



# Accelerating the Mainstreaming of Building Manufacture in Australia

A Sustainable Built Environment  
National Research Centre (SBEnc)

## Final Industry Report

Project 1.42 - April 2017



Sustainable  
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## Preface

The Sustainable Built Environment National Research Centre (SBEnc), the successor to Australia's Cooperative Research Centre (CRC) for Construction Innovation, is committed to making a leading contribution to innovation across the Australian built environment industry. We are dedicated to working collaboratively with industry and government to develop and apply practical research outcomes that improve industry practice and enhance our nation's competitiveness. We encourage you to draw on the results of this applied research to deliver tangible outcomes for your operations. By working together, we can transform our industry through enhanced and sustainable business processes, environmental performance and productivity.

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## Synopsis

The transition to offsite construction and manufacture of buildings stands to create a lucrative opportunity for the global building sector.

In particular the shift stands to generate numerous benefits, including:

- Economic benefits (such as substantial reductions in construction times),
- Social benefits (significantly improving workplace occupational health and safety by bringing the majority of building construction indoors), and
- Environmental benefits (through reduced materials wastage, reduced materials transportation, greater inclusion of energy and water efficient elements, and the potential for greater use of recycled materials).

This industry report explores a range of factors that affect the attractiveness of such benefits. It also explores the perceptions of the associated risks. For instance, in order to provide access

to the capital needed to significantly upscale building manufacture, long standing financing structures related to providing progress payments and dealing with completion risk will need to be redesigned.

## Acknowledgments

This research has been developed with funding and support provided by Australia's Sustainable Built Environment National Research Centre (SBEnc) and its partners. Core Members of SBEnc include Aurecon, BGC, Queensland Government, Government of Western Australia, New South Wales Roads and Maritime Services, New South Wales Land and Housing Corporation, Curtin University, Griffith University and Swinburne University of Technology.

The report has been informed by an industry workshop led by the Project Leader and held in collaboration with the EU Centre for Global Affairs at the University of Adelaide and prefabAUS as an official partner event of the European Union's Green Week 2016.

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# Accelerating the Mainstreaming of Building Manufacture in Australia

## Introduction

Building manufacture means applying a manufacturing approach to construction by prefabricating building elements, or entire building pieces, in transportable modules under factory conditions. Typically, this starts by using similar techniques to on-site construction and then shifting to harness the value of the centralised facility and the manufacturing approach.

Building manufacture stands to create lucrative opportunities for the global building sector in the coming decades. With the industry estimated to be worth some US\$90 billion as far back as 2012, the global market is estimated to double this by 2021.<sup>1</sup> The UK Government has stipulated that a fifth of the 165,000 new homes under the Government's Affordable Homes Programme from 2015-2018 would be delivered through housing manufacture.<sup>2</sup>

As part of the Western Australian Government's Affordable Housing Strategy for 2010-2020 it was stated that; *"The Government will 'open doors' to increase the supply and diversity of affordable housing across Western Australia by taking bold, practical measures to generate at least 20,000 additional affordable homes by 2020"*.

A media release 'Modular housing milestones for Perth projects' declared that the WA Affordable Housing Strategy has already been promoting prefabrication through government contracts, with approximately 16,000 manufactured homes built as of 2014.<sup>3</sup>

As the SBEnc Industry Report in 2015 on 'Investigating the Mainstreaming of Building Manufacture in Australia'<sup>4</sup> showed, building manufacture stands to deliver economic (reduced on-site costs, shorter waiting times and lower cost construction), social (improved workplace

safety and conditions), and environmental benefits (reduced materials wastage, reduced materials transportation and greater inclusion of energy and water efficient elements).

Despite these benefits, there is a need to shift industry and consumer perceptions around manufactured buildings being simply temporary, relocatable structures, to seeing them as high quality precision built buildings. This could be through independent quality verification, demonstration buildings, community education programs and qualifying the specific benefits.

The Asia-Pacific is the largest regional market in the world for building manufacture and is set to reach US\$100 billion by 2020.<sup>5</sup> China constituted the largest share of the Asia-Pacific market in 2012 with just over 60 percent, followed by Japan at 22, Australia at 7, and Indonesia at 5 percent.

