POLICY EVIDENCE SUMMARY June 2023

Recycling building materials to build lower carbon homes

AHURI

Based on AHURI Final Report No. 402: Building materials in a circular economy

What this research is about

This research analyses the supply chains of manufactured building materials used by the residential housing industry so as to assist the housing industry in reducing greenhouse gas (GHG) emissions.

The context of this research

Understanding the structure of building-material supply chains is essential for policy development seeking to reduce carbon intensity of new material choice and use in the housing industry. This will require the housing industry to rely less on newly made materials and more on the reuse, recycling and resource recovery of 'used' materials, which will involve efficient and responsive 'used' materials markets.

The construction sector was responsible for 18.1 per cent of Australia's carbon footprint in 2013. With manufactured building materials being a major contributor to global GHG emissions, there have been inadequate responses to growing volumes of waste and disposal, valuing, reusing, reprocessing and recycling of waste across all stages of the dwelling life cycle.

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The key findings

From a circular economy (CE) perspective (in which resource inputs and waste are minimised), demolition promotes only downcycling, whereas deconstruction retains value and, in some cases, increases value.

The nature of the housing industry and resistance to change

The Australian housing industry has two distinct sectors: the Housing Construction Industry (HCI) produces detached houses; and the Multi-Unit Apartments and Townhouse Construction Industry (MUATCI) that produces multi-unit apartments and townhouses. The two sectors produce different physical structures and use different institutional arrangements to design, finance, build and market new dwellings.

Because innovation in the Australian housing industry is slow and geographically differentiated, developing and implementing a CE strategy will not be uniform and will take time.

Increasing embodied GHG in new building materials

Over 50 years, the embodied GHG emissions in residential building materials used each year have almost doubled from 3.2 million tonnes CO_2-eq (CO_2 equivalent) in 1970 to 5.7 million tonnes CO_2-eq in 2020. Analysis of the stock and flow (i.e. inflow and outflow of materials) in the period 2007–2019 indicates that new materials being used in construction are more than double the flow of waste out, which shows that the stocks in use of predominantly new or virgin materials are growing rapidly.

Building materials flow patterns are complicated and obscure

Improving understanding of material flow patterns is complex. For example, a multitude of different construction materials are interdependent, which means that some raw materials end up in a multitude of different construction products. At the same time, each construction material is part of its own supply chain or system. The life cycle stretches from raw material extraction and materials production, then to the consumption or construction phase, the material in-use phase, and all the way to disposal and recycling.

It is estimated that concrete and bricks constitute the largest flows of high-carbon construction waste going into and coming out of the housing system. Currently this type of construction and demolition waste is being downcycled and used to supplement regional road and railway line infrastructure projects (e.g. roads and railway line ballast). It is unlikely that a high-value reuse strategy for concrete and bricks, similar to the scrap steel industry, will develop.

There are large data gaps that challenge researchers who are seeking to identify and quantify the stocks in use in the residential housing sector. Further, the databases containing relevant data are not connected. Addressing data gaps by identifying new data sources and expanding available data that can be used by decision-makers at local, regional, state, territory and national levels is essential for the development of a CE within the housing system.

Barriers to seeing construction and demolition waste as a valuable resource

The challenge is to develop policies that ensure that construction and demolition waste becomes a resource. In Australia, The National Waste Policy Action Plan (NWAP) sets a target for achieving an 80 per cent average resource recovery rate from all waste streams, along with increasing the use of recycled content. Too often construction and demolition waste use is downgraded to recycling or used for energy generation. However, there are institutional barriers to recycling this waste: the cost of reusing materials is higher than using new materials; the lack of an established market for reuse of construction and demolition waste materials; the institutionalised reluctance to use available technological and practical knowledge to reduce the waste; and the broad perception that Australia has abundant supplies of natural resources.

