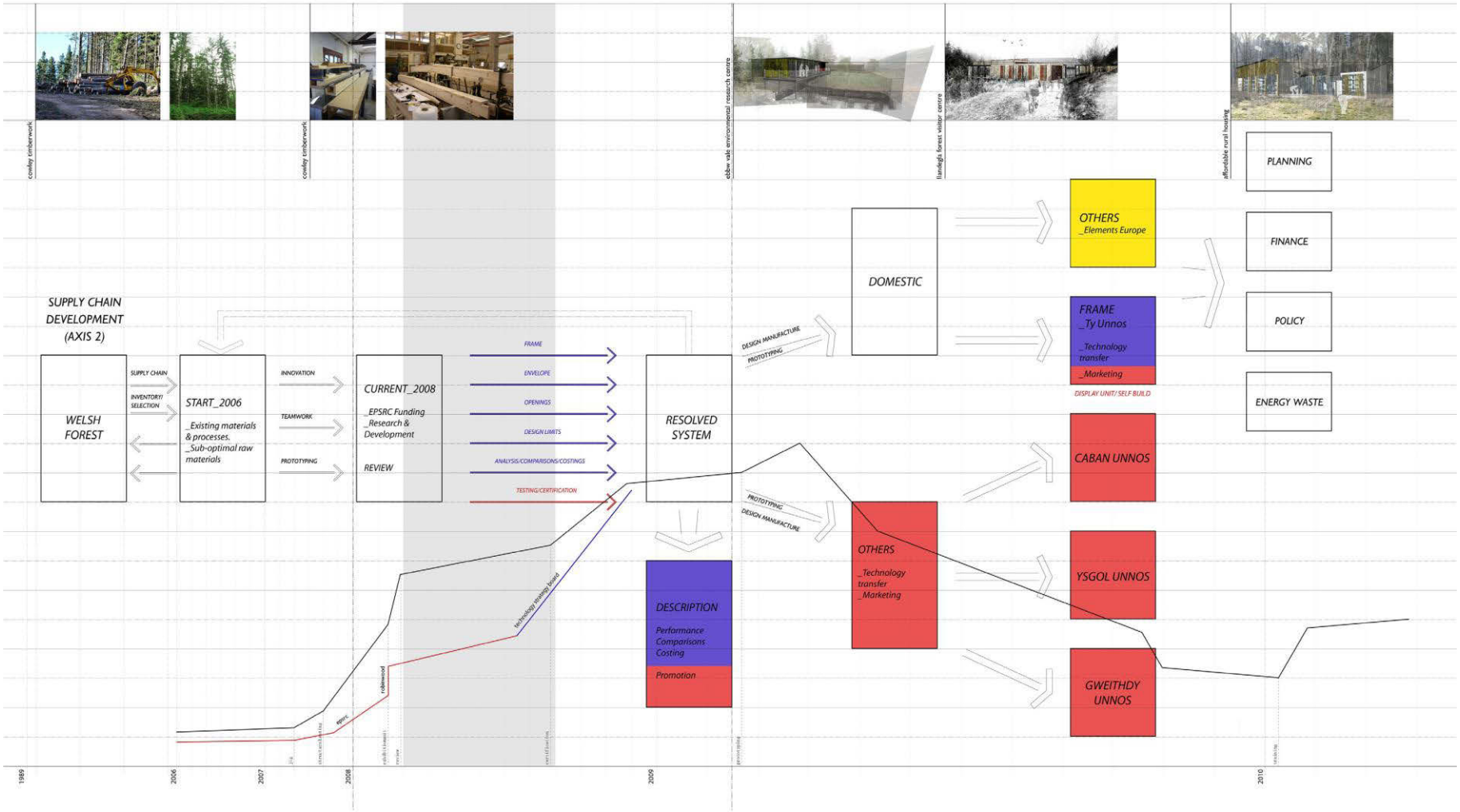
BS 14081-2: Timber structures – Strength graded structural timber with rectangular cross-section – Part 2: Machine grading; additional requirements for initial type testing. BSI London, 2005.
BS 14081-3: Timber structures – Strength graded structural timber with rectangular cross-section – Part 3: Machine grading; additional requirements for factory production control. BSI London, 2005.
BS 14081-4: Timber structures – Strength graded structural timber with rectangular cross-section – Part 4: Machine grading; grading machine settings for machine controlled systems. BSI London, 2005.
BS EN 14279: Laminated veneer lumber (LVL) – Specifications, definitions, classification and requirements. BSI London, 2005.
BS EN 14358: Timber structures. Calculation of characteristic 5-percentile values and acceptance criteria for a sample, BSI, London, 2006.
BS EN 14374: Timber structures – Structural laminated veneer lumber – Requirements. BSI London, 2005.

Source: Wood Knowledge Wales

Appendix II

Tŷ Unnos SWOT Analysis

Strengths	**Weaknesses**
• Welsh home grown product its USP • Tŷ Unnos name strong traditional value • Flexibility in design and build types • Local sustainable product marketing tool • Social benefits using public funding • Low value species transformed to high value use • Eurocode compliant system • Uses basic machinery and skills • IP open access • Competitive pricing	• Supply chain over reliant on single source supplier and manufacturer • Perception of Welsh timber in use • Non standard components • Many bespoke examples • Insufficient volume to establish brand • IP open access vs business confidentiality • Lack of funds to drive further research • Lack of air dried softwood stock piling
Opportunities	**Threats**
• All other systems rely on imported timber • Building regulations and embodied energy • Low carbon agenda • Training and job opportunities • Self build market • Further scope to develop components	• Recession affecting construction particularly affordable housing projects • Imported timber systems • Competitive market for commodity • Vulnerable supply chain • Construction Products Regulation • SMEs reluctance to use HG timber


cowley timberwork
cowley timberwork
ebbw vale environmental research centre
llandegfa forest visitor centre
affordable rural housing
SUPPLY CHAIN DEVELOPMENT (AXIS 2)
WELSH FOREST
SUPPLY CHAIN
INVENTORY/ SELECTION
START_2006
_Existing materials & processes.
_Sub-optimal raw materials
INNOVATION
TEAMWORK
PROTOTYPING
CURRENT_2008
_EPSRC Funding
_Research & Development
REVIEW
FRAME
ENVELOPE
OPENINGS
DESIGN LIMITS
ANALYSIS/COMPARISONS/COSTINGS
TESTING/CERTIFICATION
RESOLVED SYSTEM
DESCRIPTION
Performance
Comparisons
Costing
Promotion
DESIGN MANUFACTURE
PROTOTYPING
DOMESTIC
PROTOTYPING
DESIGN MANUFACTURE
OTHERS
_Technology transfer
_Marketing
OTHERS
_Elements Europe
FRAME
_Ty Unnos
_Technology transfer
_Marketing
DISPLAY UNIT/ SELF BUILD
CABAN UNNOS
YSGOL UNNOS
GWEITHDY UNNOS
PLANNING
FINANCE
POLICY
ENERGY WASTE
technology strategy board
epsrc
robinwood
1989
2006
2007
2008
2009
2010

APPENDIX III

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Various websites including Welsh Government, TRADA, BRE and others.

Tŷ Unnos Technical documents can be found on the website at:

http://www.coedcymru.org.uk/components.html