

## Wasting energy

How current energy efficiency regulations and the Carbon Pollution Reduction Scheme will increase household energy consumption.

New Australian research identifies the solution.



## **This report explores**

the unintended consequences resulting from the interaction of the Carbon Pollution Reduction Scheme and the Building Code of Australia

## **...and concludes**

that without changes to the BCA the CPRS will make inefficient houses cheaper and more appealing to the market

# The case for better energy efficiency metrics

## Executive Summary

Australia is at a crossroads. Having made a commitment to embark upon the climate change challenge, Australia must now devise a strategy with market instruments and government intervention to reduce emissions whilst promoting economic growth.

The Federal Government's *Carbon Pollution Reduction Scheme* (CPRS) is the centrepiece of Australia's climate change strategy. Energy efficiency is critical to ensuring the CPRS does not dramatically increase the cost of living for Australian households.

Despite discriminatory provisions in the Building Code of Australia, one of the easiest ways to create more energy efficient buildings is using building materials that have *thermal mass*. As demonstrated in this report, materials such as clay bricks and concrete can reduce Australia's heating and cooling energy consumption up to 22%.

Thermal mass improves energy efficiency by up to 22%

This report explores the relationship between the Carbon Pollution Reduction Scheme (CPRS) and regulated energy efficiency requirements in the Building Code of Australia (BCA) for the residential sector. It outlines how these two pieces of legislation will interact to inadvertently increase household energy consumption despite the best intentions of regulators.

Increased household energy consumption is expected because the CPRS only taxes production emissions and makes no allowance for life cycle emission savings. The CPRS will distort the building materials market in favour of lightweight materials because they require less energy to meet current BCA regulations. Under Australia's climate change strategy this is an unintended consequence because houses made with lightweight materials are less energy efficient over the life cycle of the building.

The CPRS distortion is expected to increase heating and cooling energy consumption because the BCA determines energy efficiency by the *total minimum thermal resistance* (commonly known as *R-value*) of a wall. This sole metric is problematic because it measures the benefits provided by insulation (which is critical), but not thermal mass (the other critical component).

Understandably, and with issues such as housing affordability and financial downturns exerting influence, the market will seek out lowest cost materials irrespective of their capacity to improve thermal performance. Depending on the strength of these market forces, the CPRS and BCA could increase residential heating and cooling energy consumption by up to 32% above Federal Treasury estimates by 2050.

These conclusions are drawn from three separate pieces of research:

- Phase 1 of an Australian Research Council funded, eight-year empirical research program in the Priority Research Centre for Energy at the University of Newcastle;
- thermal modelling of 120 different houses in three BCA climatic zones;
- dynamic modelling of the interaction between the CPRS and BCA.

The conclusions reinforce the Phase I recommendation by the University of Newcastle that thermal mass is critical to improving energy efficiency, and that alternative science-based energy efficiency metrics are needed to accurately reflect building performance. Such a metric (or metrics) could off-set the distortion caused by the CPRS and if used in conjunction with life cycle analysis across the building products market, could prevent the energy consumption increase projected in this report. This report recommends that the Federal Government:

- Replace R-value from Deemed-to-Satisfy (DTS) provisions in the Building Code of Australia;
- Complement the CPRS with life cycle analysis across the building products market;
- Fund the Priority Research Centre for Energy at the University of Newcastle to expand Phase II of the research program to develop new, more accurate thermal performance metrics.

# Introduction

The importance of greater energy efficiency in Australian homes is well accepted and supported.

Currently there are at least three major policy debates that have an interest in not just the energy efficiency of Australian homes, but the entire Australian economy. These debates cover housing affordability, climate change and future energy demand and generation.

Australia's energy generation is expected to more than double by 2050<sup>1</sup> to meet growing residential, commercial and industrial consumption, and by 2020 alone, the Federal Government has estimated there will be a 56% increase in residential sector energy consumption over 1990 levels.<sup>2</sup>

It is no surprise then that the Federal Government includes energy efficiency as a key priority in its climate change strategy. The long-term cost to the Government – either directly through energy generation investment, or indirectly through market intervention to support struggling families – is obvious.

This report explores the relationship between the Carbon Pollution Reduction Scheme (CPRS) and regulated energy efficiency requirements in the Building Code of Australia (BCA) for the residential sector. It outlines how these two pieces of legislation will interact to inadvertently increase energy consumption despite the best intentions of regulators.

