# Sustainable heritage buildings guide

Improving the environmental performance of heritage buildings in NSW

Department of Climate Change,
Energy, the Environment and Water

NSW GOVERNMENT

# Acknowledgement of Country

The Department of Climate Change, Energy, the Environment and Water acknowledges the Traditional Custodians of the places where we work and live. We recognise the deeply rooted relationships that have stood since time immemorial between Aboriginal people and the lands, waterways, and seas to which they are connected, known as Country. We pay our respects to Aboriginal Elders past and present who foster and sustain these relationships.

We acknowledge that all heritage buildings in New South Wales are built on Aboriginal land. We recognise that the built heritage of this state was largely constructed using materials originating from Country, such as timber, stone, clay, sand and water. This guide highlights the environmental imperative of reusing existing buildings and works to reduce future impacts on Country via the processes of reuse, retrofit and renewal.

# Heritage Council of NSW foreword

Built heritage places in New South Wales have great potential to contribute to the important transition to a net zero future. Sustainable, energy efficient and livable heritage buildings are also critical to maintaining community wellbeing in a changing climate.

In 2023, the Heritage Council of NSW demonstrated its commitment to effective action on climate change by adopting 6 climate change principles. These principles guide heritage policy development, decision-making, adaptation and rapid response to the impacts of climate change on heritage places now and into the future. This guide is one of many initiatives that implement the principles and provide guidance on the sustainable ongoing use and adaptive reuse of heritage buildings.

The reuse of heritage buildings provides us with a unique opportunity to benefit from the embodied energy invested in these structures by previous generations. Heritage buildings also present opportunities to mitigate climate change through energy efficient upgrades and the installation of clean energy systems.

Adding to existing initiatives for good design in heritage practice, the *Sustainable heritage buildings guide* aims to support owners and managers to transition their buildings towards net zero, primarily through the implementation of energy performance strategies that are sensitive to heritage significance.

The Heritage Council of NSW endorses the *Sustainable heritage buildings guide* as a valuable publication for its contribution to climate action and heritage conservation in New South Wales.

I believe this guide represents an important step towards our heritage places being part of the solution for climate change.

**Frank Howarth**
Chair, Heritage Council of NSW

# Contents

# Section A
# Guide overview

# Introducing the *Sustainable heritage buildings guide*

‘Embodied energy in heritage places and the potential contribution of adaptation measures to reduce greenhouse emissions should be considered.’

*Climate change principles*, (Heritage Council of NSW 2023)

## Vision

As New South Wales transitions to a net zero future, heritage buildings hold significant potential to contribute to this evolution. There is a unique opportunity to capitalise on embodied energy already invested in existing buildings and to build resilience to the changing climate through sustainable improvements.

As our climate changes, the needs of owners and occupiers evolve too. This guide strikes a balance between sustaining heritage significance and operating heritage buildings, adapting to futureproof our structures and embed energy and cost efficiencies.

This guide provides policy and practical guidance intended to foster meaningful progress towards more sustainable heritage buildings. Actions to improve the environmental performance of our heritage buildings don’t need to come at the cost of heritage outcomes. This guide outlines a range of interventions, from simple to more complex, that can support and enhance heritage structures while reducing their environmental footprint.

Successful improvements and retrofits to heritage buildings begin with a thorough understanding of a building’s construction method, heritage significance, previous modifications to the building, the environmental context and planned future use. Decisions about retrofit should start with this understanding with heritage conservation acting as a frame through which to improve environmental performance with thoughtful intervention.

This balanced approach will allow New South Wales to maintain the heritage significance of our buildings while optimising environmental performance, reducing energy and emissions, improving resilience and providing cost savings for building owners and managers while improving liveability for occupants and users.

> ‘[Climate] adaptation approaches go hand-in-hand with the broader objective of the NSW Government to reach net zero emissions by 2050.’
>
> *Climate risk ready NSW guide* (DPIE 2020)

## Climate change and energy reduction

The NSW Government is committed to reducing greenhouse gas emissions as part of global action on climate change. Legislation has been enacted to commit to emissions reduction targets. The built environment will play a crucial role in achieving these goals.

Buildings account for half of Australia’s electricity use, and almost a quarter of emissions (Green Building Council Australia and Property Council of Australia 2023). As support increases to ‘maximising the use of existing assets’ (Office of the Chief Scientist & Engineer 2023), the focus is shifting to retrofitting existing buildings to reduce energy use and support emission reduction targets.

> Retrofitting involves changes or upgrades that improve a building’s efficiency or performance without significantly altering its bulk, scale and form.
>
> (Whitehouse et al. 2018)

## Why improve the environmental performance of heritage buildings?

Heritage buildings can make a significant contribution in the effort to transition to net zero emissions and adapt the built environment to a changing climate. Action at a building and precinct level can also prolong the service life of supporting infrastructure, including electricity, water supply and waste services, and delay the need for carbon-intensive network upgrades or large-scale replacement. Some projects involving heritage buildings will also be required to improve environmental performance under legislation.

Improving the environmental performance of heritage buildings reduces energy usage and carbon emissions, provides cost savings to owners and managers through lower energy bills, improves comfort and liveability. These benefits support the ongoing and extended use of heritage buildings.

> Heritage places and precincts can have an enormous impact on the quality and experience of our built environments and the wellbeing of our communities … heritage places provide meaningful links to our past and have a significant role to play in the futures of our cities, towns, and rural environments.
>
> *Design guide for heritage* (GAO and Heritage Council of NSW 2018)

To ensure heritage buildings are maintained and used, it is important that these places have access to a range of performance improvement strategies that allow for well managed change to make them as comfortable, energy-efficient and cost-effective to operate and maintain as possible. Ongoing use ensures the embodied energy of heritage buildings is secured and fully utilised.

## What is heritage significance?

This term is used in New South Wales to encompass the 7 criteria used by state and local government to describe the heritage values of a place. It is used interchangeably with the Burra Charter term 'cultural significance'.

## What is a net zero building?

There is no universal definition of a net zero building. This guide has adopted the World Green Building Council's definition of the whole-life carbon approach that addresses emissions from operational energy use in buildings and the embodied energy from construction and renovations.

Not all heritage buildings will be capable of being retrofitted to achieve net zero emissions while maintaining heritage significance. Striking a balanced outcome of improving performance in all possible areas of energy use and consumption while supporting heritage values is key to the successful adaptation of heritage buildings.

## What is embodied carbon and embodied energy?

The World Green Building Council defines **embodied carbon** as carbon emissions associated with materials and construction processes throughout the whole lifecycle of a building or infrastructure. Embodied carbon can be broken down into 3 parts; upfront carbon, use stage embodied carbon and end-of-life carbon.

Prolonging the longevity and active use of heritage buildings ensures the upfront carbon expended as part of the original construction is not wasted. Retrofitting to improve environmental performance needs to consider use stage embodied carbon for any introduced materials or fabric replacement. Using sustainable materials that are locally sourced and manufactured will help limit the addition of use stage embodied carbon. Maintaining heritage buildings in active use limits the need to consider end-of-life carbon.

See the *Australian Institute of Architects Embodied Carbon Toolkit* for further detail on defining and reducing embodied carbon.

**Embodied energy** is a calculation of all the energy used to produce the materials that make up the building. It includes the energy used in mining, manufacturing and transporting the materials, as well as the services in the economy that support these processes (Australian Government 2023).

> ‘In order to understand the relationship between cultural heritage, climate action and resilience, the idea of heritage must be understood and acted upon in its broadest sense. Physical conservation of selected buildings and artefacts will not realize heritage’s potential to catalyse climate action or promote social cohesion, inclusion or equity, but neither can the promotion of resilience and sustainability be removed from the conservation of these properties.’
>
> (ICOMOS 2019a)

## Who is the guide for?

The guide seeks to support owners and those working with heritage buildings to integrate strategies to improve the environmental performance of heritage buildings. The guide will be useful for:

- owners, asset managers, and occupiers (privately owned and government assets)
- architects, heritage specialists, engineers and planners
- energy assessors
- builders, trades and maintenance staff.

## What buildings does the guide apply to?

Heritage buildings are the focus of the guide. The guide applies to a broad range of building typologies, architectural styles and time periods. Some strategies apply to all building types, while others are best considered for a single or reduced group of building types. The most suitable building types are identified against each strategy.

## Why do heritage buildings need a specific retrofit approach?

A specific retrofit approach for heritage buildings is necessary to balance the management of heritage values with the need to improve their sustainability performance and ensure usability into the future.

The balanced building approach put forward in the guide aligns with the Burra Charter Process for the sequencing of investigations, decisions and actions, while also allowing for ongoing monitoring, review and improvement. Setting out an approach to improving the environmental performance of heritage buildings, as opposed to prescriptive aims, provides a robust framework and the necessary flexibility to support the successful adaptation of a broad range of heritage buildings.

While on the surface some heritage buildings may share similar characteristics, all heritage buildings warrant a site-specific response. The approach recognises the great variety in heritage buildings, including differing levels of baseline information, alterations and additions to fabric and services and changes of use, which when comprehensively understood and synthesised will combine to inform a well-balanced retrofit design – a site-specific retrofit design that reduces energy usage and costs, maintains a healthy building and supports and enhances the heritage value of the building. Not all the environmental performance strategies set out in the guide will be appropriate in all circumstances.

Heritage buildings are irreplaceable and there are key differences from contemporary construction; applying environmental performance strategies requires different understandings, skills and materials to avoid damage or maladaptation.

## How to use the guide

Central to the successful application of the guide is considering the building and its setting as a whole. The guide establishes a place-based approach to improving the environmental performance of heritage buildings in New South Wales and, in doing so, sets out a 'balanced' or 'whole-of-building' approach that begins with a thorough understanding of the context and building as a starting point for retrofit planning. As part of the balanced building approach, you can then work through the hierarchy of performance improvements set out in chapters 1 to 4 to develop a site-specific retrofit plan.

See 'Balanced building approach' and 'Performance improvement hierarchy' sections for more detailed guidance on implementing the guide.

## How does the guide interact with legislation and policy?

The guide builds on an established and interconnected legislative and policy framework. Figure 1 outlines the relationship between the guide and relevant legislation and policies. See 'Relationship to existing policies and guides' for a more detailed outline of how the guide seeks to support various objectives across heritage, environment and climate change.

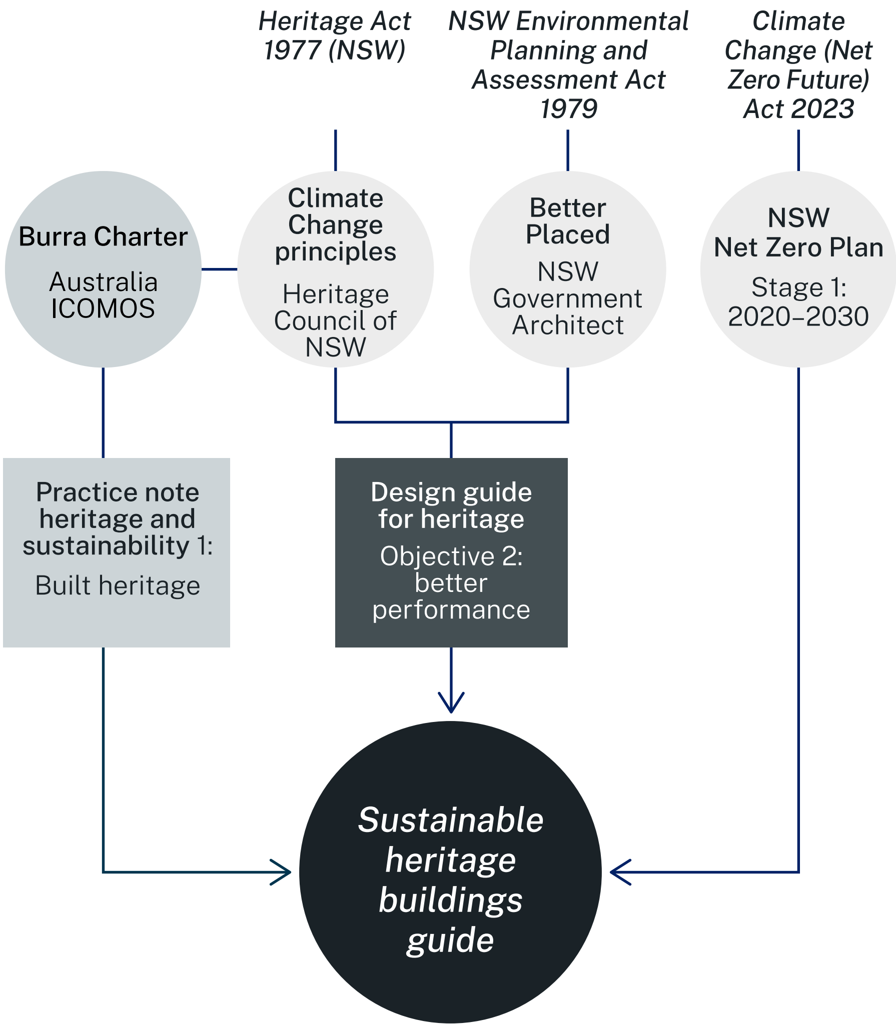
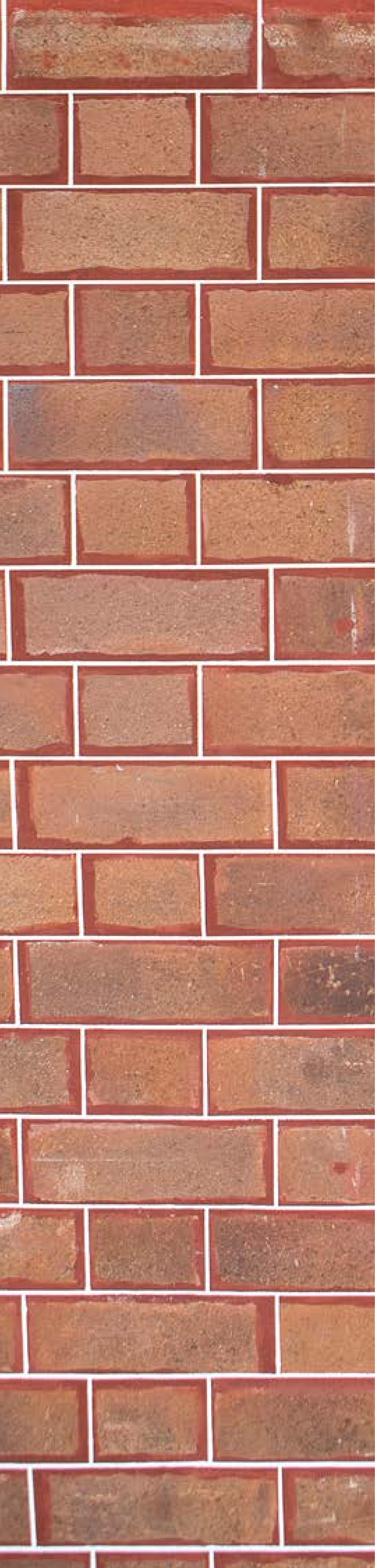



**Figure 1** Relationship between the *Sustainable heritage buildings guide* and existing legislation and guides



# Applying the guide

## Balanced building approach

A 'balanced building', or 'whole-of-building', approach recognises the need to evaluate the building overall before focusing on any one aspect of performance improvement. The approach aims to keep in balance heritage significance, environmental performance and building condition – reducing the risk of maladaptation and costly rectification. Environmental performance improvement strategies have the potential to interact with each other and the building in different ways, so thinking about the building and proposed mix of strategies as a whole is vital.

Committing to a balanced building approach should be the first step of any retrofit project or broader project where environmental performance improvements are being considered. It will underpin the successful implementation of the strategies detailed in Section B of the guide.

This section outlines how to develop, implement and maintain a balanced building approach for a site, as shown in Figure 2. It draws on well-established international precedents and has been refined to apply to the NSW context. It aligns with the Burra Charter Process for the sequencing of investigations, decisions, actions and ongoing monitoring and improvement in a connected process.

Each step provides guidance that can be applied to a broad range of heritage buildings and projects. The guidance can be applied as part of standalone retrofit project or incorporated into broader heritage scoping and investigations for major projects and renovations.