A number of conditions in Australia make it a prime market for building manufacture, such as: having some of the highest labour costs in the world which favour reducing labour needs through a manufacturing approach; a highly educated workforce that can turn its focus to blending the manufacturing and construction sectors; and relatively high costs of shipping overseas manufactured buildings to Australia.

Despite this, it will still be important for the construction industry in Australia to consider how to strategically take advantage of imported offerings, while strengthening the domestic industry. It is anticipated that without harnessing the manufacturing approach, Australian imports of buildings and components will reach a value of AUD\$30 billion by 2025, which could displace as many as 75,000 jobs nationally.





Around the world, building manufacture has achieved a range of benefits, such as up to 35 percent reductions in costs (as in the Granada Travelodge, London) as well as additional revenue due to construction finishing earlier. For example, the Kingston-upon-Thames Hospital in London was constructed in 19 weeks rather than an 35 weeks using on-site methods, saving an estimated £2m through avoided temporary bed hire.

A residential buildings project in Hackney London generated nearly £60,000 of additional rent revenue through 40 percent time savings while increasing asset value by over £4m through increased quality of the building development.<sup>6</sup>

A leading example is the development of the Little Hero Apartments in Melbourne, Australia that demonstrated the range of savings possible with building manufacture, from time to safety improvements. Built by Hickory for Delphine Holdings, Little Hero Apartments is an eight storey building, comprised of 75 prefabricated modules

which were assembled on site in just 10 days, significantly reducing the interruption to traffic in the CBD of Melbourne which would have been associated with on-site construction methods.

The total project time was nine months, which reduced the construction time by at least six months when compared to an on-site build, fast-tracking the return on investment. The development has a 50 year design life and a 20 year structural warranty on the modules.

The research presented in this report is part of a series of projects by the SBEnrc on building manufacture and picks up on the key theme of financing which was identified by partners as a key part of mainstreaming this innovative approach. This report begins with an overview of the benefits of building manufacture as identified in detail in previous projects. Findings of an industry workshop around the value of key aspects of building manufacture are then presented with an outline of innovative approaches to financing.



**BGC Precast Building Components Factory in Perth, Western Australia**

# Why is Building Manufacture so Promising?

## Opportunities Presented by Building Manufacture

Previous research by the Australian Sustainable Built Environment National Research Centre has shown that building manufacture allows for cost savings, faster delivery times, improved quality and the reduction of a number of negative impacts associated with traditional on-site building construction methods.<sup>7</sup>

### Cost Savings

The greatest cost benefits are achievable in projects where replicable structures, or those with a set number of alternative layouts can be used, such as apartments, housing developments, hotels, student accommodation, classrooms, prisons, hospitals and remote accommodation.

Direct cost savings are achieved through faster construction times along with reductions in construction waste (both from design and 30-40 percent higher reuse of materials), weather damage to materials, damage caused from on-site handling (often in restricted sites with multiple trades) and vandalism and site theft during construction.

The potential for such savings creates the opportunity for greater provision of affordable and social housing, along with the provision of a higher level of quality and non-standard inclusions in residential and commercial buildings.

In particular, it would enable sustainability-related inclusions that could deliver lower operating costs to occupants and owners, to be more economically feasible at the construction stage (especially energy-related inclusions).

### Faster Construction

Building manufacture stands to significantly reduce construction times, along with reducing on-site

delays often caused by waiting for materials delivery, coordinating service providers and subcontractors, and inclement weather.

Reduced construction times can lead to a range of benefits, such as reduced cost of land fees and taxes, equipment hire, site costs, fuel bills and staff costs. Building manufacture can also allow more buildings to be delivered in the same time, as not only is the construction time shorter, it can be carried out at the same time as site preparation (i.e. footings, retaining walls and landscaping).

Hence, as the shift from on-site construction to building manufacture is likely to reduce the labour requirements of individual buildings this will allow a growth in building output to respond to the shortage of affordable housing in Australia.

### Improved Work Place Conditions

The shift to the manufacture of buildings in dedicated factory facilities will provide a number of improvements to workplace conditions, including:

- Protection from weather, sun exposure and other hazards for both workers and materials, along the provision of appropriate lighting levels and air-conditioning 24 hours a day,
- Access to line-side services such as scaffolding hire, materials stores, tool shops and building component manufacture (such as window frames), and access to fixed cutting and fabricating equipment (rather than on-site handheld equipment), and
- Greater ability to provide elevated platforms, mini-cranes, roped harnesses and other safety equipment, due to construction undertaken in a fixed facility with flat floors and overhead beams for fixing safety equipment.