The report is divided into four sections:

1. The limitations of R-value for determining thermal performance
2. How current energy efficiency regulations actually limit improved energy efficiency
3. How the CPRS will exacerbate the limitations of current energy efficiency regulations
4. The energy efficiency solution.

The report is based on the interim results of an empirical eight-year research program undertaken by the University of Newcastle investigating the actual – rather than simulated – thermal performance of typical housing construction types under Australian climatic conditions.<sup>3</sup> The primary findings of the research are:

- Thermal mass is critical in improving the energy efficiency of a building; and
- There are limitations with the current energy efficiency regulations that rely only on *total minimum thermal resistance* (R-value) to measure the energy efficiency of a building envelope.

**A recommendation from the research is that R-value be replaced in legislation by an alternative energy efficiency metric that combines the benefits of both thermal mass and thermal resistance.<sup>4</sup>**

This report expands the research by the University of Newcastle in two ways:

- Modelling the thermal performance of two house plans in three different BCA climate zones (2, 5 and 6 which covers over 80% of the Australian population), using five different construction types across four different orientations; and
- Dynamic modelling of market forces based on the interaction of current energy efficiency regulations and the CPRS to determine future energy consumption.

Furthermore, this report explores the impact of the CPRS on the building products market which is characterised by horizontal – rather than vertical – competition between many products including (but not limited to) brick, concrete, timber, glass and fibre cement. The CPRS will have a different, disproportionate and inequitable impact on these products and in many instances will not be reflective of the products' contribution to improving energy efficiency or reducing long-term emissions.

Ultimately, this report argues that better energy efficiency metrics provide clear market guidance for the property sector and its stakeholders to tackle the problems of long-term housing affordability, future energy generation and climate change.

1. [http://www.treasury.gov.au/lowpollutionfuture/report/html/o3\\_Chapter3.asp](http://www.treasury.gov.au/lowpollutionfuture/report/html/o3_Chapter3.asp)

2. Department of the Environment, Water, Heritage and the Arts [Energy Use in the Australian Residential Sector 1986 – 2020](#) 2008

3. Sugo, H.O [Thermal Performance Studies at the University of Newcastle](#) 2007

4. Sugo, H.O, Page, A.W, Moghtaderi, B. [Thermal Performance of Buildings – Is R-value the Correct Measure](#) 2008

# The limitations of R-value for determining thermal performance

The Thermal Performance Research was initiated by the brick industry in conjunction with the Australian Research Council at the Priority Research Centre for Energy within the University of Newcastle during 2001.

The aim of the research was to undertake a comprehensive study of the thermal performance of typical housing under Australian climatic conditions. The research includes the construction and monitoring of four full scale housing test modules, each with 105 sensors.

The worst performing building consumed 173% more energy than the best performing building despite having a 16% higher R-value

After six years of data collection, the University of Newcastle has identified that there are significant limitations with the R-value metric to determine building thermal performance.

Typical Australian walling constructions were evaluated for their capacity to maintain a thermal comfort range of 18-24°C in (a) free-floating, and (b) controlled state (artificially heated and cooled) environments.

Under free-floating conditions (Table 1), the best performing building performed 14.4% better than the highest R-value building despite 18% less R-value.

When measured in a controlled state environment (Table 2), R-value was even less effective in determining the thermal performance of a building. The worst performing building consumed 173% more energy than the best performing building despite having a 16% higher R-value.

Furthermore, two buildings with almost identical R-values had nearly a 50% difference in energy consumption when artificial heating and cooling was used.

Effectiveness of R-value under free-floating conditions*	
R-value (m <sup>2</sup> k/w)	% of time in thermal comfort range
0.60	51.6
1.45	61.8
1.67	55.1
1.74	54.0

Table 1: Effectiveness of R-value under free-floating conditions

Effectiveness of R-value under controlled state conditions*			
R-value (m <sup>2</sup> k/w)	Approximate annual energy consumption (MJ)	Energy consumption compared to best performing building <sup>5</sup>	Energy consumption compared to highest R-value building
0.60	11,414	+108.1%	+15.5%
1.45	5,485	N/A	-44.5%
1.67	14,981	+173.1%	+51.6%
1.74	9,882	+80.2%	N/A

Table 2: Effectiveness of R-value under controlled state conditions

\* Analysis conducted in zone 5

5. Note that best performing building does not have the highest R-value

# How current energy efficiency regulations actually limit improved energy efficiency

Energy efficiency for buildings is regulated in Australia by State Governments through the Building Code of Australia.