Case studies into CE and residential developments: Cape Patterson

The design and construction of the Cape Paterson ecovillage houses follows design guideline requirements that go beyond minimum standards and include a NatHERS 8.5-star energy rating. The ecovillage has an emphasis on minimising material where possible, as well as selecting products that are more natural and less manufactured, meaning there is less to recycle at the end of the lifespan. Future disassembly and reuse of materials was also considered.

There were financial challenges with delivering CE across the dwelling life cycle. Increased building costs had reduced choice in building materials, and there was also an admission that the main priority was operational energy (i.e. the energy the building used to stay warm or cool). In order to build homes with best energy ratings the development team were required to educate and challenge the builders to work differently from normal.

Case studies into CE and residential developments: Park Life

The Park Life building is one of six apartment buildings in the Nightingale Village. Each building is seven to eight storeys high and, overall, the project will deliver around 200 apartments, each with an average 9+ stars NatHERS rating.

The developers took an approach that focussed on material reduction, avoiding the unnecessary claddings and finishes that are added to buildings because people think that is what the market wants. There were some examples of recycled materials, such as recycled brickwork in landscaping areas and timber flooring, but this was not delivered at scale. There were challenges preventing more widespread reuse of materials, such as cost and storage of materials. There was also an acknowledgment that materials were not particularly selected for their ability to be reused or repurposed at the end-of-life.

Being innovative with material choices was also challenging as builders would price-penalty materials that they viewed as risky. This reduced material choices away from more sustainably desirable materials such as timber, and towards cost-effective materials such as concrete. The land value and scale meant medium-residential villages appeared to have greater challenges related to financial costs in obtaining the sustainable design they desired.

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Findings from the case studies: costs restrict use of lower carbon products

The material strategies in both case studies had different circularity approaches. The Park Life Nightingale Village case study focussed more on reduction, while The Cape appeared to focus more on strategies that included materials reduction, but also on ‘refuse, reuse, rethink and repurpose’.

The designers of both case studies recognised issues that challenged movement towards circularity, specifically the financial cost of planning for building disassembly at the end-of-life; and how costs restricted the choice of lower-carbon materials and alternative construction methods. It was difficult for developers and builders to justify the costs of disassembly of existing buildings as the cost of disposing of materials in landfill is less.

Embodied energy in residential building materials

Embodied-energy intensity in building materials, which is the combination of material quantity and embodied energy coefficient of materials, is highly uneven across the housing system. Six main materials contribute to residential embodied-energy: concrete, timber, brick, steel, plasterboard and carpet. The level of embodied-energy contribution is influenced by time, as the service life of some materials in older dwellings—such as carpet and plasterboard—is shorter than others in new housing, which results in higher recurrent energy. Housing type also matters, as apartment embodied-energy intensities are nearly 20 per cent higher than houses. Timber has the lowest embodied-energy intensity, whereas reinforced concrete has the highest. Less material is required for timber housing, whereas reinforced concrete apartments require large quantities of concrete and steel with high embodied-energy coefficients.

> ‘Apartments are 18 per cent more carbon-intensive than houses.’

Understanding the supply chains that deliver building products

The research established that 27 industries deliver products and services to a residential building site where a house or apartment building is being constructed. Because residential building projects are time-limited, one-off projects, these supply chains are being continuously dismantled and remade, which limits the ability of the suppliers to introduce changes to materials or their use.

Case-study building materials: concrete, steel and timber

- **Concrete:** Apartments are 18 per cent more carbon-intensive than houses. This is because apartments are mainly constructed of concrete, whereas houses are typically built of brick veneer, timber and double brick.

  Eight CO_2 reduction pathways are nominated across the Australian cement and concrete value chain for the period 2020–2050: zero emission electricity and transport (reduce by 14%); design and construction innovation (reduce by 21%); concrete innovation (reduce by 10%); increase use of supplementary cementitious materials in concrete (reduce by 3%); new CO_2-efficient cements (reduce by 7%); alternative fuels and green hydrogen (reduce by 6%); measure concrete take-up of CO_2 (reduce by 6%); and capture remaining CO_2 (reduce by 33%).