### Improved Quality

Not only does a factory setting allow for regular quality checks, it can also provide access to high quality tools that may not be accessible on-site. The use of the superior tools found in a factory can allow smaller tolerances and improved finishes. When such tolerances are improved in the construction process, advantages in energy efficiency can be seen post-build. For example, internal heating and cooling of the completed building will be more efficient as the elimination of gaps between fittings will prevent unwanted air flow in and out of the building.

The shift to a centralised facility leads to a number of other benefits, such as greater flexibility in supplier choice (as materials can be centrally located rather than being ordered on demand at multiple sites across a city or region), a regular delivery location (with dedicated loading bay facilities reducing transportation costs of supplies), and the assurance that there will be someone to sign for materials.



**BGC Precast Building Components used in Construction in Perth, Western Australia**

## What Value Can be Created through Building Manufacture?

Having established the clear potential for multiple benefits to be realised from building manufacture the Project held an industry workshop. The workshop explored specific areas of value from the perspective of both the buildings sector and the finance sector and was facilitated by the Project Leader, Dr Hargroves.

As a formal partner event to the 'European Union's Green Week 2016', the workshop was held in collaboration with the EU Centre for Global Affairs at the University of Adelaide and PrefabAUS. The workshop was attended by 25 representatives from banks, builders, government agencies and universities. In line with the Green Week theme of 'Investing in the Future', the workshop participants were asked to prioritise the value of specific aspects of the building manufacture approach, with the results below listed from highest value to lowest.

### Reduced Risk of Delays

Faster construction times and a focus on increased quality of construction will reduce the risk that the project will be delayed, especially due to supply issues or weather related delays. This will significantly reduce the potential for liquidated damages and delay claims. Along with project-related impacts, delivering buildings sooner will see mortgage payments, rental payments and occupancy of hotels occur sooner.

A government representative commented that: *"Risk of delay is one of the greatest risks for projects and reducing this risk through a controlled construction environment is an enormous benefit."*

### Reduced Likelihood of Variations

A manufacturing approach shifts the focus from assuming that variations will occur on-site, to getting it right the first time to ensure seamless

assembly on-site. This is achieved by eliminating defects and ensuring consistent quality in design, workmanship and materials, hence avoiding costly variations.

A government client participant reflected that *"Certainty of construction cost and management of variables would mean that costs can be accurately forecast which is an advantage"*.

### Increased Construction Safety

A factory environment for building construction allows improved workplace occupational health and safety, which will reduce the number of workplace accidents and injuries and the associated impacts. Safe Work Australia estimates that some 35 construction employees are seriously injured in Australia each day, causing social impacts and project delays.

A government client participant reflected that this was, *"very important, as all builders are required to have detailed Work, Health and Safety (WHS) plans in place"*.

### More Attractive to Home Buyers

Given faster construction times, homebuyers are likely to be interested in reducing the time they wait for their high quality home to be built. This not only reduces the amount paid by the buyer in renting elsewhere or for alternative accommodation, but also sees them occupying the property sooner and hence paying the mortgage earlier.

### Greater Return on Equity

The faster construction times mean that the return on equity can be increased by completing a project sooner and re-investing the capital in subsequent projects, especially of interest for commercial projects. Given the faster construction





times, the initial capital could be invested into multiple subsequent projects in the same time that it would take to deliver an on-site construction project.

All banking participants rated this of ‘very high’ value and a government client participant reflected that *“This would be highly attractive to developers who could be rolling from one project to the next, taking advantage of markets when they are at their height. Having more product available whilst the market is high and before it cools”*.

### Reduced Materials Costs

A central facility allows for 24 hour receipt of materials in dedicated loading areas with secure storage, which will reduce costs and delays.

Materials can easily be reused as building construction is co-located, which can reduce waste by 30-40 percent, not only reducing wasted materials but also dumping related costs.

A participant from the finance sector reflected that *“This will no doubt filter down to reduced construction cost, which will directly benefit lenders and investors”*.