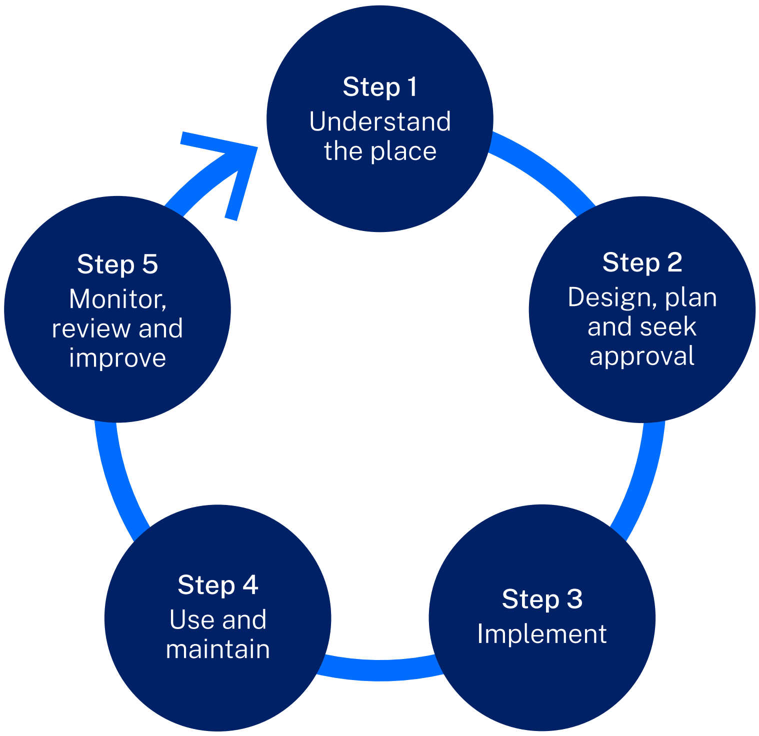



**Figure 2** Balanced building approach

Following the steps set out below along with the strategy specific heritage considerations (set out in the technical guidance chapters) and all other standard heritage considerations will help to ensure a balanced outcome is achieved. This balanced outcome will maintain the heritage significance of the building while maximising environmental performance and resilience, minimising carbon emissions and energy use.

Step 1

## Understand the place

### Key design consideration 1

Analyse the opportunities and constraints of existing structures, environmental systems, and site organisation in terms of sustainability, durability, and adaptability.

*Design g*

Planning successful environmental improvements and retrofits of any building, including heritage buildings, must begin with a thorough understanding of the environmental context, the building and setting, and planned future use. Without a detailed, site-specific understanding of a building, the risk of maladaptation increases and rectification works may result in unnecessary costs, heritage impacts and greater carbon emissions.

### Key actions:

- Understand the macro level environment of the site:
  - location and orientation
  - climate zone/region, noting changing trends and warming temperatures
  - access to sunlight, shade and prevailing winds
- Understand the micro-level setting and building-specific details:
  - setting (urban, landscaped, rural) including specific risks and opportunities arising
  - construction typology (style, form, materials)
  - services
  - alterations and additions
  - maintenance history and condition
  - current and future use
  - energy usage data
  - gather baseline data to evaluate results, e.g. temperature monitoring, temporary or permanent sub-metering
  - known climate impacts on landscape and building

- Understand the heritage values of the place, including landscape:
  - significance grading of elements to inform opportunities for change
  - climate-responsive design elements that are still present or have been removed.

Step 2

## Design, plan and seek approval

### Article 6.2

*'Policy for managing a place must be based on an understanding of its cultural significance.'*

Burra Charter

Identify the specific opportunities and risks faced by the building and its site to inform the design strategy and retrofit plan. Consider all aspects and uses of the building, and project budget to optimise results and mitigate against project risks.

Applying a balanced or whole-of-building approach doesn't mean doing everything outlined in this guide. It refers to understanding how the whole building behaves and might respond to performance improvement strategies, then developing a retrofit design that will deliver a comprehensive plan to improve environmental performance while maintaining heritage significance.

'Many older buildings are inherently energy efficient when they are used in the way they were designed to perform.'

*New uses for heritage places* (Heritage Office 2008)

### Key actions:

- Identify the climate change opportunities and risks to the building and site and the risk of applying performance improvement strategies using the balanced building approach:
  - understand the interaction between building fabric and services
  - potential risks to building fabric
  - potential risks to heritage significance/values
  - potential risks to occupant health
  - potential risks to energy savings, carbon reductions.

- Identify the building-specific opportunities for change related to environmental performance:
  - check the building Conservation Management Plan or equivalent (if one exists for the building) for previously identified opportunities and constraints and original design elements that can be reinstated where previously removed or enhanced where present but not functioning OR
  - using the information gathered in Stage 1, identify opportunities that prioritise minimising the heritage impact for maximum performance improvement.
- Develop the retrofit design (using chapters 1–4 of this guide) considering all the opportunities and risks:
  - testing and modelling may be needed to confirm effectiveness
  - consider the embodied energy of the retrofit process and materials. Select local, low-impact products where these align with heritage requirements
  - performance and alternative solutions to building code compliance from BASIX and the National Construction Code may be needed to manage heritage impacts and the implementation of environmental performance strategies.
- Obtain all necessary heritage and planning approvals prior to undertaking works (as applicable to the site and heritage listing).

Depending on the scale of the retrofit design and extent of change, measuring building performance against the relevant environmental controls for the building type may be required, such as BASIX requirements for residential, and National Construction Code compliance for commercial and public buildings.

Step 3

## Implement

Detailed investigation and design can be let down by poorly executed work. To maximise the environmental performance and minimise cost and carbon payback periods, it is important that work is carried out to a high standard.

### Key actions:

- Ensure all works are carried out in accordance with relevant building standards and product specifications
  - depending on the scale of the project this assurance may need the professional assistance of an architect, engineer or building certifier. It is best to get professional help if you are unsure.
- Use qualified tradespeople with practical experience working on heritage buildings to carry out the work.

Step 4

## Use and maintain

Communicating how a building has been retrofitted to improve its environmental performance and clearly outlining the expectations for user interaction and ongoing maintenance is crucial. The best outcomes will be achieved where the building is actively managed and occupants have the information and tools needed to effectively interact with and maintain the building and systems.

### Key actions:

- Prepare a user manual to outline the upgrades and how to maximise overall benefit. Including diagrams, plans or photographs of the completed works along with required actions can help in communicating expectations and highlighting how buildings require interaction to perform well.
- Ensure new systems and services are added to conservation and maintenance plans and establish processes so general maintenance is continued. For example:
  - check output of solar systems and schedule periodic cleaning to maintain performance
  - for buildings with a building management system, establish regular checks to confirm systems are operating efficiently.

Step 5

## Monitor, review and improve

Once work has been completed it is important to monitor the effects on the building and occupants and adjust strategies where required.

This step will ideally include qualitive and quantitative review, so it is important to have access to comparable baseline data. Gathering and sharing data beyond the project is an important part of supporting the broader retrofit priority for heritage buildings.

### Key actions:

- Gather and compare energy usage data for 12 to 24 months before a project to create a baseline, and after the retrofit is complete. This duration of data allows for variance in weather conditions, building use, etc.
  - For fabric upgrades, monitor building condition closely to ensure there are no unintended consequences such as moisture build-up and rectify immediately if any issues are located.
- Identify opportunities for continual improvement of specific building elements and/or education and behaviour change of users and building managers.
- If rectification or adjustments are required, check to confirm if new heritage and planning approvals are required.

## Article 3.1

The guide hierarchy aligns with the Burra Charter requiring 'a cautious approach of changing as much as necessary but as little as possible'.

Burra Charter

# Performance improvement hierarchy

## Why does the order of improvements matter?

The greatest and most cost-effective benefits can often be found through improving energy efficiency and supporting large-scale renewable energy transition. It would be counterproductive to energy reduction targets to switch to renewable energy without first investigating and implementing measures to reduce overall energy use as part of a balanced building approach.

The guide sets out a hierarchy of improvements based on the balanced building approach, with a chapter dedicated to each level of the hierarchy, shown in Figure 3. It starts with reducing energy demand through easy-to-implement, low-impact improvements and behaviour change, followed by services, then building fabric upgrades, and finally renewable energy. ICOMOS supports this approach of 'formulating a step-by step approach, going from "least impactful" to "most impactful"' (ICOMOS 2019b).

Following the balanced building approach will identify the relevant chapters and performance improvement strategies for a particular heritage building. The strategies outlined in the technical guidance are not intended to be exhaustive and others may warrant consideration in project planning.

1. **Building maintenance and management:** Reduce unnecessary energy and resource use
2. **Building services upgrades:** Mitigate unavoidable energy use
3. **Energy efficiency fabric upgrades:** Improve the performance of building fabric
4. **Renewable energy:** Introduce appropriate renewable energy technologies

**Figure 3** Guide hierarchy to improving the environmental performance of heritage buildings in New South Wales

## Summary assessment key

When deciding on which strategies to pursue for a heritage building, it is important to assess the potential impact on energy savings and heritage significance against value for money. A summary assessment is provided for each strategy, outlining key criteria according to impact on energy savings, heritage, upfront cost and ongoing maintenance. The summary assessment is general across building types and climate zones and the results will vary according to site.

The summary assessments for the guide can be found at the start of each chapter.

**Table 1** Summary assessment key

| Symbol | Interpretation |
|---|---|
| **Energy savings category** | |
| | Minimal impact on energy usage |
| | Reduces energy usage and costs in most cases |
| | Substantial reduction in home energy usage and costs |
| **Heritage impact category*** | |
| | Unlikely to impact heritage significance or positive impact |
| | Some heritage impact |
| | More substantial change to heritage fabric or significance |
| **Upfront costs category** | |
| $ | Low or no cost |
| $ $ | Moderate cost depending on difficulty and scale |
| $ $ $ | Typically higher cost |
| **Maintenance category** | |
| | Low or no ongoing maintenance |
| | Periodic cyclical maintenance required |
| | System or product needs regular maintenance |

**Notes:** The summary assessment does not negate the need for a heritage assessment or approval. Always check with the statutory authority or heritage advisor to determine the correct pathway.

# Section B
# Technical guidance

Photo: Steven Barry/Transport for NSW

Photo: Steven Barry/Transport for NSW

# 1 Building maintenance and management

## Reduce unnecessary energy and resource use

The energy reduction strategies set out in this chapter prioritise low heritage impact and minimal financial investment. These strategies are a necessary first step to improving the environmental performance of heritage buildings. They can be undertaken at any time, independent of a major renovation or project.

Understanding how people interact with buildings is key to realising improved performance. Routine maintenance ensures the longevity of scarce and valuable materials and underpins all the performance improvement strategies that follow in the guide.

The potential energy and cost saving benefits of this first chapter are considerable. The International Energy Agency (IEA) estimates that enhancing energy efficiency can provide one third of the emissions reductions needed to reach net zero emissions by 2050 (IEA 2022). Once efficiencies are realised under this first step, upgrades to building services and fabric can be assessed to move building performance closer to modern buildings.

This chapter covers 6 areas of building maintenance and management. Table 2 outlines the potential impact of each of these across energy savings, heritage impact, upfront costs and maintenance difficulty.

> *The greenest and cheapest energy is the energy we don't use.*
>
> International Energy Agency

**Table 2** Impact summary – building maintenance and management

| | Energy savings | Heritage impact | Upfront costs | Maintenance |
|---|---|---|---|---|
| Improving building interaction | ●●○ | ●○○ | ●○○ | ●○○ |
| General maintenance | ●○○ | ●○○ | ●○○ | ●○○ |
| Improving natural ventilation | ●●○ | ●○○ | ●○○ | ●○○ |
| Improving airtightness | ●●○ | ●○○ | ●○○ | ●○○ |
| Floor and window coverings | ●●○ | ●○○ | ●○○ | ●○○ |
| Landscape | ●○○ | ●○○ | ●○○ | ●●○ |

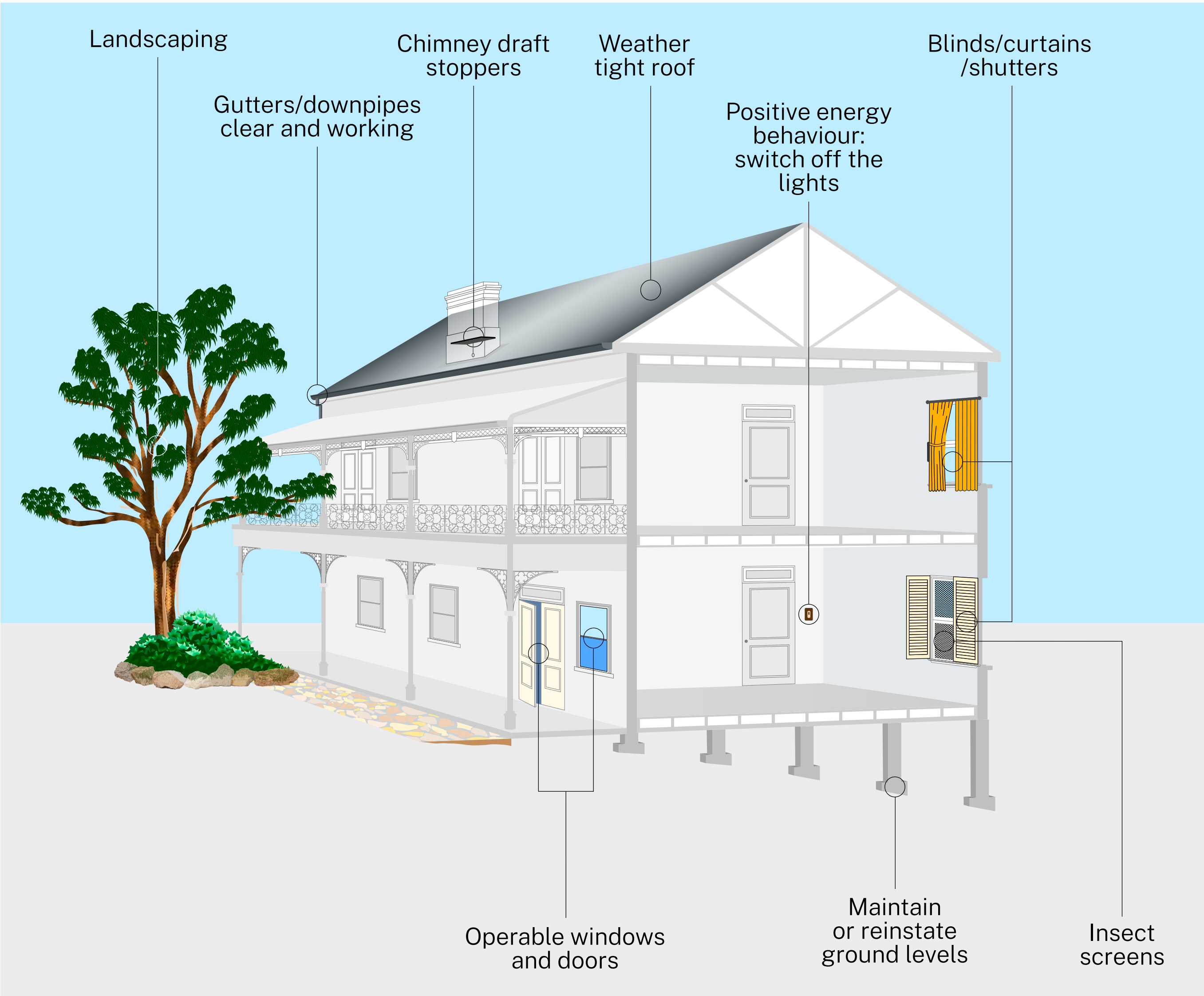



**Figure 4** Diagram illustrating a summary of the energy reduction strategies under building maintenance and management

## Improving how you interact with your building

Simple no-and low-cost improvements to the way owners and occupants interact with their building can make substantial contributions to energy efficiency. This is known as 'positive energy behaviour' and can reduce energy consumption by up to 20% (ARUP et al. 2011). Heritage building occupants generally engage in positive energy behaviours (Wise et al. 2021), but there is always room for improvement. This section will help you identify positive energy behaviour suitable for your heritage building.

### Application

Improving building interaction as a performance improvement strategy is relevant for all building types, time periods and architectural styles. It can also be scaled from small to large buildings and precincts, and households to organisations.

### Environmental principles

How buildings are managed and occupied greatly affects the amount of energy consumed. The opportunities for improvement vary based on the building size and number of people using the building. For households and small buildings, the opportunities can be implemented through changing things like temperature settings and simple behaviour change. For larger buildings with many users, energy use is anonymous and a longer-term change management approach is required.

Below are some key opportunities to increase positive energy behaviour.

**Individuals and small buildings**

- Undertake a home energy assessment or energy audit for small businesses (see useful links below).
- Focus on reducing the major energy uses in the building, which may include:
  - turning off lights when leaving a room
  - turning off appliances at the switch and not leaving them on standby
  - adjusting temperature controls of hot water systems
  - keep air conditioning within an energy-efficient range, e.g. 24–25 °C in summer and 16–18 °C in winter
- active management of the building
  - opening and closing windows to manage the flow of cool and warm air.

**Organisations and large buildings**

- Commission an energy audit to understand how the building is used and main energy uses.
- Update systems to limit heating/cooling and lighting in unused spaces, e.g. sensor lights in storage and hallways.
- Consult with occupants/staff on barriers to positive energy behaviour and develop solutions to address these.
- Create a building-specific low-energy user guide and policy to support all building users.
- Provide energy training to occupants/staff.
- Provide accurate feedback on energy savings to building users and celebrate success.