- **Steel:** Steel production produces between 7 per cent and 9 per cent of GHG emissions. The MUATCI dwellings are the greatest user of steel, as apartment buildings are usually constructed using reinforced concrete. There is growth in the volume of steel products, with an estimated 12–13 per cent of steel production going into the residential housing industry in 2018–2019, with an increase of about 2 or 3 per cent in the five years prior to that.

  The use of scrap steel in new steel production reduces emissions, however there are two issues: first, the availability of scrap steel is a constraint; second, contaminants limit the use of recycled steel for certain products, such as reinforcing bars in the construction industry. Nevertheless, every tonne of scrap used for steel production avoids the emission of 1.5 tonnes of carbon dioxide.

  The two most prospective zero-carbon steelmaking technologies are hydrogen-based steelmaking and electrowinning, which involves extracting metals electrolytically from ore, both of which require massive electricity infrastructure.

- **Timber:** Timber is a low-emission biomaterial that is used in both HCI and MUATCI residential housing. Imported timber represents approximately 20 per cent of annual timber supply. The wood product industry supplying the housing industry is structured around two supply chains: lightweight small-dimension timber for trusses, wall frames and floors; and engineered wood products in forms such as cross-laminated timber, glue-laminated timber and laminated veneer lumber.

  Mass timber buildings generally have lower-embodied carbon than concrete buildings, with findings that the use of 17 per cent of timber in construction as an alternative to brick, aluminium, steel and concrete, can reduce GHG emissions by about 20 per cent. By growing trees, which sequester atmospheric CO_2, using structural timber in building construction can act as carbon sinks.

However, timber industry supply chains are resistant to change. First is the difficulty in getting timber to be used: MUACTI industry housing can be built with timber, but this innovation has largely not been adopted. Second, there is considerable scope for reducing waste and increasing the flow of materials through the timber supply chain by greater use of digital technologies such as robotic manufacturing and using linked data sets so timber processors deliver timber of the exact size required for each building design.

For most businesses in the demolition and the housing industry, recycled timber is regarded as 'waste' as opposed to 'resource', as it is perceived as having little to no value. Another challenge with reuse is the potential toxicity of treated timber products.

Barriers to materials recovery and reuse

The recovery and reuse of building materials is also difficult in the absence of regulation and due to other factors such as underpricing of landfill; the absence of markets; poor waste-stream data collection; and designs that do not support material end-of-life recovery.

What this research means for policy makers

The research identifies the following areas for policy development, and outlines preliminary ideas for their further development.

- **Materials data collection and analysis:** the research identified significant gaps in data necessary for understanding the flow of materials used in the construction of housing, materials already in the housing system, construction and disassembly waste, and reuse. The Australian Housing Data Portal established by the CSIRO has made considerable progress in the development of a data system, but better builder reporting is required.
- **Incentivising disassembly and reuse:** policy development should focus on incentivising disassembly for material reuse, as well as encouraging other ways to reduce embodied energy through material selection and the use of local products that require less transportation.
- **Regulation for low carbon:** regulation could expand the scope of sustainability regulation to support housing-system decarbonisation, including supporting reuse, rethink, repurpose or remanufacture.
- **Tilting investment flows:** investment flows can support the decarbonisation of materials manufacturing and stimulate demand for recycled materials. Strategic use of public procurement is a complementary form of support. The use of taxation policy can also guide optimisation of resource use in material life cycles.
- **Building CE capacity:** the idea that carbon is embodied in building materials is a new concept for most people involved in the residential housing system. Expanding the pool of people with a knowledge of CE education, training and skill development is a high priority.
- **Supply-chain decarbonisation planning:** there is a case for establishing housing-industry supply-chain councils to develop supply-chain decarbonisation plans.

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Methodology

This research reviewed the literature; modelled residential housing system material stocks and flows; interviewed key personnel in two residential case studies; and analysed the institutional arrangements underpinning three case-study building materials: concrete, steel and timber.

To cite the AHURI research, please refer to:

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