### Less Theft, Vandalism and Damage of Materials

Given the construction is undertaken in a factory environment, materials and tools can be better protected from weather conditions and from theft (reducing insurance premiums). It is reasonable to assume that as much as \$5,000 of materials is stolen or vandalised for each house constructed.



Participants at the workshop hosted by the Project Team as part of EU Green Week 2016

## Considerations for Building Manufacture and On-site Installation

Before presenting findings from the Project related to accelerating the uptake of building manufacture, to capture such benefits we present Table 1 as a checklist of building manufacture considerations.

The checklist forms part of a performance framework that provides a description of the required characteristics of modular construction from fabrication and transport to installation. The checklist also suggests information that can be used to evaluate these characteristics

The performance framework has four elements:

1. User requirement is a statement of needs as seen by all stakeholders of the modular unit during all phases of construction: fabrication, lifting, transport and installation.

2. Performance description is a qualitative statement of the ability of the modular unit to fulfil the user requirements.
3. Performance parameter is a listing of variables used to quantify the performance description.
4. Evaluation describes the methods used to demonstrate conformance with the performance description.

Findings from this element of the research project have been included in an academic paper presented by Prof. Lam Pham to the '24th Australasian Conference on Mechanics of Structures and Materials' (ACMSM 24) held at Curtin University in December 2016.<sup>8</sup>

**Table 1:** Summary of building manufacture characteristics and associated performance related information

Regulations	
Building Acts	Relevant parts of these documents are parts of user requirements. They also set limitations on weight and size of module for handling and transport.
National Construction Code	
Transport Regulation	
Work Safe Regulation	
Limitations	
Site condition	Specific to local conditions
Lifting condition	Subject to Transport and Worksafe regulations
Transport condition	
Responsibilities and Liabilities	
Building architect/designer	Division of responsibilities/liabilities of the parties must be well described
Erection designer	
Module designer	
Manufacturer	
Other specialists	
Design	
Design for in-service	Building regulation
Design for fabrication, transport and handling	Building, Transport and Worksafe regulations
Manufacturing	
Support conditions for manufacturing	Self-weights are the main action
Actions due to manufacturing	
Temporary strengthening for manufacturing	
Resistance of unit during manufacturing	
Handling of Units	
Support conditions for handling	Unit may have to be turned over
Actions due to handling	
Temporary strengthening for handling	
Resistance of unit during handling	

Lifting	
Support conditions for lifting	Locations of lifting points
Actions due to lifting	Sling angle, impacts
Temporary strengthening for lifting	
Resistance of unit during lifting	Lifting, brace and fixing components
Crane and rigging equipment	
Transport	
Support conditions for transport	
Actions due to transport	Vibration, impact, wind
Temporary strengthening for transport	
Resistance of unit during transport	
Storage	
Support conditions for storage	Include stacking of unit
Actions due to storage	
Temporary strengthening for storage	
Resistance of unit during storage	
Installation	
Support conditions for installation	Including removal of temporary elements
Actions due to installation	Connection between units
Temporary strengthening for installation	
Resistance of unit during installation	
Documentation	
Specifications for components	All components should be specified
Testing records	
Computation records	
Product certification records	For lifting equipment, etc.
Instructions for operators	For all stages: fabrication, lifting, etc.
Structural plans	
Fabrication drawings	
Erection drawings	
Inspection reports	At end of stage: fabrication, transport, installation
Tolerance	
Tolerance on modular unit	To be specified depending on the design and installation procedures
Tolerance on components within an unit	
Inspection	
During manufacturing	For Quality Assurance
Before transport	Check supporting conditions for transport
After transport	On-site check for damage, lifting gears for installation
After installation	On-site check for damage and appropriate installation
Repair	
Factory repair	If required – who by? How?
Site repair	If required – who by? How?
Standards and Specifications	
AS/NZS 1170.0 General principles	These standards are used for evaluation of the actions and resistances of the components
AS/NZS1170.2 Wind actions	
AS2550 Crane, hoists and winches	
Standards Australia Technical Specification 101 – Design of post-installed and cast-in fastenings for use in concrete	For anchors cast in concrete
Other relevant standards e.g. AS4100, AS3600	Vary depending on the materials used in the module
Specifications for lifting gears	
Specification for testing	
AS3850 Prefabricated concrete elements Part 1: General requirements Part 2: Building construction	Most information not concrete specific and can be used for modular construction. Appendix A of Part 1 'Testing of materials and components' has common elements with Standards Australia TS 101