There are two general methods to comply with the energy efficiency regulations in the BCA: (1) *Deemed-to-Satisfy* (DTS), and (2) *Alternative Solutions*. The DTS method is prescriptive and based on *Total Minimum R-values* for walling systems; the Alternative Solutions method is performance based and compliance is generally demonstrated using second generation thermal modelling software which requires specific skills and knowledge<sup>6</sup> (eg AccuRate, BERS or Energy Plus).

Table 3 is an excerpt from the DTS provisions for external walls in Section Three of the BCA<sup>7</sup>. While there are a number of different ways to meet the minimum requirement, within the market the additional costs (real or perceived) of using methods (b), (c) or (d) (zone 5) or methods (b) or (c) (zone 6) (refer Table 3), is creating a convergence of thinking toward achieving compliance through method (a): "Achieve a minimum Total R-value".

As outlined in the excerpt below, this convergence is reinforced by the BCA because it outlines DTS provisions and places the onus on the builder to demonstrate compliance if these are not used. It is currently estimated that less than 20% of houses pass their BCA requirements using the *Alternative Solutions* method<sup>8</sup>; arguably in the competitive marketplace, the DTS provisions are seen as an easier and cheaper solution.

*"There is no obligation to adopt any particular option contained in Section 3 of the Housing Provisions, if it is preferred to meet the Performance Requirement in some other way. However if one of the options described in Section 3 is not complied with, then the appropriate authority must be satisfied that the Performance Requirements have been met."*<sup>9</sup>

Zone	(a)		Achieve a minimum Total R-value of 1.9
5	(b)	(i)	Achieve a surface density of not less than 220 kg/m <sup>2</sup> ; and
		(ii)	Incorporate insulation with an R-value of not less than 0.5.
	(c)	(i)	Achieve a surface density of not less than 220 kg/m <sup>2</sup> ; and
		(ii)	Be constructed on a flooring system that is in direct contact with the ground, such as a concrete slab-on-ground or the like.
	(d)	(i)	Achieve a surface density of not less than 220 kg/m <sup>2</sup> ; and
		(ii)	Have masonry internal walls.
6	(a)		<b>Achieve a minimum Total R-value of 2.2</b>
	(b)	(i)	Achieve a surface density of not less than 220 kg/m <sup>2</sup> ; and
		(ii)	Incorporate insulation with an R-value of not less than 0.5; and
		(iii)	Be constructed on a flooring system that is in direct contact with the ground, such as a concrete slab-on-ground or the like.
	(c)	(i)	Achieve a surface density of not less than 220 kg/m <sup>2</sup> ; and
		(ii)	Incorporate insulation with an R-value of not less than 1.0.

**Table 3: BCA Minimum Energy Efficiency Requirements**

6. From 1 May 2009 only 2<sup>nd</sup> generation software will be accepted under the BCA

7. Building Code of Australia Volume 2, Section 3.12, Table 3.12.1.3, pp 512-514

8. UDIA WA Presentation by SEDO, October 24 2008

9. Building Code of Australia Volume 2, Section 3.12, Table 3.12.1.3, pp 512-514

Since the introduction of mandatory minimum energy performance requirements in the BCA on 1 January 2003 there has been a small, but noticeable change in the building materials market. According to a recent ABS survey<sup>10</sup>, from 1999 until 2005 there was an 11% increase in the number of brick veneer homes constructed and a decrease in lightweight materials such as timber (12%) and fibre cement (23%).<sup>11</sup>

In contrast, since 2005 there has been an increase in lightweight materials (fibre cement 19% and timber 1%) and a decrease in heavyweight materials (brick veneer 1% and double brick 6%) which are more expensive to construct but have similar R-values.