## Heritage considerations

Physical changes to a building resulting from this energy reduction strategy are unlikely. There is great energy and cost saving potential with little to no heritage impact.

## Measuring benefit

Understanding baseline energy use across a full year is important to measuring the benefit of improved building interaction. Using historical bill data and comparing to a year of data where sustained effort has been committed to behaviour change can be an effective means of quantifying the benefit.

### Useful links

NSW Climate Energy and Action – Home energy assessment

NSW Climate Energy and Action – Energy management courses

Ben Slee (2020) – We don't need sustainable buildings – we need sustainable people

## Related strategies

Window upgrades

## Article 1.5

Maintenance as an energy mitigation strategy supports good heritage practice and the Burra Charter. 'Maintenance means the continuous protective care of a place, and its setting.'

Burra Charter

# General maintenance

General maintenance of heritage buildings is essential in supporting optimal environmental performance and underpins all the strategies that follow in this and later chapters. For example, the benefits of improving natural ventilation can only be realised if windows are well maintained and can be opened and closed. Heritage buildings may also feature scarce and valuable materials that can be difficult and carbon-intensive to replace, such as slate, stone and hardwood timbers. Promoting longevity of those materials through regular maintenance is an important step in reducing material usage and embodied carbon through replacement over time.

## Application

General maintenance as a performance improvement strategy is relevant for all building types, time periods and architectural styles. It can also be scaled from small to large buildings and precincts.

## Environmental principles

A focus on quality maintenance will ensure a building is operating efficiently and underpin improved environmental performance. Key principles focus on excluding unwanted moisture and ensuring operability.

- Ensure the **roof** is weathertight to prevent excess moisture, and that ventilation systems are working.
- Check that **gutters and downpipes** direct water away from the building and do not contribute to any damp issues.
- Ensure all **windows and doors** can open and close as needed to facilitate improved natural ventilation.
- Maintain or reinstate original **ground levels** around a building to ensure build-up doesn't create damp issues which will impact performance. This may mean lowering ground levels if they have been built up over time or introducing air-drains.

## Heritage considerations

Regular inspections and well-planned preventative maintenance are positive actions that will support the condition and presentation of buildings and help to sustain heritage significance.

Most maintenance work to heritage buildings can be undertaken without approval, but it is best to check and confirm what is exempt depending on council area and level of heritage listing. See useful links below.

## Measuring benefit

Maintenance supports sustainability from an environmental, financial and cultural perspective. Energy and cost savings from general maintenance are difficult to measure as the benefit relates to avoiding a worse scenario of extensive repair and replacement. However, regular maintenance identifies faults before they become a major problem, using fewer material resources than a more extensive repair. Dilapidated buildings also don't perform as well, so energy use can be expected to increase without regular maintenance. Investing in maintenance saves money in the long term and helps to retain significant heritage fabric. Well-maintained heritage buildings also provide visual and streetscape amenity and improve liveability in terms of internal air quality.

### Useful links and resources

Heritage NSW – Heritage maintenance guides

Heritage NSW – Preparing a maintenance plan

Ian Evans (1988) – *Caring for old houses*

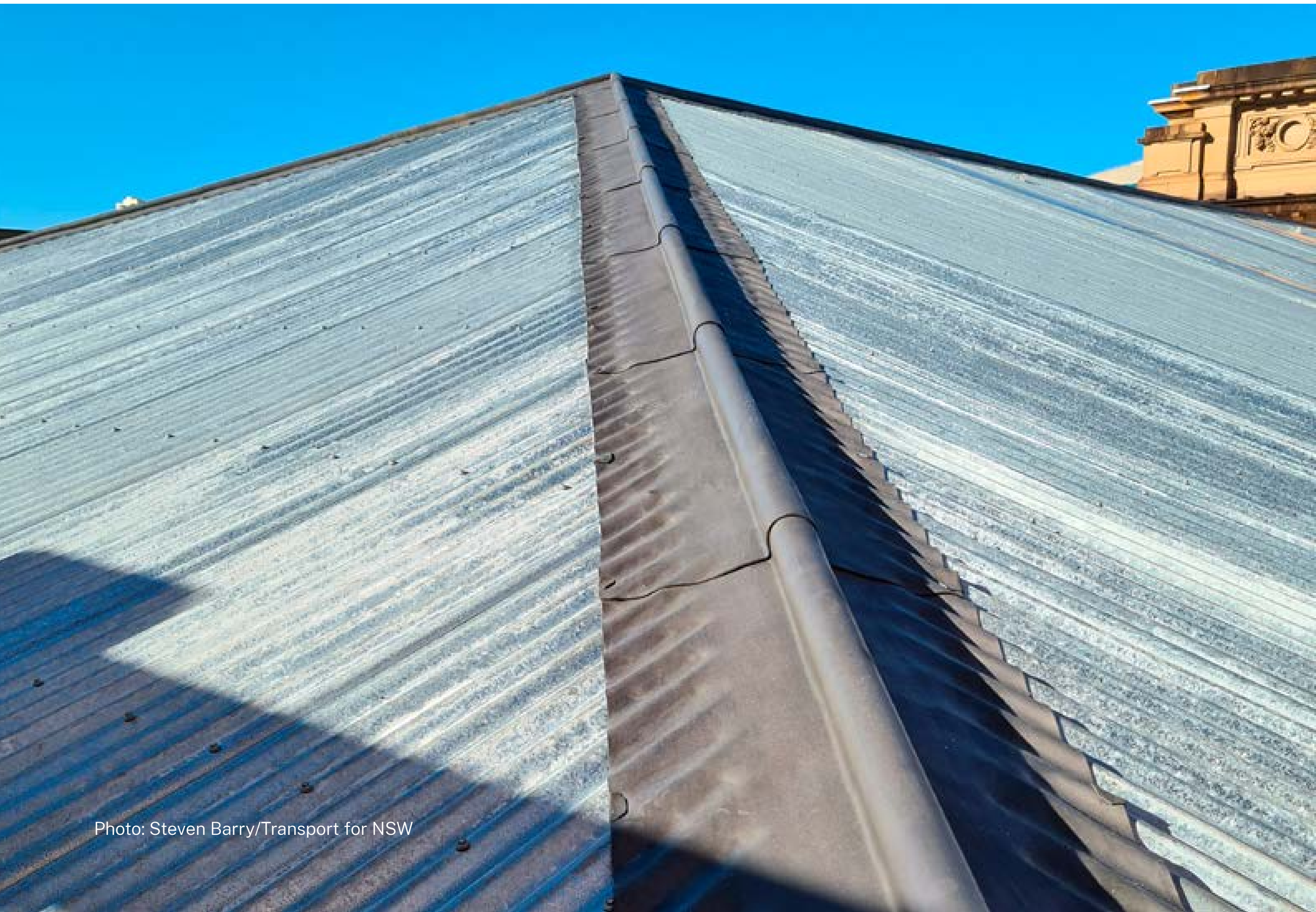


Photo: Steven Barry/Transport for NSW

## Related strategies

Roof ventilation

Window upgrades

## Key design consideration 2

Identify existing effective passive design systems. Rejuvenate them if possible. Consider removing additions that compromise environmental performance.

*Design guide for heritage –* Better performance

# Improving natural ventilation

Most heritage buildings were designed to be naturally ventilated, with air conditioning only becoming widely available in Australia in the last 30 years. Changes to a building over time may have compromised its ability to maintain thermal comfort through natural ventilation.

Extreme temperature events are becoming more common (Naughtin et al. 2022) and people's expectations around thermal comfort have changed. Improving natural ventilation can reduce reliance on mechanical heating and cooling (e.g. air conditioning) and provide energy and cost savings.

## Application

Improving natural ventilation is more relevant during warmer weather and in warm climate areas of New South Wales, but the benefits of fresh air for building occupants is universal. Improving natural ventilation as part of a retrofit plan and a performance improvement strategy can be applied to most building types, time periods and architectural styles.

There will be exceptions where natural ventilation is not desirable for heritage buildings, such as when the building is being used as museum or for collections management, where a controlled environment is required, or where the original design relied on mechanical ventilation.

## Environmental principles

Managing natural ventilation by actively opening and closing windows, doors, louvres and skylights can increase evaporation helping to cool occupants and reduce the demand for mechanical cooling. Providing fresh air and ventilation is also important to maintaining good air quality and managing humidity and mould.

## Heritage considerations

Understanding how a building was intended to be naturally ventilated is key to informing decisions to improve and reduce reliance on mechanical cooling. The complexity of the natural ventilation systems will vary greatly across building types. For residential buildings, the system will be relatively simple and based on windows, doors, verandahs, breezeways, louvred openings and vented ceiling roses. Commercial and public buildings might rely on more complex systems that may have been removed, truncated or obscured by later changes.

To improve natural ventilation, consider the following steps in forming an understanding of the building.

- Check site context for physical evidence of natural ventilation systems.
- Review drawings, including building sections, to understand the system and how it was intended to operate. Identify changes that might have compromised optimal performance, for example changing window types and subdivision of internal spaces.
- Understand the types of systems and regional influences that were being employed at the time of construction to further inform how the building was intended to operate.

Measures to improve natural ventilation with low or positive heritage impact include:

- installing insect screens to allow windows and doors to be used
- establishing a strategy for ventilation during different seasons. For residential or small buildings this might be an informal plan, but for larger-scale buildings ensure the strategy is communicated to building users.

More substantial measures as part of a building renovation or adaptive reuse could include:

- reinstating windows that can open and close where they have been removed or infilled
- analysing the internal building layout and relationship to openings for cross-ventilation
  - if the internal layout is original/early and significant but cross-ventilation improvements are desirable, consider discreet wall vents, ventilated chimney caps and/or roof ventilation
  - if the internal layout is not original and not significant and the changes are compromising the ability to provide cross-ventilation, consider removal. This needs to be considered against the building function and impacts on use
- sensitively incorporating 'smart' solutions for ventilation (automation) for larger buildings and precincts to optimise performance. Systems can be retrofitted to existing openings and hardware to operate windows and louvres according to building use, weather etc.
- developing a hybrid approach that combines natural ventilation and some air conditioning could result in a better balance for heritage buildings that still reduces operating costs and energy use. Air conditioning operation should be optimised in line with the strategies in 'Building services upgrades'

The infants department at the Burke Ward Public School, designed by the NSW Government Architect, incorporates several design elements to naturally ventilate the building and overcome the extreme heat of Broken Hill. The roof with extended verandahs, louvred and slit openings to the gables and vented cupola all contribute to maximising natural ventilation (Photo by David Burdon)

## Measuring benefit

Heating and cooling accounts for up to 40% of energy use in buildings (Arens International 2016). Natural ventilation can play a significant role in reducing energy use and costs associated with the use and maintenance of mechanical systems.

Maximising energy and cost savings from natural ventilation requires regular user interaction or integration with automation technologies. Operation of windows, louvres and doors to provide a high level of thermal comfort requires a basic seasonal understanding of when to close and open the building to maximise results. An understanding of how to utilise wind directions can further improve thermal comfort.

## Improving airtightness

**Related strategies**

Heating and cooling options

Insulation

Window upgrades

Improving airtightness in old and heritage buildings needs to strike a fine balance between maintaining adequate ventilation for the building to breathe and sufficient sealing to reduce the flow of cold and warm air.

Several factors can influence the airtightness of a building, including the fit of windows and doors, flooring, fireplaces and chimneys, introduced services such as plumbing and electrical, and cracks and gaps from building movement.

### Application

Improving airtightness as an energy efficiency strategy is relevant to all buildings. Improving airtightness is most relevant during cooler seasons and in cooler climate areas of New South Wales.

### Environmental principles

Improving airtightness of buildings aims to reduce the amount of heating and cooling energy needed to maintain internal temperature. Older heritage buildings can be draughty, allowing heating and cooling energy to be lost to the outside environment. Draughts can account for up to 15% of heat loss from a building (Energy Heritage 2008).

Draughts can be managed by ensuring that there is no corresponding exit for air movement. For example, if air enters through a loose-fitting window and there is an unsealed fireplace in the same room, air will be drawn through more quickly. Minimising the extent of corresponding entry and exits for air movement is an important strategy in moving towards a more tightly sealed building envelope.

### Heritage considerations

Careful design is needed for airtightness measures in heritage buildings to ensure that the risk of condensation does not increase in the process. It is important to ensure that moisture is allowed to escape and that porous materials like brick and stone are left untreated. If not, it can inadvertently lead to accelerated deterioration of building fabric and unhealthy internal conditions for occupants.

Windows and doors in heritage buildings often fit loosely within their frames and are typically unsealed. Replacing windows and doors for better performing contemporary options is not necessary for many heritage buildings; however, applying seals can significantly improve airtightness and thermal performance. There are various options for seals including frame-integrated or surface-mounted options. Seals should be selected based on the site-specific requirements. Requirements will vary between timber and steel windows.

Fireplaces are a common feature in many heritage buildings and can be a significant source of air leaks. When chimneys are no longer used, they should be sealed to prevent air transfer. There are various readily reversible options for chimney draught stoppers. It is important to remember that the stability and condition of a masonry chimney relies on drying from the heat while it is in use. If no longer used, the condition will need to be checked more regularly. Ventilated chimney caps may be useful in managing moisture.

Later service openings and cracking from building settling can also be a source of air movement. It is important to ensure openings around penetrations are neatly sealed. Cracking should be repaired once the source of the building movement is resolved and footings stabilised.

## Measuring benefit

Owners in cool climate areas can expect substantial energy and cost savings from improving airtightness, reducing reliance on mechanical heating. The effectiveness of airtightness improvements can be measured through airtightness testing before and after installation; however, it is unlikely that this testing would be necessary in most cases, particularly in residential homes and small buildings. Airtightness will also reduce noise.


Photo: James Horan for Museums of History NSW

## Floor and window coverings

**Related strategies**

External shading

Window upgrades

Historically, floor and window coverings have played a critical role in the climate control of buildings. This includes carpet, rugs, curtains, blinds and shutters. Contemporary taste has seen a simplification of soft furnishings, such as removal of carpet or area rugs to expose timber floors. This broad trend extends to heritage buildings.

Original and/or early interior soft furnishings can be significant elements for some heritage buildings. In these cases, conservation should be prioritised. Reinstatement of floor and internal window coverings, or considered replacement during renovation or retrofit projects, can make a meaningful difference to a building's liveability, reduce energy costs, and complement or enhance the heritage features of a building.

### Application

Floor and window coverings can be considered for heritage buildings from all time periods but are best suited to residential homes, including apartments, through to civic and commercial buildings.

### Floor coverings

#### Environmental principles

Carpets and area rugs in natural fibre materials, such as wool, can make important contributions to the energy efficiency of heritage buildings by insulating floors. Heat loss through floors is estimated to be as high as 10 to 20%, so it is particularly relevant for cool and cold climate areas.

#### Heritage considerations

Soft furnishing will have a relatively short service life in comparison to most heritage buildings and will be replaced with changing taste and when they reach end of life. It is important that installations are durable to ensure longevity but also readily reversible if interacting with significant heritage fabric.

For significant floors where improved thermal performance is desired, area rugs offer a solution with minimal change to the heritage building.

Installation requirements vary by flooring substrate and impacts on significant flooring should be considered. For example, when carpeting over an original or significant hardwood floor, where any necessary heritage approvals have been obtained, installation should limit the use of staples and avoid the use of adhesives to maximise reversibility.

#### Measuring benefit

Energy and cost savings of internal floor coverings are quantifiable through airtightness testing before and after installation; however, it is unlikely that this testing would be

High-performance double waffle blinds in the main bedroom at J Tuck House in Gordon have an angle-shaped head custom fitted to the slope of the raked ceiling. These blinds reflect the western sun in summer and provide additional insulation in winter as well as night time privacy. The angle-shaped head allows them to follow the line of the shallow pitched butterfly roof supporting the Modern aesthetic of the home. J Tuck House was designed by Harry Seidler in 1951 and is a local heritage item (Photo: Steven Barry/Transport for NSW)

necessary in most cases. There is anecdotal evidence for the thermal comfort associated with floor coverings, such as wool carpet, improving occupant comfort.

## Window coverings

### Environmental principles

The options for both warm and cool climate areas include blinds, curtains, and shutters. The use of window coverings to control light and heat transfer forms part of improving how you interact with your building.

In cool and cold climate areas, heavy curtains or tight-fitting blinds can help reduce heat loss through exposed glass.

In warm climate areas and on hot days direct sunlight on windows is a key source of heat gain, so tightly fitted window coverings can prevent heat from entering deep into a building.

On hot days keep blinds, curtains and shutters closed during the daytime to keep direct sunlight out and open at night, along with windows, to allow heat to escape from the building. It is important to note that this option only mitigates heat that has already entered through the glass and is less effective in managing heat gain than external shading (see 'Energy efficiency fabric upgrades'). In some cases, new external shading may not be appropriate in a heritage context and internal window coverings will be the most appropriate solution for thermal benefit.