# Accelerating Uptake of Building Manufacture?

## Innovative Construction Phase Funding

In order to provide the access to capital needed to significantly upscale building manufacture, and capture the associated benefits, long standing financing structures in the building sector that are traditionally based on progress payments at different stages of on-site construction need to be redesigned. When asked how much of a risk the issue around progress payments was, nearly 70 percent of participants in the workshop responded 'High' (25%) or 'Very High' (44%) and no respondents indicated the risk was low.

With traditional on-site construction, title and ownership of any improvements transfer to the developer once they are installed on the site and become a fixture. This provides effective security for the lender as they become a priority interest under the Torrens system of registration. In the case that the builder or manufacturer defaults or becomes insolvent, the lender is protected as the majority of what has been paid for was received.

However, in the case of building manufacture it is common that the title of the building elements remains with the builder until the building has been installed on the site. In the USA, the various building elements are not legally considered real estate until final installation. Hence, lenders are hesitant to release payments to developers for something they do not have title or ownership of yet, and is located in an offsite factory facility.

Where appropriate construction financing cannot be secured, the issue of progress payments is currently being overcome through the developers, or even the building manufacturers, providing the funding required for the construction phase, to then allow customers to seek purchasing finance based on the completed building. Although this model allows for the client or owner to secure traditional loan products based on a completed building there are drawbacks that are hindering acceleration of industry growth.



[Visit the SBEnrc YouTube channel for a short film on this project](#)



There are two key financing factors to consider:

1. This model lends itself best to large companies who can afford to provide construction phase financing. For example, attracted by a shortage of hotel rooms in Perth, the Chinese conglomerate CIMC (operating in Australia as CIMC Modular Building Solutions) decided to provide construction phase financing for a number of new hotel developments. The hotels will be manufactured and shipped from China and once installed on-site will attract financing from banks and other lenders.<sup>9</sup>

Smaller operators, however, are forced to mortgage their own assets (or require customers that have appropriate assets to leverage) and, given that the Australian construction market is dominated by smaller operators, this presents a significant challenge to the domestic expansion of building manufacture. Similarly, since 2011 the Victorian-based prefabricated home builder Modscape has provided the finances required for construction, to be reimbursed when the client secures a traditional loan based on the final on-site product.<sup>10</sup>

2. The model means that the risk is carried by the builder or manufacturer until payment is made. Since the purchase finance cannot be secured prior to the construction stage, this leaves the builder open to risks, such as the customer not being able to secure funding after the building is complete, or having the client change their mind before the building is completed. In the USA, manufactured homes are eligible for government-insured mortgage loans offered by the Federal Housing Administration (FHA).

Government-insured loans encourage mortgage lenders to finance manufactured homes by protecting the lender against the risk of default by the buyer. The buyer pays an upfront insurance premium, along with an annual premium based on the declining balance of the loan over a maximum term of 20 years. However, despite such progress, in 2012, according to the Consumer Financial Protection Bureau, approximately 68 percent of all manufactured housing purchase loans in the USA were classified as high-priced mortgage loans.

## Encouraging Funding through Standards and Certification Schemes

Internationally, certification schemes have been formulated to seek to provide assurance to lenders of the quality and durability of manufactured buildings.

Such schemes are aimed to assure lenders that manufactured buildings provide sufficient security for lending and typically do so by either providing construction standards to be met, or by certifying the building manufacturer based on their process and quality of construction.

### Manufactured Home Construction and Safety Standards

The U.S. Department of Housing and Urban Development has developed the 'National Manufactured Home Construction and Safety Standards Act of 1974' for building manufacture. These provide standards for design, construction and installation, to assure quality, durability, safety and affordability. Each section of the home is certified and can be identified by a red certification label on the exterior.

The standards include a dispute resolution component, along with the provision for inspections and record keeping. The standards were designed to supersede state and local laws and apply to manufactured homes produced after June 15, 1976. The Department may inspect factories and retailer lots and review records to enforce the standards. If found to not conform to federal standards, the manufacturer must take appropriate actions.