## In all cases the most energy efficient building contained thermal mass

In spite of these trends, the same ABS report stated that, "High thermal mass materials such as brick and stone are more energy efficient as they take longer to respond to temperature changes, compared to fibro (*sic*) cement and timber." This statement is supported by the comprehensive thermal modelling analysis undertaken for this report to test the outcomes by the University of Newcastle.<sup>12</sup>

Using DTS provisions on two floor plans (Plan A and Plan B), the thermal modelling analysis compares 120 different building constructions to determine if *total minimum R-value* without thermal mass could improve energy efficiency. To ensure the widest sample possible, the modelling considers:

- three different BCA climatic zones (2, 5 & 6),
- four different orientations (north, south, east, west), and
- five different housing constructions
  - insulated brick veneer
  - insulated timber
  - double brick
  - insulated double brick
  - reverse brick veneer.

The construction types chosen above represent over 80% of the current housing stock (detached or semi-detached); brick veneer (44.5%), double brick (24.3%) and timber (13.1%).<sup>13</sup> Insulated double brick and reverse brick veneer were included in the modelling because they both represent emerging trends.

Graph 1 compares the lowest energy consumption for each construction type and orientation. It shows that in all cases the most energy efficient building contained thermal mass and furthermore, insulated double brick outperforms all other types of construction except for Plan B in zone 2 where uninsulated double brick performs 2.7% better than insulated double brick.

### APPROXIMATE ANNUAL HEATING AND COOLING ENERGY CONSUMPTION



Graph 1: Annual energy consumption per construction type & zone

10. ABS *Environmental Issues: Energy Use and Conservation* 4602.0.55.001 March 2008

11. During this period there was also a 5% decline in double brick homes which can arguably be attributed to builder preference toward timber-framed homes. It is assumed part of the 11% increase in brick veneer homes was the shift from double brick to brick veneer.

12. Thermal modelling was conducted by *Energetics* who is Australia's leading energy and greenhouse consultancy, and is on the verification and life cycle assessment panel of the Federal Government's *Greenhouse Friendly Program*

13. ABS *Environmental Issues: Energy Use and Conservation* 4602.0.55.001 March 2008

Graph 2 is a comparison between insulated timber and construction types that include thermal mass. In 21 of the 24 cases thermal mass improves the energy efficiency of a home, and in every case except Plan B in zone 2 (where double brick performs the best), insulated double brick improves energy efficiency by at least 7.1%. The large exception (double brick on Plan B in zone 6) is caused by the cooler winter months where the addition of insulation (eg insulated double brick) will prevent excess heat loss and improve energy efficiency by nearly 17%.

These are best-case scenario figures where thermal mass improves performance by 9.5%. Using worst-case scenario figures thermal mass improves energy efficiency in 23 of the 24 examples used in Graphs 1 and 2, and on

average by 22%. Furthermore, insulated double brick can improve energy efficiency by nearly 48% in zone 6 compared to lightweight materials.

Across the averages of best and worst case scenarios thermal mass improves energy efficiency by more than 13%.

To put these results into perspective, an average improvement of 13% for heating and cooling equates to approximately 151kg of carbon dioxide equivalents per Australian household. **Across Australia in 2008 this is equal to more than 900,000 additional tonnes of greenhouse gases (Table 4). Using the 22% worst-case scenario figures, this is equal to an additional 1.6 million tonnes of greenhouse gases.<sup>14</sup>**

### ENERGY EFFICIENCY IMPROVEMENTS PROVIDED BY THERMAL MASS



Graph 2: Comparison to no thermal mass

	Emissions Intensity factor	Approx. tonnes of Co2 per household from 22% reduction	Number of Households	Approx. tonnes of Co2 saved per state
VIC	1.22	0.18422	1,601,811	295,086
NSW	0.89	0.13439	2,071,900	278,443
QLD	0.91	0.13741	1,267,862	174,217
TAS	0.12	0.01812	170,897	3,097
WA	0.87	0.13137	678,380	89,119
NT	0.69	0.10419	49,571	5,165
SA	0.84	0.12684	546,895	69,368
<b>Australia Total</b>			<b>6,387,316</b>	<b>914,494</b>

Table 4: Impact of Energy Efficiency Savings

14. These calculations assume that 100% of electricity is used for heating and cooling.

# How the CPRS will exacerbate the limitations of current energy efficiency regulations

The CPRS will have a different, disproportionate and inequitable impact on individual products and companies within the building products market.

These impacts will not reflect the products' ability to improve energy efficiency or reduce long-term emissions, but rather be based on the energy used to make each product.