In cool and cold climates, open window coverings on windows receiving direct sun to maximise heat gain in the day and close at night to retain heat.

### Heritage considerations

Fixings, such as screws, to reinstate or install new blinds, curtains and shutters, including associated hardware, should be carefully considered to minimise impact to heritage fabric.

Fabric of lesser heritage significance or material that can be readily repaired is preferred for new fixings locations if existing holes cannot be reused or are insufficient. This helps ensure that new work is reversible.

If considering using internal shutters, be aware of the visual appearance of internal shutters from the exterior of a heritage building. Check the building for evidence of prior use and review drawings or photographs to support reinstatement or explore an alternative design solution that is appropriate to the significance of the building.

The restoration of the Seagull Room as part of the Bondi Pavilion renewal introduced heavy curtains to help control heat and light. The timber windows were restored and made operable allowing natural ventilation, assisted by discreet contemporary ceiling fans (Photo: Brett Boardman for TZG)

### Measuring benefit

Maximising energy and cost savings from internal window coverings requires regular user interaction or integration with automation technologies. These can improve thermal comfort and also provide an opportunity for reconstruction of historic interior furnishings and provide visual amenity for occupants.

## Useful links

Heritage NSW – Repair of tongue and groove floorboards

## Related strategies

Water and waste management

'Green spaces, in the form of public and private gardens, green infrastructure, forests and broad-scale landscapes can transform microclimates and help with adaptation to a changing climate. They contribute to carbon capture and climate mitigation on a global scale. They are vital for human health and wellbeing, contribute to biodiversity and sustain wildlife in urban areas, cool our towns and cities, capture pollutants and alleviate flooding.'

(Australian Garden History Society 2022)

# Landscape

Landscapes can have heritage significance and often mature gardens evolve alongside buildings. Changing attitudes to maintenance and the use of outdoor spaces has seen some significant landscapes undergo decline, simplification or removal.

The benefits of landscape in influencing the microclimate of a building are well documented, from providing shading to directing natural air flow (Hyde 2013). Using landscape as a performance improvement strategy requires long-term vision and planning, but the benefits can be far-reaching. Additional benefits include greater on-site water retention, reducing pressure on stormwater systems, potential to mitigate localised flooding and increasing vegetation to help combat urban heat impacts.

## Application

Sustaining the setting and landscape as a performance improvement strategy is relevant to all buildings. Looking to past applications provides useful insights for the future.

Everglades House and Gardens is an example of a building and purpose designed landscape in the lower Blue Mountains. The property is managed by the National Trust NSW (Photo: National Trust NSW)

## Environmental principles

The environmental principles of landscape interventions centre around controlling the amount of solar access and resulting heat gain, and directing wind flow. Solar access is how much direct sun can reach a building surface.

For warm climate areas in New South Wales, planting deciduous trees on the east-and west-facing aspects can provide shading in summer and sunlight access in winter to moderate heat gain within the building and minimise energy usage for heating and cooling. Research has shown that established trees to the north and west of a building can decrease summer electricity consumption by 5% on average (ReNew 2009).

For cold climate areas in New South Wales, careful consideration is needed on the location and size vegetation, which if not planned and managed may negate the benefits of solar access and heat gain. Regular pruning might be suitable to control size and shape to maintain good solar access. Additional requirements for pruning may apply if the garden and/or landscape is of heritage significance.

Strategic placement of trees and bushes can also be used to great effect to direct cooling breezes through existing openings and promote natural air movement and passive cooling.

## Heritage considerations

Landscaping requires some additional consideration to supplement 'Understanding the context and building' before making decisions.

| **Has the heritage value of the existing landscape been assessed? Is it of heritage significance?** | |
|---|---|
| **If significant** | • Maintain and enhance the existing landscape.<br>• Identify further landscape opportunities to improve the energy performance of the building that complement the significance of the landscape and building. |
| **If not significant, or if landscaping is no longer present** | • Check site context for evidence and review drawings, photographs and aerial imagery.<br>• Design a landscape scheme that complements the significance of the building and maximises energy performance opportunities. |

Further practical considerations when planning landscaping around heritage buildings include:

- water management around the base of buildings to maintain footing stability and avoid rising/penetrating damp from watering practices (see 'Salt attack and rising damp' under Useful links for detailed set-out and ground-level recommendations for gardens in relation to historic buildings)
- species selection to ensure compatibility with the site context, focused on the following criteria:
  - complementary to heritage significance, and ideally low water needs
  - root behaviour to avoid structural impact to building footings
  - consideration of full-grown tree size to ensure introduced landscape does not block key or significant views in the long term.

## Measuring benefit

Direct energy and cost savings from landscaping interventions are difficult to measure as it takes time for new landscaping to reach full potential; however, the benefits will be tangible through actively managing heat gain for both heating and cooling.

Landscaping will also provide visual amenity, support wellness through localised air quality improvements and support local biodiversity.

### Useful links

Heritage Council of NSW – Salt attack and rising damp: A guide to salt damp in historic and older buildings

Australian Garden History Society – Climate Adaptation

Eryldene Historic House and Garden – Environmental and Sustainability Action Plan

Australian Institute of Landscape Architects – Climate Positive Design

## Key actions checklist – building maintenance and management

| Strategies | Key actions |
|---|---|
| Improving how you interact with your building | ☐ Review the 'key opportunities' table and identify actions specific to your situation<br>☐ Collate baseline energy usage data for comparison<br>☐ Identify and undertake energy efficiency training relevant to your situation. |
| General maintenance | ☐ Develop a site-specific maintenance plan<br>☐ Implement the maintenance plan to realise optimum building performance and support energy efficiency<br>☐ Seek out specialist heritage trades for more complex maintenance tasks. |
| Improving natural ventilation | ☐ Decide if improving natural ventilation is desirable for your building<br>☐ Research the way your building was intended to be naturally ventilated and what is required to reinstate the intended operation<br>☐ Seek advice from a heritage specialist if these changes require physical changes, e.g.:<br>– reinstating window and door openings<br>– wiring and connections for smart integration<br>☐ Seek heritage and/or development approval and implement changes identified. |
| Improving airtightness | ☐ Decide if improving airtightness is suitable for your heritage building (for example, additional sealing of a fragile stone building might not be suitable)<br>☐ Identify and install low-impact seals suited to your heritage building and application. Seek out experienced tradespeople for more complex installations<br>☐ Use seals that are easily reversible and visually discreet<br>☐ Test airtightness before installation of any draught improvement measures to help to identify the major sources of air leaks so they can be targeted. |
| Floor and internal window coverings | ☐ Check heritage listing and site-specific heritage documentation to determine if floor and internal window coverings are of heritage significance. Seek advice from a heritage specialist if unsure<br>☐ Identify opportunities for where floor and window coverings can be upgraded for environmental performance when the current fittings reach end of life<br>☐ Install and operate new fittings consistent with the established criteria. |
| Landscape | ☐ Check heritage listing and site-specific heritage documentation to determine if the landscape is of heritage significance. Seek advice from a heritage specialist if unsure<br>☐ Research the landscape specific to your building or building style and develop a complementary scheme according to the key criteria set out in the section<br>☐ Develop and implement landscape improvement plans consistent with the established criteria. |

Case study

# Ultimo TAFE, Building C

## Quick facts

**Project type:**
Education/Commercial

**Client:**
TAFE NSW

Heritage listing:
Local heritage list

TAFE S170 Heritage and Conservation Register

**Project team:**
Project lead – NSW Public Works

Architecture – Purcell Architects

Heritage Consultant – Public

Works Advisory
Structural

**Location:**
21 Mary Ann Steet Ultimo

**Year:**
2023

‘The old roof was in a bad state, a patchwork of repairs over [the] last few decades. It is so rewarding to see the 130-year slate being replaced and ready for the next 100 years!’

Graeme Erskine, Senior Heritage Project Manager

NSW Public Works led the conservation of the former Technological Museum (Building C) at Ultimo TAFE to ensure long-term maintenance of the building.

Over a 5-year period NSW Public Works and TAFE NSW worked to scope and deliver a meticulous conservation program for the exterior of the building. The conservation program started with a whole-building condition assessment to understand the challenges and inform long-term solutions.

The completed works focus on maintenance and selective repair, safeguarding the exceptionally significant building and fabric to support ongoing use of the space for exhibitions, conferences, office accommodation and storage.

### Keeping the water out

The new slate roof with reinstated terracotta ridge tiles and restored dormer windows. (Photo: Michael Nicholson for NSW Public Works)

Stage 1 was initiated in response to ongoing water leaks in the roof and included:

- replacement of the Vermont Green slate roofing, which had reached the end of its functional life
- salvage and reinstatement of the terracotta ridge tiles to conserve original fabric and limit the amount of new material required on the project, minimising additional embodied carbon
- restoration of the curved dormer windows
- renewed roof insulation to improve thermal performance.

## Taking care of the facade

The striking facade of the building comprises elaborate polychrome brickwork, terracotta and sandstone, ornate timber windows and doors and intricate stone carvings (Photo: Sebastian Mrugalski for NSW Public Works)

Stage 2 focused on the facade of the building and included:

- repointing brickwork and sandstone, facade cleaning and desalination
- replacement of deteriorated sandstone elements
- repairs to timber frames and broken glazing in windows and doors, and filling the gap between brick reveals and windows.

These actions all contribute to maintaining a weathertight exterior and support optimal building performance. The approach to window and door repairs conserved significant fabric, with improvement expected to airtightness and the efficiency of mechanical cooling and heating.

### Heritage significance and history

The former Technological Museum building is a rare surviving example of a purpose-built nineteenth-century technological museum building. It was the first building of its type in Australia, and one of the first in the world.

It was built in 1892 as part of the new Sydney Technical College complex, designed by the Department of Public Instruction's architect, W.E. Kemp. The Technological Museum operated in Building C until the exhibits were transferred to the converted powerhouse and tram depot complex, known as the Powerhouse Museum. The Powerhouse Museum administration remained in Building C until 1995. The building is now managed and actively used by TAFE NSW.

Photo: Steven Barry/Transport for NSW

# 2 Building services upgrades

### Key design consideration 3

Sensitively integrate new environmental initiatives where appropriate to improve environmental amenity and sustainability performance.

*Design guide for heritage –* Better performance

## Mitigate unavoidable energy use

The building services upgrades set out in this chapter prioritise low heritage impact through discreet installation and moderate financial investment. They can be undertaken at any time independent of a major renovation or project, but some efficiencies are more likely to be realised if grouped with a broader program of work.

Modern services have a short service life compared to heritage buildings and must be installed to have minimal impact to building fabric, through visually discreet design to enable removal and ongoing replacement as technology evolves.

This chapter also recognises the importance of electrical equipment as part of a holistic assessment of building services and progress to full electrification. Ensuring appliance selection prioritises low energy and low heat emissions are important factors to realising the full benefits of a retrofitting strategy. There are incentives for NSW businesses to upgrade existing appliances and equipment to promote energy efficiency funded by the NSW Government as part of the Energy Savings Scheme.

This chapter covers 5 areas of building services. Table 3 outlines the potential impact of each of these across energy savings, heritage impact, upfront costs and maintenance difficulty.

> ‘Updating or altering building services plant can potentially yield large carbon reductions with no heritage impact.’
>
> (ARUP et al. 2011)

**Table 3** Impact summary – building services upgrades

| | Energy savings | Heritage impact | Upfront costs | Maintenance |
|---|---|---|---|---|
| Lighting | 2/3 | 1/3 | $ $ (2/3) | 1/3 |
| Heating and cooling options | 2/3 | 3/3 | $ $ (2/3) | 2/3 |
| Hot water system upgrades | 2/3 | 1/3 | $ $ (2/3) | 1/3 |
| Water and waste management | 1/3 | 1/3 | $ $ (2/3) | 2/3 |
| Smart technologies | 2/3 | 2/3 | $ $ (2/3) | 1/3 |

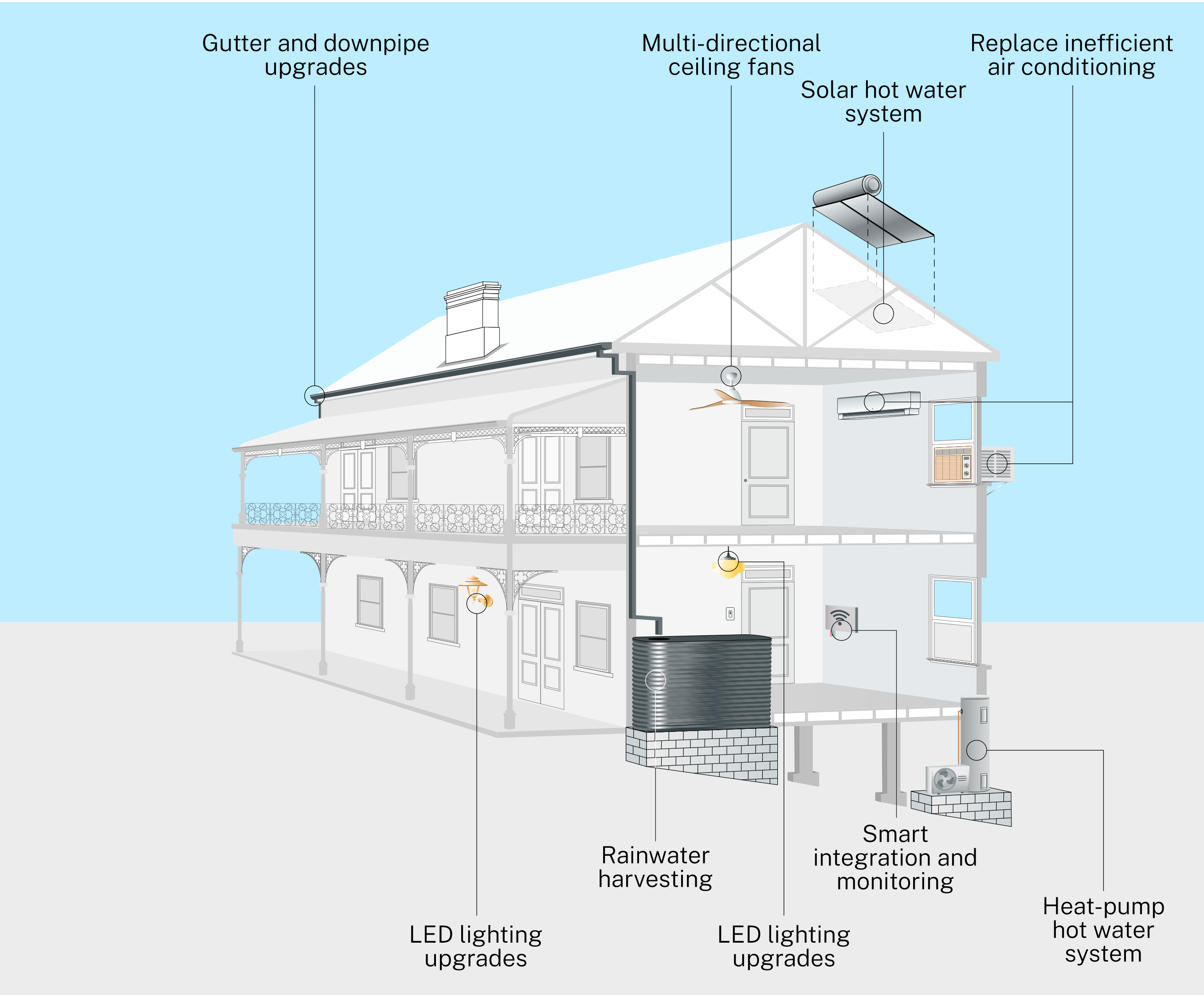



**Figure 5** Diagram illustrating a summary of the energy reduction strategies under building services upgrades

# Lighting

**Related strategies**

Smart technologies

Natural lighting

## Article 21

Adaptation may involve the introduction of new services. The Burra Charter notes that adaptation is only acceptable where the adaptation has minimal impact to cultural significance, minimal change to significant fabric, and alternatives have been considered.

Burra Charter

'Energy-efficient lighting uses less energy without compromising on brightness and quality.'

(NSW Office of Environment and Heritage 2016)

Lighting can account for a significant proportion of a building's energy use, so it is an important building service to consider in any retrofit strategy. For some businesses, lighting can account for up to 50% of energy use (OEH 2015).

The technological development of electric lighting has been rapid over the past 150 years. This consistent evolution is often evident in changing light fixtures and the historical records of heritage buildings.

Retrofitting lighting fixtures is not a new concept. In the conversion from gas lighting to electric, new wiring was often threaded through the hollow tubing of the gas fitting to power the lighting. In the same way, lamps and fixtures can now be upgraded to more energy-efficient light sources.

## Application

Energy-efficient lighting as a performance improvement strategy relevant to all buildings.