In Australia, the Modular Construction Codes Board was formed in 2016 to produce a code of best practice for modular construction with the aim *“to share the experience and knowledge advances in module manufacturing and construction for improving safety, productivity and quality in industrial practices”*. Although such efforts provide greater guidance for effective offsite construction, the ultimate goal is to have these materials incorporated into mainstream building standards and codes.

#### Warrenty or Assurance Schemes

In Japan, owners of prefabricated buildings are provided with a standard 20 year warranty which involves after sales service provisions. In the UK, efforts to increase the viability of securing construction financing have focused on providing independent certification of the processes used in offsite construction and building manufacture, in collaboration with the Council of Mortgage Lenders and the UK's four largest mortgage lenders. The 'Build Offsite Property Assurance Scheme' (BOPAS) seeks to provide assurance to lending institutions that buildings constructed offsite are sufficiently energy efficient and durable and will be readily saleable for a minimum of 60 years. The certification process consists of two components:

1. A durability and maintenance assessment that provides an independent technical assessment of housing suitability and encompasses issues

relating to reparability, maintainability and suitability for housing.

2. Accreditation of the design and/or construction processes that is solely risk based; in which designers, manufactures and constructors are evaluated on key performance areas at each stage of project development, from concept design to project completion. Here, the focus is on process control along with management of risks, competency, configuration and procurement.

With BOPAS, an organisation initially undergoes a gap audit in which significant weaknesses are highlighted and adoption of best practice is facilitated. A full implementation audit is then undertaken in which key performance areas are examined against a best practice standard, with accredited organisations undergoing regular visits to ensure proficiency is maintained.

## Panel of Approved Competitors

As well as concerns about access to capital, there is also uncertainty around managing completion risk. Given that the building is in the possession of the manufacturer up until delivery there can be hesitation as to whether it can be easily completed should the manufacture halt operations (may be affected by issues related to intellectual property hindering a shift in manufacturer if required).

When asked how much of a risk the issue around completion risk was, over 80 percent of workshop participants responded 'High' or 'Very High'. At the workshop, participants considered the option to create in effect a 'Panel of Approved Competitors' to provide clients with assurance that in the very unlikely case that a provider is unable to complete a project, a short-list of competitors that are capable of picking up where they leave off will be provided and appropriate collaborations take place to ensure feasibility.





## Conclusion

There are numerous economic, social and environmental benefits associated with building manufacture. New approaches to design, materials and expanding the use of modular techniques can take advantage of faster fabrication times, lower costs, less waste, high quality standards and shorter on-site construction periods. These enhanced outcomes provide benefits to builders, developers, owners and financiers.

In order to capture the potential value of building manufacture, the building sector needs to quickly develop the infrastructure for the construction of buildings in centralised facilities and their transport and assembly on site. This may involve a transition strategy that includes an initial push for the use of panelised onsite construction to build momentum in the manufacture and erection of prefabricated components and modules.

It is particularly important to develop the sector in a manner that takes advantage of the cost effectiveness of sourcing building modules off-shore, otherwise such offerings may compete with, rather than compliment domestic construction. If countries slow to invest in this new sector do not seize the opportunity, offshore interests will certainly continue to bring them to market, which if not part of the sector's overall development, could lead to job losses across the building sector and its supply chain.

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## SBEnc Overview

The Sustainable Built Environment National Research Centre (SBEnc) is the successor to Australia's CRC for Construction Innovation. The Centre is a key research broker between industry, government and research organisations for the built environment industry.

The SBEnc is continuing to build an enduring value-adding national research and development centre in sustainable infrastructure and building with significant support from public and private partners around Australia and internationally.

Benefits from SBEnc activities are realised through national, industry and firm-level competitive advantages; market premiums

through engagement in the collaborative research and development process; and early adoption of Centre outputs. The Centre integrates research across the environmental, social and economic sustainability areas.

Among the SBEnc's objectives is to collaborate across organisational, state and national boundaries to develop a strong and enduring network of built environment research stakeholders and to build value-adding collaborative industry research teams.

This research would not have been possible without the ongoing support of our core industry, government and research partners.

## SBEnc Core Partners



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