While this approach in general can reduce energy use across the economy, the way the BCA is written necessitates alternative and/or complementary policies for the building products market to ensure the CPRS doesn't inadvertently increase energy consumption by exacerbating the principal-agent barrier.

Already, one of the most striking consequences of the current energy efficiency legislation is the number of new building products in the market that are promoted specifically as having a high R-value. Given the reduced efficiency of homes built without incorporating thermal mass, these new products are examples of innovation driven not by improving energy efficiency, but rather meeting and exceeding legislative requirements at the lowest possible cost.

Graph 3 depicts the principal-agent barrier as it exists today. It compares average external walling costs in 2008 across Australia<sup>15</sup> with average energy consumption across climate zones 2, 5 and 6. At either end of the spectrum there is a considerable difference in price to build compared to price to operate with insulated timber approximately 39% cheaper and up to 22% less efficient than insulated double brick.

Market behaviour dictates that in most examples, builders and developers choose the building products that enable them to sell their product for the greatest profit. Without changes to the BCA the CPRS will make inefficient houses cheaper and more appealing to the market because carbon costs for lightweight materials will be less than heavyweight alternatives.

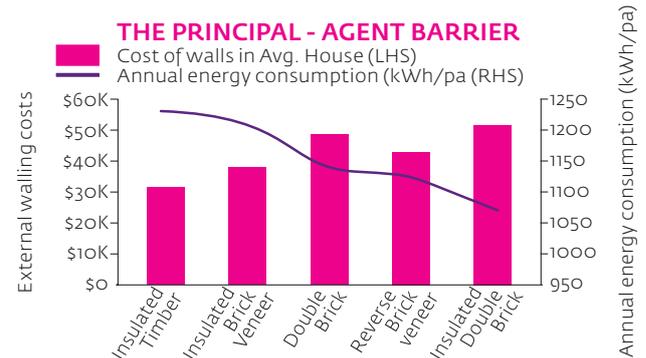
In addition to this, Emissions Intensive Trade Exposed (EITE) payments are also likely to further distort the building products market where manufacturing facilities cater for both domestic and export markets. In these cases, because the trade exposed component of the business cannot be quarantined, it is likely to manifest itself as investment in technologies which the EITE payments help off-set.

Graph 4 demonstrates the increased energy consumption that results from the interaction of the CPRS and BCA. This occurs because the market will change the mix of housing over the next 40 years in favour of cheaper lightweight building materials.

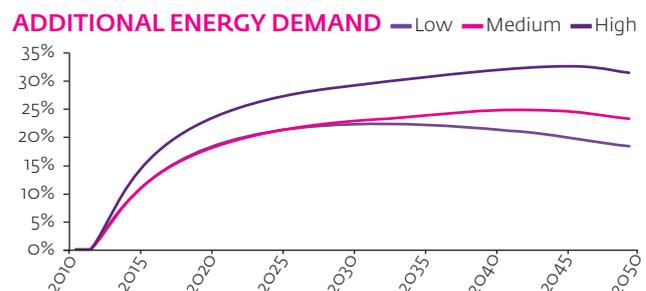
Graph 4 illustrates a sharp rise during the first 5-10 years of the CPRS, after which energy increases flatten out. This is based on the assumption that through Government assistance and technology development both in Australia and internationally, heavy walling industries will reduce their carbon exposure and reduce the price difference between building materials. If this does not occur, the additional energy demand will be higher.

Other differences between the high, medium and low scenarios illustrated in Graph 4 are: the degree of shift toward lightweight housing (based on the up-front impact of the CPRS); how long it takes the brick industry to develop and implement new technologies that reduce kiln emissions; and the introduction and full implementation of 100% clean energy in both new and existing houses.

It should be noted that although 100% clean energy for new and existing homes will address climate change issues, this modelling assumes solar passive principals will also improve energy efficiency as a standard design feature for most houses within 25-35 years. If this does not occur – and the current energy efficiency metrics do not promote solar passive design – while additional carbon dioxide will no longer be a problem, long-term affordability and energy generation issues will still impact the economy.



Graph 3: The principal-agent problem



Graph 4: Additional Energy demand caused by CPRS and BCA interacting

15. Compiled from Rawlinsons Construction Cost Guide 2008

# The energy efficiency solution

Although the energy efficiency benefits of thermal mass are widely acknowledged, legislation has been forced to focus exclusively on R-value because no equivalent, simple metric exists to recognise thermal mass.