## Environmental principles

Improving lighting efficiency is closely linked to 'Improving how you interact with your building' and 'Natural lighting'. The priority for achieving lighting efficiency is understanding lighting requirements and reducing unnecessary or wasted usage. For example, infrequently used spaces may be lit all day, or natural lighting may not be used to supplement the required lighting levels. Infrequent use can be addressed through discreet motion sensors. 'Daylight linking' of lighting can be achieved with smart control systems. (See 'Smart technologies' in this chapter for further detail on zoning and lighting controls.)

Once opportunities for using natural lighting and zoning are integrated, the next step is to identify lights that could be upgraded to more energy-efficient globes. The use of LED lighting is widespread, but it is important to select lighting options suited to the building application.

## Heritage considerations

Building elements such as skylights, roof lanterns, clerestory windows and pavement lights were common design elements for many heritage buildings and have often been removed or reduced. Reducing energy usage from lighting should start with identifying opportunities to reinstate natural lighting where it was part of the original design.

### Actions

- Check site context, original drawings and aerial imagery for evidence of natural lighting elements that have been removed.
- Include policies in conservation planning documents to promote reinstatement of natural lighting elements or include reinstatement into project scopes.

Lighting requires some additional consideration to supplement 'Understanding the context and building' before making decisions.

| Has the heritage value of the existing lighting been assessed? Is it of heritage significance? | |
|---|---|
| If significant | • Maintain and seek to improve the efficiency of the existing lights.<br>• Confirm whether the existing light fixture can be retrofitted with a low-energy light source such as LED without changing the exterior appearance.<br>• Confirm that the required light quality, such as colour temperature, can be achieved with low-energy lighting. |
| If not significant, or if original lighting is no longer present | • Check site context for evidence and review drawings and photographs for original/early lighting fixtures.<br>• Where evidence of original/early lighting fixtures can be obtained, seek to reproduce feature lighting as an interpretation opportunity while incorporating low-energy lighting. |

The redevelopment of the Walsh Bay Arts Precinct as a public arts and cultural hub in Sydney reused the existing enamelled pendant lights which were sensitively retrofitted with LED fixtures (Photo: Brett Boardman for TZG)

Further practical considerations when planning lighting upgrades to heritage buildings include:

- review existing lux levels (lux is the unit of measurement for illuminance) and adjust the number and intensity of the lights to suit the activity, optimising the amount of energy used. Original or early light fixtures should not be removed to achieve this; however, it may be possible to introduce alternative circuits for more control over lighting levels
- sensitively incorporating 'smart' solutions for motion sensors and daylight linking to optimise lighting performance. Systems can be retrofitted to existing lighting and hardware to control lighting levels according to building use and levels of natural light available
- decorative or significant ceilings and ceiling features should be treated carefully. For example, the placement of new lighting where required should avoid decorative ceiling elements
- new cabling containment for lighting, circuits and smart integration should be neat and discreet.

## Measuring benefit

Most buildings will have had some level of energy-efficient lighting incorporated as low-energy lights and globes have become the default option. However, undertaking a holistic review to improving lighting efficiency is likely to result in cost savings and reduced energy use.

> 'LED lights use only 15% of the electricity of standard incandescent bulbs for the same light output, while lasting 12.5 times longer.' (Whitehouse et al. 2018)

The longer life expectancy of contemporary lighting options will also reduce the maintenance cycle and reduce further costs.

Reviewing lighting can also provide improved amenity and support productivity and worker safety.

### Useful links

Australian Government, DCCEEW, Energy.gov.au – Lighting

International Energy Agency – LED guideline for the promotion of lighting retrofitting

## Related strategies

Improving natural ventilation

Improving airtightness

Floor and window coverings

## Key design consideration 5

Maximise passive heating and cooling and waste and water management in the design of any new work or additions.

Design guide for heritage – Better performance

## Heating and cooling options

Most heritage buildings were designed before the widespread availability of mechanical heating or cooling. In historic buildings, and some Modern buildings, there was a focus on building materials, orientation and ventilation to maintain thermal comfort. This can pose challenges when replacing or installing new mechanical heating and cooling systems in heritage buildings as they were not designed for the high level of reticulated services required by Modern systems (e.g. pipework, electrical services, plant and equipment). Poorly considered installations can result in damage to significant heritage fabric and unsightly visual outcomes.

> 'Heating and cooling together use the largest amount of energy in the average Australian home, accounting for around 40% of household energy use.'
> (Australian Government 2014)

'Global extreme temperature events are reaching unprecedented levels' (Naughtin et al. 2022). Heating and cooling options will be needed to supplement other environmental passive measures to insure against extreme weather and maintain livable and workable interior conditions.

Determining the need for, and improving the efficiency of, heating and cooling options is closely linked to several performance improvement strategies in chapters 1 and 3.

Given the high percentage of energy expenditure on heating and cooling, the first priority is to reduce the frequency with which it is needed and the second is to ensure efficient operation when it is in use. For example, a building in a warm climate with appropriate levels of insulation, external shading and optimised natural ventilation should require mechanical cooling less often to manage extremes of heat. Incorporating window and door seals and tightly fitted window coverings will help ensure efficient operating of mechanical cooling systems when they are in use. Finally, adding mechanical heating and cooling systems to site-specific maintenance plans will help maximise efficient operation. The reverse is equally true for cold climate areas of New South Wales.

There are a few notable exceptions where heritage buildings have led innovation in this area. For example, at the Sydney Opera House, 'installations such as the sea water heat exchange system for the mechanical services and the chilled ceiling in the Drama Theatre were recent innovations at the time and are still considered leading-edge and energy-efficient' (Croker 2017).

Similar systems have also been incorporated into contemporary projects featuring heritage buildings, such as the Sydney Modern project at the Art Gallery of NSW. This project integrates a seawater heat exchange for the building cooling system. Proximity to sea water and project scale will determine the viability of integrating systems such as these.

The transformation of this Federation house by Architect George incorporates a contemporary ceiling fan to the living space to assist with natural ventilation. The fan and pendant light carefully avoid the decorative roped plasterwork. The fan and lighting combine with high-quality interior finishes, including area rugs and curtains that also contribute to improving the environmental performance of the space and liveability (Photo: Pablo Veiga for Architect George)

## Application

Heating and cooling options as a performance improvement strategy are relevant to all buildings.

## Multidirectional ceiling fans

### Environmental principles

In conjunction with 'Improving natural ventilation', multidirectional ceilings fans can be an energy-efficient and cost-effective strategy for increasing air movement and improving thermal comfort.

Ceiling fans are generally energy-efficient and can be used in a hybrid system alongside air conditioning, allowing the air conditioning to be set at a higher temperature in line with recommended settings outlined in 'Improving how you interact with your building'.

Multidirectional fans can spin clockwise or anticlockwise to warm spaces in winter and cool occupants in summer. The clockwise movement forces hot air down, helping the room feel warmer and reducing the reliance on the stack effect for heating.

The application of ceiling fans can be scaled for most types of buildings from residential homes and educational spaces to commercial and industrial buildings.

### Heritage considerations

In smaller spaces and residential settings, a ceiling fan would often replace a light and need to be in the centre of a room for effective operation. The following practical heritage considerations apply:

- if the interior is significant, it may not be appropriate to install ceiling fans. Determine if a ceiling fan is visually appropriate and supports the heritage significance of the building. In addition:
  - if there are significant light fixtures present, they should be avoided and alternative strategies sought
  - if there are significant and/or decorative ceiling elements, they should be assessed to determine if a ceiling fan can be installed without damaging the ceiling through installation or operation (vibration)
- options for integrated lighting with retractable fan blades may be appropriate in some instances and lessens the visual impact when not in use.

In larger-scale commercial, educational and industrial settings, the following practical heritage considerations apply:

- placement and set-out should be consistent and relate to building design
- choose a ceiling fan design and scale appropriate to the building style, typology and size

- services reticulation should be discreet and neat, which includes:
  - avoiding physical and visual impacts to heritage fabric and elements
  - using spare capacity and designing to allow easy access to accommodate future change
  - work should be reversible and avoid cumulative impacts through incremental bad practice.

### Measuring benefit

Ceiling fans do not lower the temperature of a room, but the increased air movement can improve a room's thermal comfort by up to 3 °C on warm days (Whitehouse et al. 2018). The energy-efficient operation of ceiling fans for aiding in both cooling and heating can be a cost-effective option allied with other strategies outlined in this guide, specifically Chapter 1 where a building is not undergoing a major renovation.

## Air conditioning

### Environmental principles

The scale and complexity of air conditioning systems in heritage buildings will vary from wall-mounted split systems and ducted air conditioning through to large commercial applications.

Air conditioning provides temperature-stable, dry and filtered air and is increasingly seen as a necessity for climate management. This expectation needs to be challenged in the face of the climate emergency. Originally developed to filter out noise and pollutants, air conditioning has led to a global expectation of universal internal building conditions without consideration or integration with nature and weather or external air quality.

As part of the balanced building approach and the implementation of other performance improvement strategies, the need for and use of air conditioning should be reconsidered along with the size of the system. Building modifications to allow natural ventilation and challenging standard practice of building management that sees the consistent use of air conditioning needs to be challenged so that air conditioning is only used to manage occupant comfort in extreme weather.

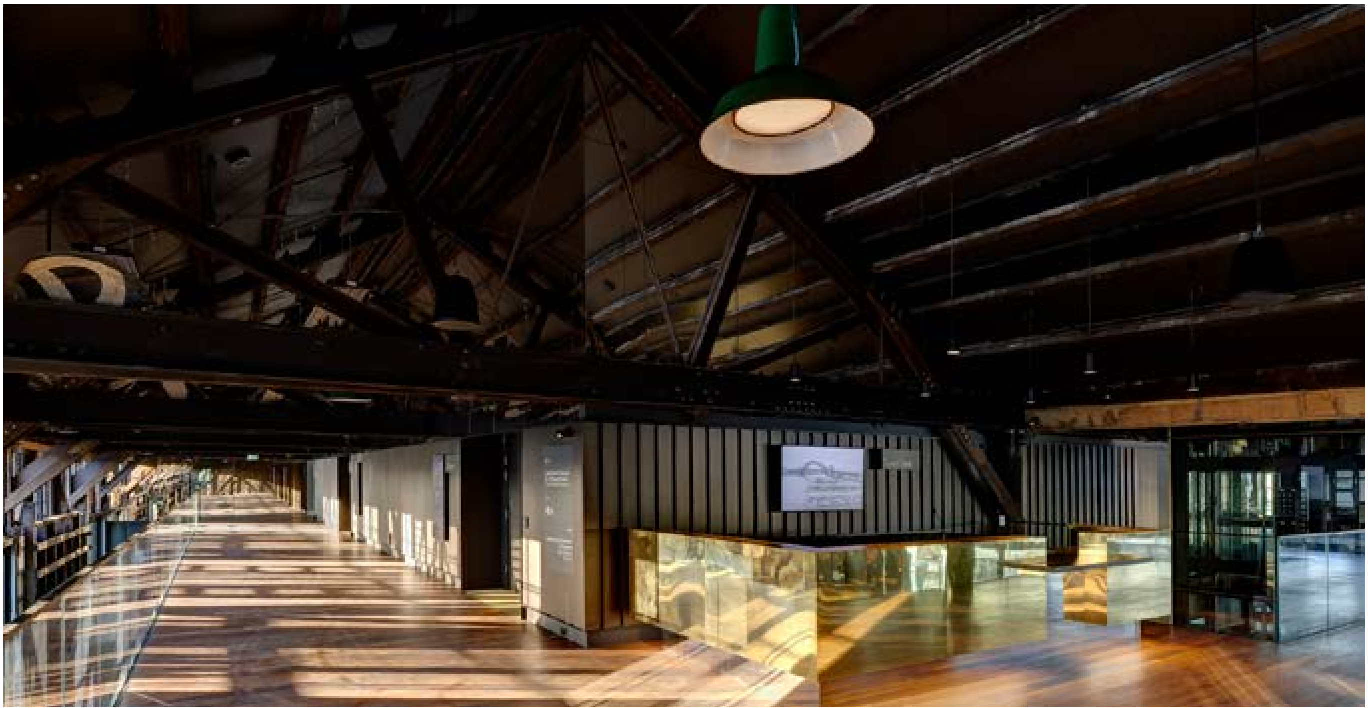
If the internal performance requirements of a building cannot be met by other means and air conditioning is deemed necessary, replacement with a more efficient system and optimisation are important next steps.

Air conditioning systems have become increasingly efficient over time and older systems could be costing more to operate than they would to replace. Any decision to replace ahead of end of life should be informed by an assessment from a mechanical engineering consultant to determine the benefit. This would also need to be balanced against the additional embodied carbon that a new system would introduce. Making sure the size of the system is appropriate to the building, factoring in intended use and environmental passive contributions to thermal comfort, is also important to ensure the efficient operation of the equipment.

Optimisation of air conditioning systems can yield substantial energy and cost savings. For small-scale and residential applications this could be as simple as upgrading systems and adding additional zoning. Zone control provides greater flexibility to help ensure that spaces that aren't being used are not being heated or cooled unnecessarily.

For large-scale and commercial applications where heating, ventilation and air conditioning is linked to a building management system, optimisation is more complex but can save considerable energy and costs. The NSW Office of Environment and Heritage publication *I am your optimisation guide: heating, ventilation and air conditioning* (OEH 2015) provides a detailed summary of key optimisation opportunities relevant to heritage buildings, as well as useful information on the support required to realise the benefit of this change.

Cleaning filters regularly and checking ductwork connections are important maintenance tasks to ensure the efficient operation of the system.



The internal layout of the Walsh Bays Arts Precinct separates the spatial functions that require a higher level of mechanical servicing, such as the theatre spaces, from the transient spaces that do not, such as the entry lobbies and circulation. The theatres spaces and offices are located to the centre of the building in sealed compartments which reduces the area being air-conditioned and improves the efficiency. This also means there is far less pressure on the external envelope of the building to achieve a level of airtightness to support efficient HVAC operations (Photo: Brett Boardman for TZG)

## Heritage considerations

Removing or downsizing air conditioning systems in heritage buildings, supported by the implementation of other performance improvement strategies to naturally improve internal conditions, is the first preference for heritage buildings. In extreme cases, the dry internal air produced by air conditioning can lead to or accelerate deterioration of significant heritage fabric. If systems are being removed completely or downsized, all redundant non-significant equipment should be removed and any damage to significant fabric made good.

Where air conditioning cannot be removed entirely, a hybrid approach would ideally be developed whereby an appropriately sized system is used to manage extremes of temperature only.

Further practical considerations when installing or renewing air conditioning in heritage buildings include:

- installation should be carefully planned to avoid damage or removal of significant elements:
  - loading of the existing structural members should be checked to ensure structure is not overloaded by additional equipment
  - placement of vents and registers should avoid significant fabric or decorative elements
  - services reticulation should be discreet and neat.
- positioning of external equipment should avoid primary views, minimise visual impacts and ensure adequate air flow for efficient operation. Ground mounting is more appropriate than mounting on walls in most instances. Placement needs to consider the adjacent heritage fabric, particularly stone or porous brickwork, where accelerated drying can increase salt damage from damp-related issues.

## Measuring benefit

Removing, reducing, optimising and maintaining air conditioning systems will all contribute to measurable reductions in energy use and costs associated with heating and cooling. Comparing energy bills before and after changes should provide data on reduced usage. For more specific data collection, temporary or permanent sub-metering can be considered for high energy use areas.

Removal or replacement with a well-designed system is likely to yield positive heritage impacts, especially in instances where the previous installation has resulted in physical or visual impacts to a building.

### Useful links

IPART Energy Sustainability Schemes – Eligible activities and equipment

The NSW State Heritage Register listed Metcalfe Bond Stores were conserved and reimagined to serve as COX's Sydney studio. A comprehensive suite of environmental performance upgrades were incorporated with sustainability as a driving force for the project.

One of the key sustainability outcomes was incorporating a mixed mode ventilation strategy combining nature with technology, allowing users to control their environment and take advantage of natural sea breezes. A weather station connected to the building management system (BMS) automatically shuts down the mechanical ventilation system when temperatures sit between 19–26 °C. An alert is sent to all staff who manually open and close windows. Individually controllable ceiling fans bolster air flow. This highlights the importance of behaviour change and communicating change to users to make best use of upgraded services and initiatives. Incorporating passive design principles has saved 74% in total air-conditioning usage due to opening the windows and taking advantage of natural cross-ventilation.

Further information on the full range of measures and sustainability approach can be found on COX's website (see References for details) (Photo: Nicole England for COX)

## Water and waste management

**Related strategies**

General maintenance

Landscape

The need for building-scale infrastructure, such as rainwater tanks to allow on-site water collection and waste management, has declined as public infrastructure has developed to serve our cities. Some heritage buildings in rural or remote areas of New South Wales retain those self-sustaining systems and have been continuously upgraded to serve the needs of the occupants.

Rainwater collection and grey water recycling have re-emerged in recent years as essential considerations for most new residential buildings and for alterations and additions through the BASIX requirements and environmentally sustainable design principles for larger projects. Even where these are not requirements, taking the opportunity to incorporate on-site water collection and waste management for existing and heritage buildings, either as reinstatement of lost systems or as new works, supports broader energy reduction and climate resilience strategies.

Switching to water-efficient fixtures (such as taps, toilets and showerheads) and appliances can prevent water wastage and underpin a broader strategy for water and waste management. Installing water-efficient fixtures and appliances can result in up to 35% reductions in water usage and cost, and up to 65% savings on water heating (DCCEEW 2023).

> 'The United Nations predicts that up to 5.7 billion people will experience water scarcity at least one month per year by 2050.' (Naughtin et al. 2022)

Buildings and owners have become reliant on external systems for managing water and waste. Focusing on water and waste management at a building scale supports 'General maintenance' and care for heritage buildings and improves resilience in times of less predictable weather patterns and 'extreme and unprecedented weather events' (Naughtin et al. 2022).

This approach also reduces pressure on broader public infrastructure networks, such as water supply, waste treatment and stormwater, to manage increasing loads as populations grow. This pressure on public infrastructure from population growth and peaks from increased storm intensity inevitably lead to carbon-intensive expansion or upgrading that can be minimised with a local site-specific approach. The role of community is emphasised in Infrastructure Australia's Resilience Principles (2022), which give weight to local action in supporting resilient and sustainable infrastructure.

### Application

Water and waste management as a performance improvement strategy is relevant to all buildings.

## Environmental principles

As our climate changes, the frequency and intensity of storm events is increasing and water and waste management needs to be a central consideration in adapting heritage buildings to changing conditions.

The priority for water and waste management is ensuring water is excluded from the building. This is achieved through ongoing maintenance of the existing system, ensuring roofs, gutters, downpipes and stormwater drainage are all clear and functioning – this requirement is not unique to heritage buildings, but the consequences can be more extreme if building fabric is more fragile. Where an existing system isn't performing effectively, leading to water damage, sensitive adaptation of the system to increase capacity is required, which may include sensitively increasing gutter capacity and adding additional downpipes.

From there, opportunities for on-site rainwater collection and integration with grey water and landscape use can be investigated. Water run-off from increasing areas of hard surfaces is leading to localised flash flooding in our cities. Slowing the rate of flow to stormwater systems through incorporating on-site rainwater collection, deep soil planting and soft landscape can contribute to reducing pressure on essential systems and reduce risk for heritage buildings overall.

The gutters on this historic building are being replaced with extra-large ogee profile gutters. The increase in capacity enables the storage of water during storm events. Additionally, a rear flashing has been introduced behind the back of gutter to prevent overflow into the roof space (Photo: Hector Abrahams Architects)

Eryldene historic house and garden installed 3 large rainwater storage tanks beneath the driveway. The discreet underground tanks provide 27,000 litres storage capacity to support the exceptionally significant garden with its rare horticultural collection of camellias and azaleas through increasing periods of prolonged heat and dry conditions (Photo: Lindy Kerr for the Eryldene Trust)

## Heritage considerations

Improving water and waste management in heritage buildings must start with understanding how the original system was designed and how it has been adapted to inform adaptation and improve building resilience.

### Actions

- Check site context and original drawings or early photos for evidence of original rainwater goods and rainwater tanks.
- Design sympathetic adaptations to existing or renew systems based on documentary evidence and historic information related to the buildings age, typology and style.

The following case study illustrates how hydraulic systems can be adapted and compromised over time, and how additional capacity can be achieved through a heritage-led process.

In focus

# Spare capacity in the details – Mount Victoria Railway Station

Replacement of the platform awning guttering at Mount Victoria Railway Station demonstrates how targeted historic research can yield improved climate resilience and a good heritage outcome.

Completed image of the reinstated ogee eaves gutter (Photo: Transport for NSW)

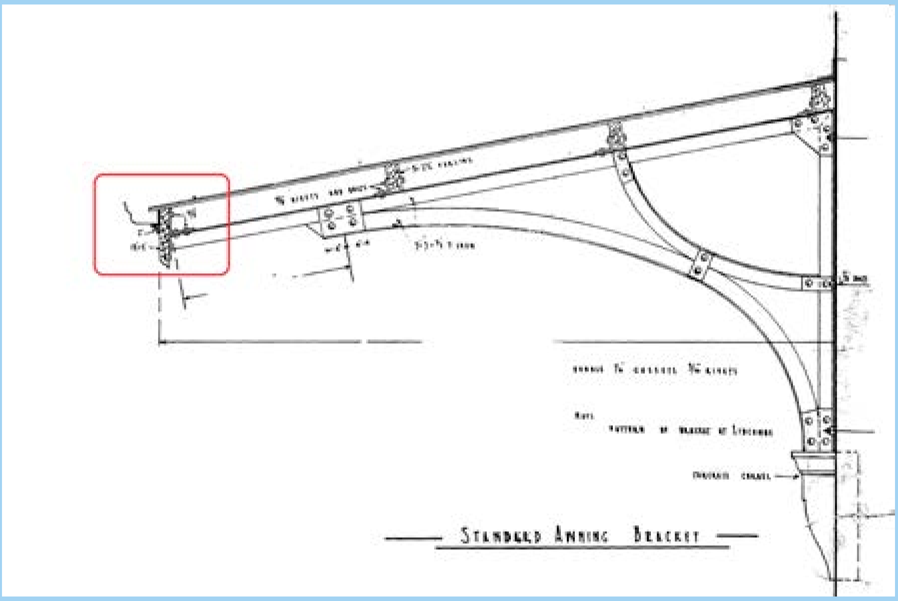
The station is listed on the NSW State Heritage Register and the group of buildings demonstrate the expansion of the site over time. The constant use of the buildings since 1867, alongside major additions and maintenance, has resulted in changes that have compromised the performance of certain elements. One specific area which has been addressed as part of a recent project is the platform awning guttering and drainage.

Underperforming guttering and drainage was leading to internal damp issues and pooling of water on the platform. This was damaging historic building fabric, impacting internal building conditions for staff and customers and posing a safety issue for slips, trips and falls. The team commissioned a hydraulic assessment of the guttering and drainage in a heritage-led process to identify rectification opportunities.

On-site analysis and documentary research confirmed that previous works had reduced the size and changed the profile of the awning guttering. The roof catchment area had also increased with additions to the building and the smaller modern quad gutters couldn't meet the required capacity.

Close analysis of the 1926 awning drawing illustrated that the original gutter was a high-capacity 7-inch (or 175 mm) ogee eaves gutter that had been replaced with a undersized quad gutter. The decision was made to reinstate the historic gutter profile and size with an additional high back option to prevent surcharge. This change tripled the capacity of the gutters.

Along with downpipe adjustments and investigations to below-ground stormwater management, this reinstatement of original building details at Mount Victoria has improved the resilience of the building in high-volume rain events. It serves to protect the historic building fabric and reinstates original detailing.




Extract from 1926 drawing for proposed awning brackets showing the ogee eaves gutter. The sizing was determined by scaling dimensioned elements such as the fascia board and purlins (Image: Transport archives with graphic overlay).

Elements such as rainwater and septic tanks were common design elements for many heritage buildings. As these elements deteriorate they are often removed and not replaced as reliance shifted to centralised public infrastructure.

Rainwater collection and use on site to support heritage landscapes is another important element. During drought it may not be possible to use mains water for landscapes which may increase the risk of damage, particularly to non-native exotic species which form part of the significance of a site.

Increasing capacity for on-site rainwater collection and waste management requires some additional consideration to supplement 'Understanding the context and building' before making decisions.

| **Has the heritage value of any existing rainwater collection and water management systems been assessed? Is it of heritage significance?** | |
|---|---|
| **If significant** | • Maintain and seek to sympathetically improve capacity of existing systems if needed. |
| **If not significant or if no longer present** | • Explore opportunities for the sympathetic introduction of systems that support improved water and waste management, including:<br>– rainwater tanks<br>– grey water recycling. |

Further practical considerations when planning water and waste management in heritage buildings include:

- placement of rainwater tanks needs to consider scale, siting and materials
  - scale must be appropriate to the climate and size of building. See historical information for typical sizing
  - rainwater tanks were historically sited to the rear or sides of buildings. Maintain the primary elevation and discreetly locate tanks
  - material selection and detailing should be of a high quality and reflect historic precedent and be appropriate to the age and building type. For example, galvanised iron tanks were common
  - if an aboveground location cannot achieve a discreet outcome, consider a concealed location, such as under a deck or underground. Underground options introduce other risks and costs, including archaeology and disposing excavated material, which need to be factored into the assessment.

- compatibility of all roofing materials and new elements needs to be checked to avoid galvanic corrosion, which can lead to accelerated deterioration of fabric
- grey water recycling should seek to reuse existing pipework
  - new pumps, pipework and cabling where required should be neat and discreet.

## Measuring benefit

Comparing water bills before and after changes should provide data on reduced usage. For more specific data collection, temporary or permanent sub-metering through smart water meters can be considered. Other site-specific benefits of implementing good water and waste management will include protection of building fabric through proactively managing water, and the opportunity to maintain landscapes through drier periods by using collected rainwater when watering from mains supply is not permitted.

Quantifying the energy and cost benefits to the public infrastructure network are more difficult. Decreasing the pressure on water supply, waste and stormwater management may prolong the serviceability of existing infrastructure and delay the need for carbon-intensive upgrades or replacement, but this would require widespread uptake by the community.

### Useful links

Renew Australia – Rainwater tank sizing


Advertisement from 1919 in ***Building*** magazine for a 'bath heater' showing how far technology has advanced. (Image: NLA, ***Building*** magazine, vol. 24, no. 142, 12 June 1919)

## Hot water system upgrades

Hot water systems have evolved rapidly over the last 100 years – from coppers, wood chip burners and boilers through to electric and solar hot water systems, they are now an essential service for any building. Heating water still accounts for approximately 20% of energy usage despite these advances (Whitehouse et al. 2018).

Heritage buildings may show evidence of this development of hot water systems over time, such as a redundant gas copper in a ceiling space. Historic systems are rarely still in use as the demand and efficiency of early systems have long since been surpassed.

Minimising usage through water-efficient appliances and fixtures, selecting an efficient hot water system and upgrading piping can make a meaningful difference to reducing energy usage and costs.

### Application

Hot water system upgrades as a performance improvement strategy are relevant to all buildings.

### Environmental principles

Hot water system upgrades are closely linked to 'Water and waste management'. Reducing use of hot water through upgrade and installation of water-efficient appliances and fixtures is an important first step in upgrading a hot water system. This will help ensure that the selected hot water system is sized appropriately for the building needs and that excess water isn't being heated unnecessarily. Reviewing water temperature and setting it to an appropriate level for the system type can represent significant energy savings. The temperature can be set to 50 °C for instantaneous hot water systems. Where hot water systems have a storage component, the minimum temperature is usually set to 60 °C to prevent bacterial growth. A further upgrade to improve the overall efficiency of the system is adding insulation to hot water pipes. This keeps water hotter on the path from the tank to a tap, appliance or machinery and helps to minimise energy loss.

In residential and small-scale buildings there are a few options for efficient hot water system upgrades, including electrically boosted solar hot water systems and air-sourced heat pump hot water systems. Both systems are more energy-efficient than traditional electric element or gas hot water systems but need to be closely considered for climate and heritage suitability. Heat pumps can reduce water heating consumption by up to 60% compared to conventional electric water heaters. Electric options provide the opportunity for integration with renewable energy that isn't possible with gas. A heat pump hot water system needs to be installed in a well-ventilated area, while being located as close as reasonably possible to the main areas of hot water use (i.e. bathrooms, kitchen, laundry). Solar hot water systems can be visually bulky, but with options to install the storage tank unit at ground level they can be far less intrusive than historical examples.

Heat pumps can also be used for general ‘Heating and cooling’ and the climate and heritage considerations are consistent with those outlined here for hot water systems.

In larger buildings and commercial settings, hot water and steam systems can use a significant amount of energy. NSW Climate and Energy Action sets out the following upgrades as examples of how heating can be minimised:

- adjusting the controls on your system so your boiler runs only when needed
- optimising boiler blowdown rate and control
- installing heat recovery systems to utilise the low-grade waste heat in other applications
- eliminating steam leaks and steam trap losses
- minimising boiler/steam generator heat loss through better insulation.

## Heritage considerations

The lifecycle of hot water systems is very short compared to heritage buildings. Modern services, including hot water systems, must be installed to enable removal and ongoing replacement without damage to building fabric. Installations should also be visually discreet.

Further practical considerations when installing or renewing hot water systems in heritage buildings include:

- installation should be carefully planned to avoid damage or removal of significant elements
- loading of the existing structural members should be checked to ensure structure is not overloaded by additional equipment
- services reticulation should be discreet and neat, including considering retaining and reusing existing service pipework.

### Air source heat pumps and electric element hot water systems

- Positioning of external equipment should avoid primary views, minimise visual impacts and ensure adequate air flow for efficient operation.
- Ground mounting is more appropriate than mounting on walls in most instances.
- Placement needs to consider the adjacent heritage fabric, particularly stone or porous brickwork, where accelerated drying can increase salt damage from damp-related issues.

### Electrically boosted solar hot water systems

Positioning of roof-mounted equipment should avoid primary views and minimise visual impacts. This is particularly relevant for solar hot water systems. These systems can be visually bulky and are unlikely to be supported from a heritage approvals perspective on primary elevations.

If solar hot water is being considered, an assessment should be made taking into consideration the following factors:

- whether there is a secondary structure of no or lesser significance (e.g. a service building or garage) that could accommodate the installation
- the roof geometry
- significant or primary views
- whether a secondary elevation provides a more visually discreet option AND an appropriate solar orientation to operate effectively.

Industrial and later commercial buildings are more likely to retain hot water and steam systems that relate to a building-specific process, such as steam pumps. When working in these spaces try to understand the building or process being undertaken to determine if the system is original or significant and whether it has ongoing relevance to the building use or can be adapted to a new use.

## Measuring benefit

Reducing hot water usage through water-efficient appliances and fixtures, and installing an efficient hot water system coupled with temperature settings and insulated piping, can make a substantial difference to energy usage and costs. Comparing energy bills before and after changes should provide data on reduced usage. For more specific data collection, temporary or permanent sub-metering can be considered for high energy use areas.

## Useful links

NSW Climate Energy and Action – Hot water and steam systems (for businesses)

NSW Climate Energy and Action – Upgrade your hot water system (households)

## Smart technologies

> What are smart technologies? 'Self-monitoring, analysis, and reporting technology.'

Technology continues to transform daily life. Integrating smart technologies into buildings makes it possible to capture and make use of real time data to optimise energy efficiency. The opportunities for networked systems to take full advantage of performance improvement strategies through home automation and more sophisticated building management systems is a logical next step in further refining the retrofit approach.

While the potential benefits of networked integration are considerable, it can pose challenges in heritage buildings. As noted throughout this chapter, heritage buildings were generally not designed for the high level of reticulated services (e.g. electrical services, equipment and sensors) required for successful integration with smart technologies.

### Application

Incorporating smart technologies to optimise energy mitigation strategy is relevant for all buildings, although the greatest benefits will likely be seen in larger-scale applications.

### Environmental principles

Temporary or permanent sub-metering and smart water meters for energy monitoring are well-developed technologies that underpin integration with smart technologies. Understanding where energy and water is being used in a building can help occupants and building managers modify behaviours to reduce usage and identify leaks or issues as they arise to prevent energy or water wastage.

Smart technologies can then be selectively overlaid to optimise building elements and systems that are contributing most to energy use or haven't responded to other interventions, including things such as window automation, internal window coverings, lighting, heating and cooling, and on-site renewable energy.

The most relevant category of smart technology for building optimisation is 'Internet of Things' or IoT devices. This refers to a network of devices that use internet connectivity, software, sensors, and analytics to enable static elements to be manipulated through a building management system (BMS).

Digital connectivity refers to the ability of technology, systems or devices to connect and communicate, generally through internet or another network. There are physical requirements to enable implementation of smart technologies, which are explored further in the table below.

Embedded technology captures information on specific aspects of the local environment which is fed back to the software supporting the application. Analysis of the information against pre-set parameters then determines an automated response or triggers a notification for response through the building system or performance monitoring. This data can also be useful in identifying areas for improvement to be addressed through 'General maintenance'.