Instead of attempting to correct the unintended consequences resulting from the interaction of the CPRS and BCA by using additional compensation or incentives for builders to use thermal mass, the Government should focus on developing alternative energy efficiency metrics to simplify and provide assurance that the emission reduction targets are achieved.

A metric that combines the benefits of thermal mass and thermal resistance in one simple measure (based on climate zone) will minimise long term energy consumption in Australian homes and provide clear market guidance for the development of more energy efficient new homes (and renovations).

Although alternative metrics have been suggested before, the difficulty has been in developing a metric that reflects how thermal mass works (especially when used in conjunction with insulation). To date, mathematical equations and models have struggled to simulate the real world performance of thermal mass, however, because of its nature and extent, the research by the University of Newcastle can potentially overcome this problem.

Since 2003 the University has been measuring the interaction of thermal mass with the Australian climate and has developed one of the most extensive databases in the world that is now capable of overcoming the limitations of previous mathematical models based purely on theory.

At the current stage of the Thermal Performance Research the University of Newcastle is confident that with one-off additional support, the database can be used as a key component in developing appropriate and fully representative alternative energy efficiency metrics.

## Recommendations for a more energy efficient future

To improve the long-term energy efficiency of Australian houses, promote innovation in the building products market, and reduce the time to develop effective new energy efficiency metrics, it is recommended that the Federal Government:

- Replace R-value from Deemed-to-Satisfy (DTS) provisions in the Building Code of Australia;
- Complement the CPRS with life cycle analysis across the building products market;
- Fund the Priority Research Centre for Energy at the University of Newcastle to expand Phase II of the research program to develop new, more accurate thermal performance metrics.

These actions cut to the core of the energy efficiency problem and provide clear market guidance for not only building product manufacturers, but also builders, developers and the entire property sector.

## Facts and Figures

- Australia's energy consumption is expected to more than double by 2050 to meet growing residential, commercial and industrial consumption
- An unintended consequence of the CPRS could be 32% higher energy consumption above Government forecasts. This is possible for two reasons: the BCA energy efficiency regulations favour lightweight building materials, and the CPRS currently makes no allowance for the life cycle emission savings provided by building materials with thermal mass
- Updating energy efficiency indicators could remove up to 1.6 million tonnes of greenhouse gas from the atmosphere
- Thermal mass can reduce household heating and cooling energy consumption by up to 22%
- The Thermal Performance Research is a partnership between the University of Newcastle and the Australian clay brick industry (jointly funded by the Australian Research Council) to learn how building materials can reduce energy consumption
- The Thermal Performance Research is conducted independently by the University of Newcastle and includes actual buildings, each with 105 sensors taking measurements every five minutes
- The major recommendation from the University of Newcastle is the need to update energy efficiency indicators to include thermal mass (eg clay bricks).

## Introducing Think Brick Australia

In Australia the brick industry is worth \$2.6bn to the economy and employs 30,000 people nationwide in the manufacturing and installation of its product.

The peak body representing Australia's leading clay brick and paver manufacturers is Think Brick Australia. Think Brick Australia has been conducting research that contributes to innovation and improvement in building standards and technical training for the construction industry for over fifty years and continues this proud tradition today.

In partnership with the world-ranked University of Newcastle and the Australian Research Council, Think Brick Australia is currently undertaking Australia's most extensive research into the thermal performance of Australian housing. The findings of this research will assist Government and the building and construction industry create more energy efficient buildings.

## University of Newcastle Priority Research Centre for Energy

The University of Newcastle consistently ranks in the top 10 research higher education institutions in Australia. World-class facilities and talent, teamed with forward-thinking local and global corporate partners are a key part of the University's research success.

The University's Priority Research Centres focus resources into our research strengths across a range of areas, including energy. The Priority Research Centre for Energy (PRCfE) focuses on one of the most challenging contemporary issues: the management of Greenhouse Gas Emissions (GHG).

Through its research themes, the PRCfE members are undertaking cutting edge research and development across a range of fields including: Renewable Energy Systems, Energy Efficiency (particularly in buildings and process industries), Energy Conversion & Transportation Fuels, as well as Low Emission Coal Technologies.

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