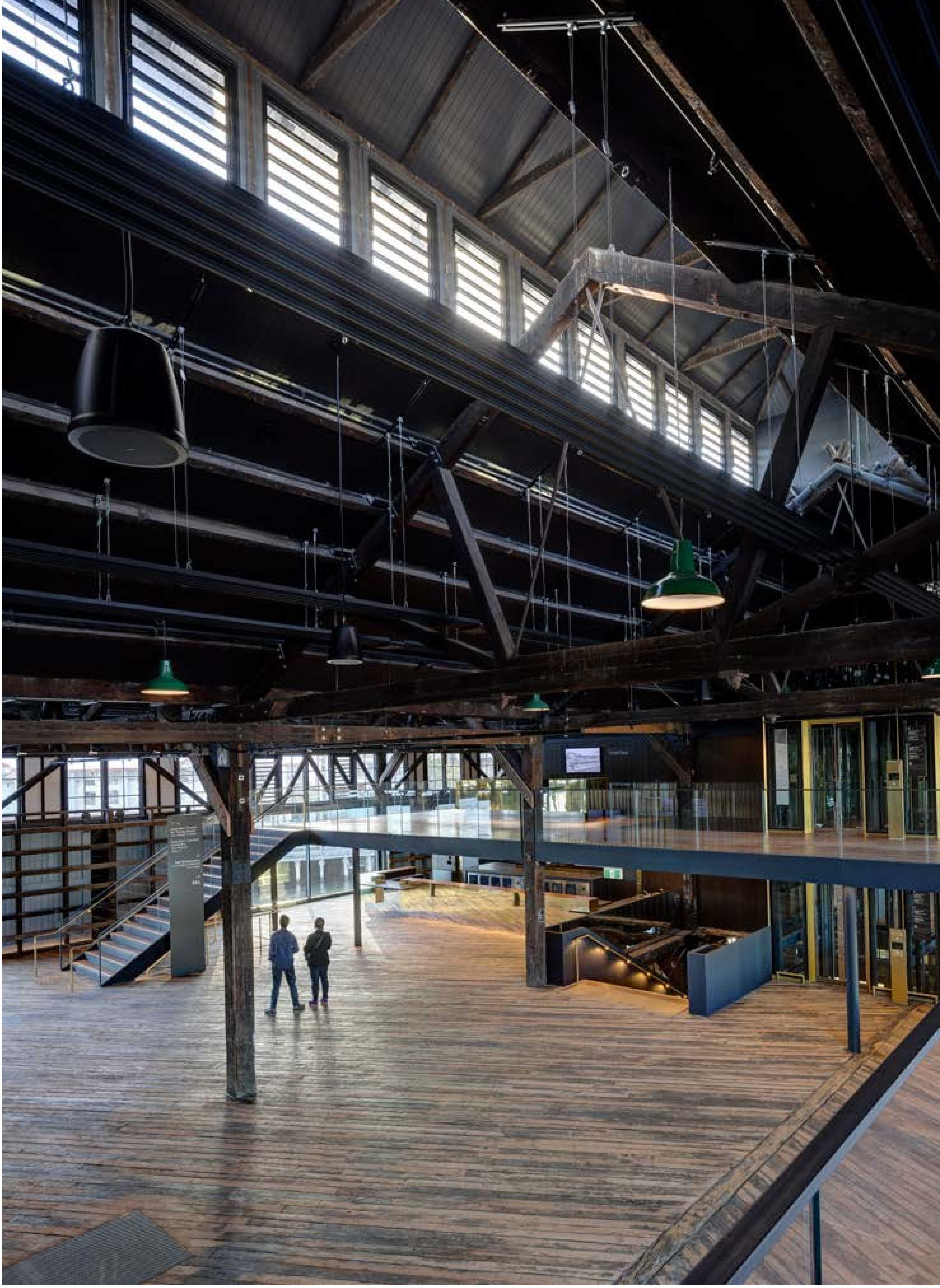
Table 4 summarises the key inputs and outputs of implementing smart technologies.

**Table 4** Summary of key inputs and outputs of implementing smart technologies

| Physical requirements and 'readiness' | Platform/ application level | Technology examples (hardware) | Outputs |
|---|---|---|---|
| • Wiring/ electricity<br>• Digital connectivity (4/5G, LoRaWan)<br>• Data racks/ modems | • Datasets<br>• Backend platform/IoT system | • Smart lighting/air conditioning<br>• Sensors<br>• Temperature/ environmental monitor<br>• Smart glass | • Performance monitoring (dashboard)<br>• Asset management/ repair visibility<br>• Energy efficiency/ optimisation |

For example, sensors connected by smart networks to lighting and air conditioning equipment could detect when employees enter a meeting room so that lights and air conditioning turn on only when needed. In open areas, occupancy sensors can detect the number of people and adjust the temperature and intensity of air conditioning accordingly.

Automated ventilation controls can be adapted to existing windows. Integration with outdoor temperature sensors, wind and rain sensors, $CO_2$ monitoring and internal thermostat readings can combine to automatically monitor and adjust window opening to maximise airflow and minimise reliance on mechanical heating and cooling. Weather and external temperature data can also be harnessed as an input to refine the internal temperature settings to be more aligned to the external temperature.



The ridge louvres of the Pier 2/3 building at the Walsh Bay Arts Precinct have been fitted with motorised actuators and connected to the BMS to provide automated opening and closing as needed (Photo: Brett Boardman for TZG)

The opportunities and potential benefits of integrating smart technologies into a building will vary by site. Input by specialists in buildings services and automation technology will be required.

## Heritage considerations

A careful balance needs to be struck between discreetly integrating new sensors, cabling and systems required to facilitate smart technologies and the fabric and visual presentation of heritage buildings.

Further practical considerations when installing smart technologies in heritage buildings include:

- the scale and amount of equipment should be relative to the size and function of a space so as to not overwhelm the heritage character
  - equipment should be discreet
- installation should be carefully planned to avoid damage or removal of significant elements:
  - equipment placement should be grouped and not be physically attached or obscure heritage elements
  - services reticulation should be discreet and neat
- positioning of external equipment, such as sensors, should avoid primary views.

## Measuring benefit

Realising benefits from smart technologies needs to be underpinned by the implementation of the applicable performance improvement strategies outlined in this guide. Smart technologies alone will provide some benefit, but coupled with reductions in net usage and energy efficiency they can provide an extensive amount of information to monitor and measure building performance and identify opportunities to further refine and improve building performance, providing substantial energy and cost savings.

### Useful links

Smart Irrigation Management for Parks and Cool Towns (SIMPaCT)


Substation No. 164 featured the adaptive reuse of a DC electrical substation and the Norman Shelley Spirit Warehouse to serve as Built's head office in Sydney. Retaining the existing buildings and reusing as much of the buildings original material as possible reduced the upfront carbon footprint by 21%.

By showcasing exposed concrete, original bricks, and timber structure, the design aesthetic conserves resources and minimises the use of virgin materials while promoting a strong connection with the heritage fabric of the buildings. The project demonstrates the principles of neat and discreet services installation. The heritage service features are retained alongside new well-planned service runs all consistently mounted and painted dark to be recessive against the underside of the retained timber structure and floorboards.

Further information on the full range of measures and sustainability approach can be found on Built Australia's website (see References for details) (Photo: Raw Life Studios for Built)

## Key actions checklist – Building services upgrades

| Strategies | Key actions |
|---|---|
| **Lighting** | ☐ Identify opportunities for reinstatement of natural lighting and daylight linking to reduce artificial lighting needs<br>☐ Research the existing building lighting to determine if it is of heritage significance and to inform options for improvement<br>☐ Assess current lighting use and cost, lighting levels and existing systems to control lighting, such as zoning and sensors<br>☐ Use the above analysis to inform a site-specific lighting approach to remove or reduce lighting, install sensors for more efficient operation, and upgrade fittings to energy-efficient lighting<br>☐ Lighting upgrades need to be undertaken by licensed tradespeople and should be informed by lighting specialists. |
| **Heating and cooling options** | ☐ Research and understand how the building was designed to provide thermal comfort (Note: this may not be the case for some more recent heritage buildings)<br>☐ Improve internal comfort as much as possible by other means, including ceiling fans, before installing air conditioning<br>☐ Consider air conditioning installations or renewal only where extremes of temperature (hot and cold) cannot be managed by other means<br>☐ Keep air conditioning within an energy-efficient range, e.g. 24–25 °C in summer and 16–18 °C in winter<br>☐ Heating and cooling upgrades need to be undertaken by licensed tradespeople and should be informed by a heritage specialist. |
| **Water and waste management** | ☐ Upgrade non-significant appliances and fixtures with water-efficient options<br>☐ Research the existing building rainwater goods and implement sympathetic adaptations to improve capacity and resilience where storm damage and water ingress is occurring<br>☐ Identify opportunities for maintenance or installation of rainwater collection and grey water recycling. |
| **Hot water system upgrades** | ☐ Reduce hot water usage through water-efficient appliances and fixtures<br>☐ Identify opportunities for insulating pipework for improved efficiency<br>☐ Research, select and install a hot water system that is suited to the climate and heritage context<br>☐ Hot water system upgrades need to be undertaken by licensed tradespeople. |
| **Smart technologies** | ☐ Install internet-compatible smart energy and water metres<br>☐ Engage a building services consultant to identify elements and systems where smart technologies could be applied to the building to improve energy efficiency. |

Case study

# Inner West House

## Quick facts

**Project type:**
Residential

**Client:**
Owner occupier

**Project team:**
Home Energy Efficiency and Sustainability Consultant – Melanie Lupis, Sustainability Certified

**Location:**
Sydney NSW

**Year:**
2022–23

**Awards:**
Commendation for Sustainability, Inner West Council Built Environment Awards, 2023

‘This retrofit is the best thing I’ve spent my money on … the house is far more comfortable to live in … we have futureproofed the house for next 115 years and for future owners … and futureproofed against bill shock and reduced our electricity bill.’

Owner

The comprehensive retrofit of a Federation brick home in Sydney’s Inner West to transform the energy efficiency and amenity of the house.

After living in the home for over a decade, the owners embarked on a journey to transform a draughty double-brick Federation-era house into a resilient home ready for the future. Guided by a Residential Efficiency Scorecard Assessment, the owners worked to scope and sequentially implement a balanced series of upgrades that in time would deliver a 10-star rated home.

The retrofit project worked within the existing building footprint and focused on replacing dated and inefficient services as well as select upgrades to fabric. The project demonstrates how a series of well-considered works to a historic house can enhance user amenity and energy efficiency without compromising the original layout and details.

Following an initial 3-star rating, the owners set about transforming the house in stages. Works were thoughtfully planned to maximise benefit and avoid potential rework. For example, upgrading the roof insulation was the last activity undertaken to ensure all other work to the ceiling space had been completed and the new insulation would be undisturbed.


Photo: Owner

The project included conservation, maintenance and repair works to the house, including underpinning and repointing supporting the environmental performance improvement strategies.

Key contributors to the poor environmental performance of the existing home were:

- inefficient underfloor ducted air conditioning and a wall-mounted split system air conditioner
- gas hot water, cooktop and heating
- exposed timber floorboards with no underfloor insulation
- inconsistent loose full insulation to the ceiling.

Stage 1 was set out as a series of short-term goals and included:

- replacing halogen downlights with LED, an important precursor to upgrading ceiling insulation
- upgrading existing double-hung sash windows with double-laminated glass, including reweighting and sealing for airtightness
- sealing gaps and cracks throughout the home, including chimney stoppers
- installation of a 1.7 kW solar photovoltaic system.



The hot water heat pump and solar photovoltaic system have been discreetly located to the side and rear of the house. The solar photovoltaic system avoids the slate roof and fixed to the corrugated steel roof instead (Photos supplied by owner)

Stage 2 comprised long-term upgrade options and included:

- removing the underfloor ducted air conditioning, which had reached the end of its functional life following multiple repairs. The resulting space was used to install underfloor insulation
- installing efficient wall-mounted split systems as well as a ceiling fan to the bedroom
- adding weather strips to the external doors and further draughtproofing to vents and skirtings, and patch repairs of holes in the floor
- replacing gas appliances for full electrification, including installation of an induction cooktop and hot water heat pump, and ceasing use of the gas heater
- upgrading window coverings, including heavy curtains, with 'invisible' pelmets and honeycomb pleated blinds
- replacing roof insultation to eliminate gaps and achieve a consistent R-value
- increasing the solar photovoltaic system to 4.7 kW capacity to better support energy requirements.

Following installation of the retrofit initiatives, the homeowners engaged in significant behaviour change to optimise the energy efficiency of the home. Hot water, cooking and heating have all added to the electricity demand following disconnection from natural gas. Despite this, a substantial reduction in electricity usage has been captured with monitoring through bill analysis and smart metering. Monitoring has confirmed that electricity usage is down to approximately 25% of the pre-upgrade usage.

## Key design consideration 4

Retain and recycle original fabric and materials to preserve embodied energy, where possible.

*Design guide for heritage –* Better performance

## Key design consideration 6

Select new building materials and systems to enhance energy efficiencies.

*Design guide for heritage –* Better performance

Steven Barry/Transport for NSW

# 3 Energy efficiency fabric upgrades

## Improve the performance of building fabric

The building fabric upgrades set out in this chapter are the next step in improving the environmental performance of heritage buildings and supporting energy reduction at the levels required to transition to net zero emissions. These strategies will also help to ensure heritage buildings remain desirable places to live, work and enjoy.

Understanding the relative heritage significance of the component parts of a building and their tolerance for change is vitally important for the strategies set out in this chapter. That analysis and knowledge about a place should form the basis of options analysis and inform the design development of sensitive and appropriate solutions. The environmental performance of heritage buildings can be improved substantially through a combination of appropriate measures that are technically and visually compatible with original fabric and construction typology. The heritage significance of some buildings or specific fabric may restrict progressing some or all of the strategies in this chapter.

The building fabric upgrades outlined below may have greater heritage impact depending on the significance of a building and certain elements. Some strategies may also require a higher level of financial investment. Upgrades need to be carefully planned and delivered to ensure the full benefits of works are achieved and lasting outcomes are achieved. Some of the fabric upgrades may be undertaken at any time independent of a major renovation or project, but greater efficiencies are more likely to be realised if grouped with a broader program of work. Implementation of all relevant strategies to a building at one time is likely to form part of a project or more major renovation.

This chapter covers 6 areas of building fabric upgrades. Table 5 outlines the potential impact of each of these across energy savings, heritage impact, upfront costs and maintenance difficulty.

> 'The nature of heritage buildings mean opportunities for fabric improvements are less, but it is a vital step in carbon reduction that should not be overlooked.'
>
> (ARUP et al. 2011)

**Table 5** Impact summary – Energy efficiency fabric upgrades

| | Energy savings | Heritage impact | Upfront costs | Maintenance |
|---|---|---|---|---|
| Insulation | ●●● | ●○○ | ●○○ | ●○○ |
| Roof ventilators | ●●○ | ●●○ | ●○○ | ●○○ |
| External Shading | ●●○ | ●●○ | ●●○ | ●○○ |
| Window and door upgrades | ●●○ | ●●○ | ●●○ | ●○○ |
| Natural lighting | ●●○ | ●●○ | ●●○ | ●●○ |
| Roof/facade colour | ●●● | ●○○ | ●●○ | ●○○ |

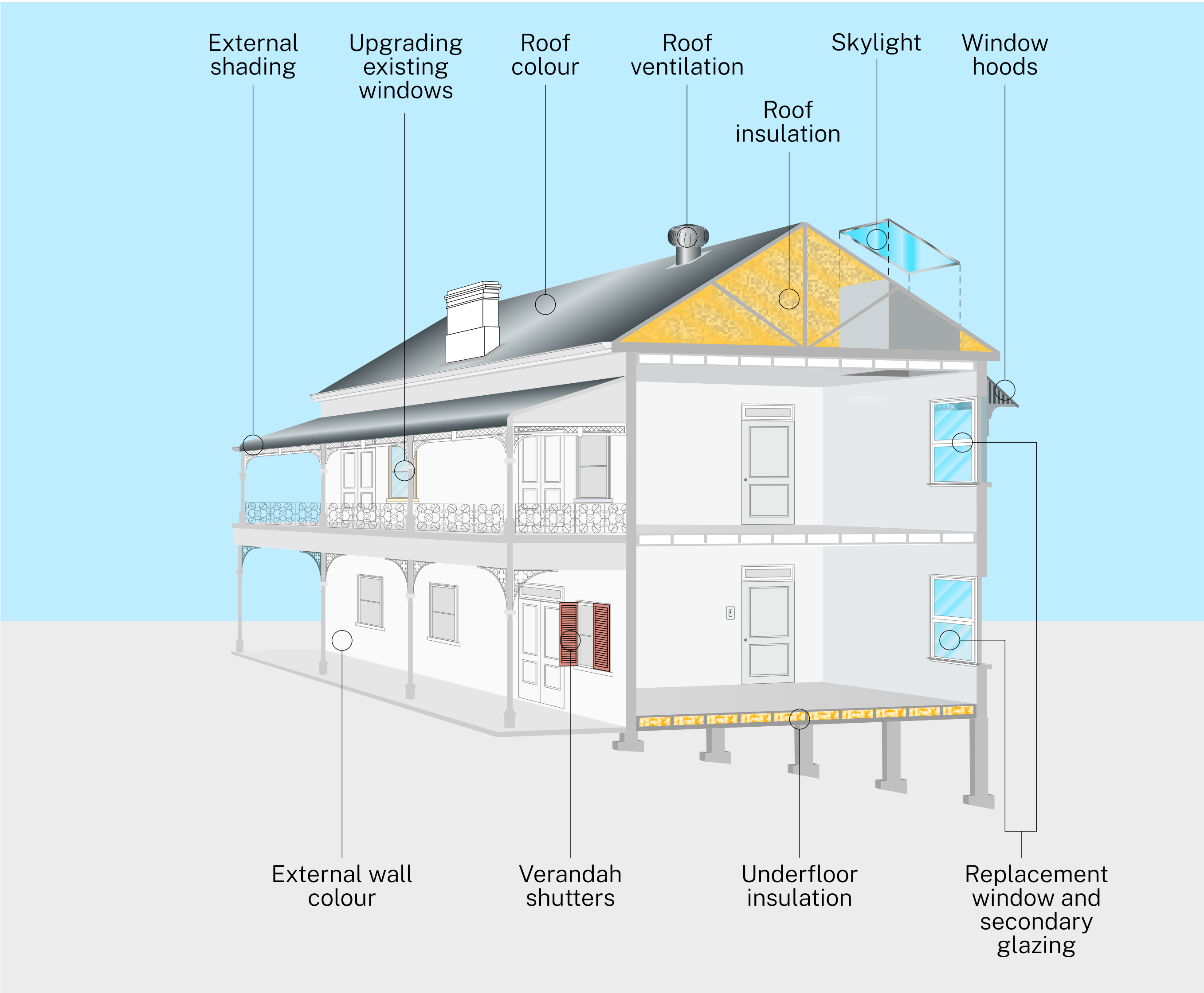



**Figure 6** Diagram illustrating a summary of the energy reduction strategies under energy efficiency fabric upgrades

Related strategies

Improving airtightness

'Keeping cool in a hotter world is using more energy, making efficiency more important than ever.'

(International Energy Agency 2023)

## Insulation

Insulation is the most critical of all the thermal upgrades outlined in this chapter and should be prioritised. It is central to improving the thermal performance and energy efficiency of buildings and maintaining safe and comfortable conditions for occupants, and must be considered for the roof, floor and walls.

The use of treated bark being laid on ceilings as an insulating material below slate roofs is recorded as early as 1850 in Australia (*Australia's home,* 1952). But while insulating buildings is not a recent innovation, the types and efficiency of available products have evolved substantially.

In the nineteenth and early twentieth century, insulation generally consisted of either loose or fibrous materials obtained and processed locally, including sawdust, seagrass, straw or grass and charcoal. These organic materials were gradually superseded by manufactured products, such as mineral or rock wool, generally imported from Britain (Lewis 2024). Through the 1930s, there was significant growth in products and articles promoting the benefits and availability of insulation for ceilings, walls and floors evidenced in building journals from this period.

Developing a thorough, sensitive insulation strategy requires a thorough understanding of the building type, construction and material properties of the existing building. Options should be assessed for new or renewed roof, wall and floor insulation that is well suited to the building and works to stabilise internal conditions and reduce the reliance on mechanical heating and cooling.

### Application

Insulation as an energy efficiency strategy is relevant to all buildings. In warm climate areas of New South Wales insulation can assist to exclude heat gain, and in cold climate areas help to retain heat.

### Environmental principles

Building insulation works by reducing the flow of heat between the interior and exterior of a structure. Heat flow is reduced through low thermal conductivity, minimising convective heat flow through the inclusion of air pockets and, in some cases, incorporating reflective surfaces to inhibit heat transfer through radiation. Insulation is installed in the ceiling space, walls and floors to create a thermal barrier. This barrier prevents the escape of heat during cold weather and entry of heat during hot weather, reducing the need for energy-intensive cooling and heating efforts (i.e. air conditioning) to create comfortable internal conditions.

The effectiveness of insulation is measured by its R-value, which quantifies its resistance to heat flow. Higher R-values indicate better insulation performance. Each climate region has a maximum R-value above which the benefits of reduced heat flow become minimal. Higher R-values will also add bulk, which may not be possible in all heritage buildings, so ensuring the R-value of insulation is optimised to the building and climate context is important in achieving a balanced outcome.

Insulation efficiency is dependent on correct installation to ensure that there are no or minimal gaps or thermal bridges that might compromise the insulation's effectiveness. Additionally, airtight construction and moisture control measures are often incorporated to enhance overall building performance and durability.

## Roof/ceiling insulation

Given the high exposure of the roof to direct heat gain through sunlight, roof and ceiling insulation should be prioritised above wall and floor insulation in a retrofit strategy. The approach and R-value of roof/ceiling insulation will vary depending on the climate zone. For warm climate areas in New South Wales, the purpose is to minimise heat gain and protect from overheating. In cool climate areas, where the roof can be a significant contributor to heat loss, the objective is to keep warm air in.

There are 2 standard approaches to roof insulation. These are insulating at the ceiling level or at the line of the roof. The approach to roof/ceiling insulation in heritage buildings will largely be determined by the roof and ceiling arrangement – for example, whether or not there is a ceiling, or the internal lining follows the rake of the roof which will set the insulation size and location. Typical roof/ceiling insulation is available in a range of materials from standard bulk insulation to natural fibre board.

In most circumstances, natural materials are preferable in heritage buildings as they are better able to buffer moisture. Vermin resistance needs to be considered for all insulation locations, including roof/ceiling, walls and floors, which is leading to a higher uptake of board insultation products.

### Heritage considerations

Original/early roof insulation may survive in some rare circumstances. If present, it is likely to be of heritage significance for its research value and should be retained where it's safe to do so, recorded and supplemented with additional insulation where needed. Professional input will be needed to retain, record and advise on supplementary insulation where needed.

#### Ceiling insulation

Ceiling insulation is typically the more straightforward approach and can be laid between ceiling joists. If ceiling access hatches are not present, or are insufficient to provide access to the ceiling space, it may be possible to install a new ceiling access hatch. New ceiling access hatches should be installed in visually discreet areas, ideally in non-original ceiling fabric. Where impacting original ceilings for access is unavoidable, care should be taken to reduce visual impact by ensuring hatches:

- are limited in size
- avoid decorative elements
- are painted to match the existing surrounding ceiling.

Installation of ceiling access hatches also supports 'General maintenance', facilitating ready access and inspection of the roof space.

Installation needs to consider the condition and fragility of existing original and early ceilings to avoid accidental damage. A close fit between ceiling joists is required to ensure the insulation is effective. Electrical cabling should be assessed by licensed tradespeople and managed to ensure safe and easy access.

**Roof insulation**

An alternative to bulk ceiling insulation is reflective under-roof insulation, which can be installed below the roof sheeting or tiles as part roof replacement works. This is relevant where there is no ceiling present, or where the internal ceiling lining follows the line of the roof. The thickness of insulation and R-value that can be achieved will largely be determined by the space available in the roof space. Insulation that is too thick may result in buckling of roof sheeting or crushing of the insulation, which will impact effectiveness.

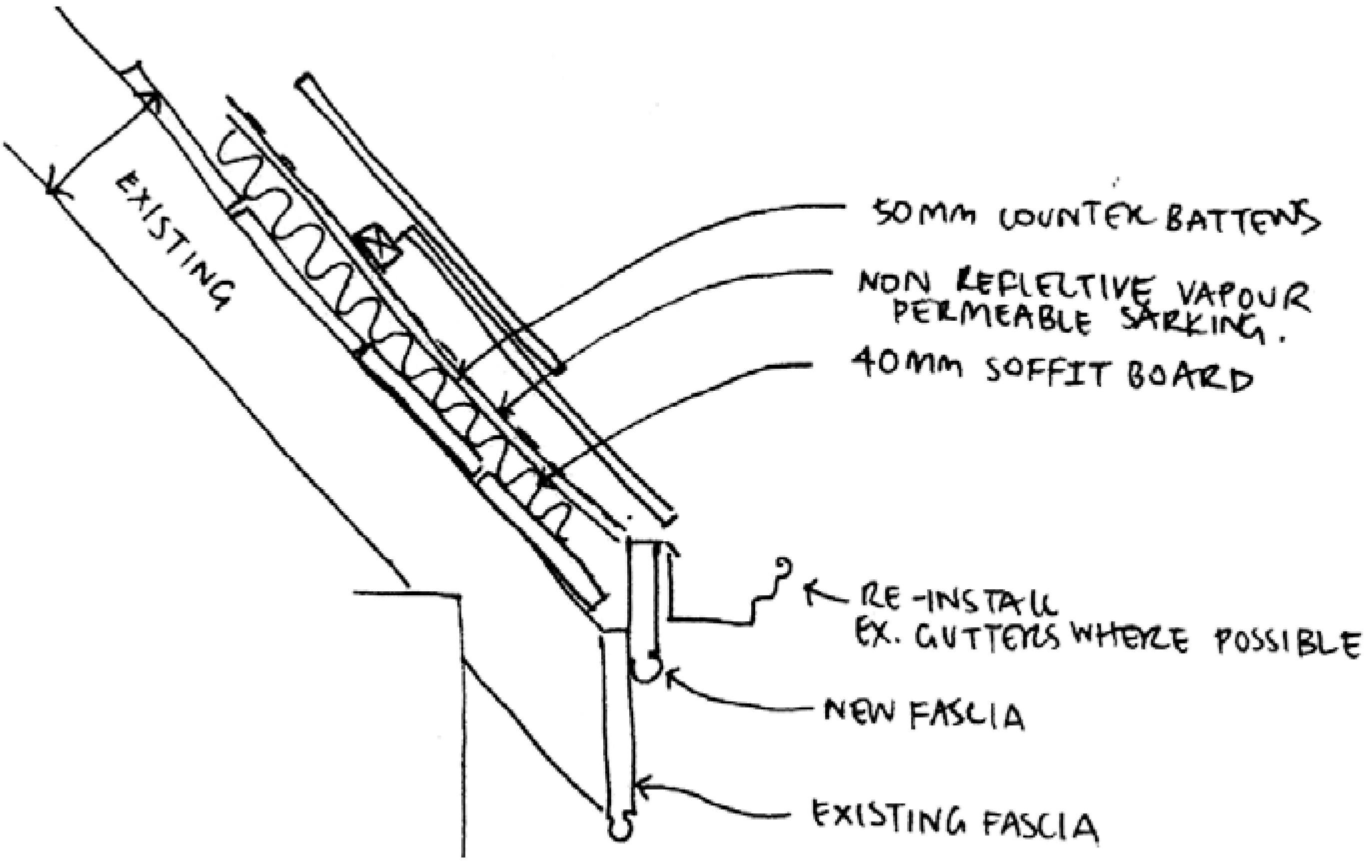
It may be appropriate to raise the roof structure slightly to accommodate roofing insulation as seen in the example of roof replacement at St Judes (page 76). Additional roofing battens were added to accommodate the introduction of an efficient solid board insulation layer beneath the renewed slate roof. This approach balanced the visual outcome with improving the environmental performance of the building. In this example it was not possible to install insulation at a lower level due to an intact decorative ceiling.

Where there is no ceiling lining present, such as in industrial buildings, the visual impact of adding roof insulation and the support mesh will need to be considered.

Insulation should not be added to building areas where the underside of the roof is an exposed finish and the cladding is intended to remain visible, such as verandahs, canopies and soffits.

Further practical considerations when planning roof/ceiling insulation upgrades to heritage buildings include:

- review to ensure safe ceiling spaces with consideration for lead and asbestos contamination and fire risks associated with recessed halogen lighting.
- allow for roof ventilation. See 'Roof ventilation' for further specific information.





Roof replacement works at St Jude's Parish Centre in Randwick included the addition of roof insulation. The works provided for the opportunity to slightly increase the depth of roof structure to accommodate insultation as shown in the sketch. Installing from above in conjunction with new slates, lead sheeting and guttering meant the decorative internal ceiling lining remained undisturbed (Photo: Erin White/Transport for NSW, Diagram: Hector Abrahams Architects)

## Wall insulation

Retrofitting wall insulation can be difficult depending on the construction type of the building and the scope of intended works. The R-value of existing materials is also often undervalued in ratings tools. Given that adding wall insulation is not a simple upgrade, it is important to understand the R-value of the existing wall material to avoid unnecessary work and potential heritage impact through the addition of wall insulation. Typical wall insulation is available in a range of materials from standard bulk insulation and natural fibre board.

As insulating walls can be difficult due to access and not possible in many cases without major intervention to the building fabric, focusing on thermal properties of windows and doors may be a more viable approach to address heat transfer impacts of walls. Refer to ‘Window upgrades’ below.

Injected foam insulations are becoming more readily available for difficult-to-access walls and may be attractive as an easy solution; however, this is non-reversible change and doesn’t align with heritage practice. The cavity is designed to manage water and the air gap also provides some insulation, so injected solutions need to be very carefully considered in a heritage context.

### Heritage considerations

The heritage significance, construction typology of the buildings walls and planned works will determine the viability and approach to wall insulation.

Buildings with no wall cavities, such as double-brick construction or exposed timber structures with lining on one side only, offer limited opportunity for introducing wall insulation. See ‘Landscape’ for alternatives, including deciduous planting to the east and west elevations to reduce direct heat gain to unimproved wall surfaces.

Wall insulation can significantly improve the thermal performance of weatherboard construction. If the external cladding or internal wall lining is being removed as part of a broader project, inclusion of insulation is a logical option. However, unless one layer of lining is being removed for another purpose it may be decided that the disruption and potential damage to the cladding or wall lining means that wall insulation should not proceed, and alternatives such as ‘Landscape’ need to be considered.

Other factors to consider in determining adequate wall insulation is any external shading that protect the walls from direct heat gain such as wrap-around verandahs or sunrooms which would control heat gain to some degree.

## Floor insulation

Uninsulated floors can be a significant source of cooling and heating loss. Floor insulation is most commonly applicable to residential houses, ground floor apartments and civic buildings that have a suspended floor with exposed cavities. Adequate access is the primary factor in determining the feasibility of retrofitting floor insulation. Floor insulation can be fixed to the underside of the floor joists, held in place by timber runners attached to the joists, or be provided through rigid self-supporting products. Floor insulation is available in a range of materials from standard bulk insulation through to natural fibre board and polystyrene. Depending on the type of insulation selected, additional support or netting may be required to prevent the insulation sagging and losing effectiveness over time.

### Heritage considerations

The heritage significance of the existing floor and access to the underfloor cavity or crawl space will determine the viability of and approach to underfloor insulation.

If the existing floor is solid, such as flagstones or concrete, and it is original/early and of heritage significance, removal for the installation of insulation alone is unlikely to be worthwhile or supported in heritage terms. If the floor is being lifted for other reasons, it is worth considering an insulated sub-floor to form a base for the reinstated significant floor surface.

Floor insulation can be more readily integrated to suspended floors, such as timber floorboards. Suspended floors typically sit 300 to 500 mm above ground level, although this can be significantly less, and are carried by joists supported on dwarf walls or piers.

Integration of floor insulation for suspended floors requires some additional consideration to supplement 'Understanding the context and building' before making decisions.

**Has the heritage value of the existing flooring been assessed? Is it of heritage significance?**

**If significant, and access to the floor cavity is readily available**

- Determine the correct R-value for floor insulation based on climate zone and select a product for installation by a qualified installer.

**If significant, and the floor cavity is inaccessible**

- Consider whether floor access hatches will provide satisfactory access for the installation of insulation.
- If yes, ensure any new integrated sub-floor access hatches are placed in visually discreet areas. The hatch should match the existing floor and be neatly finished level to the existing floor.
- The underside of the hatch should be insulated to the same standard as the surrounding floor.
- Installation of floorboard access hatches also supports 'General maintenance', facilitating ready access and inspection of the sub-floor space.
- If floorboard access hatches will not provide satisfactory access, consideration needs to be given to carefully lifting the flooring to allow installation of the insulation. It may be decided at this stage that the disruption and potential damage to the flooring means that floor insulation should not proceed, and alternatives need to be considered (see below). Lifting floors will be more viable in instances where the flooring is being repaired, consolidated or replaced for other reasons.

**If significant, and the floor cavity remains inaccessible despite investigations**

- Consider internal floor and window coverings, specifically area rugs and carpets with an insulating underlay, to improve airtightness and limit air movement through the floor.

Further practical considerations when planning floor insulation upgrades to heritage buildings include:

- review existing sub-floor space to ensure adequate free air movement to maintain the structural integrity of the flooring components. This should include removal of loose debris or rubbish that may have accumulated and could attract or provide nesting for pests or vermin.
- depending on the age of the building and flooring type, underfloor archaeology may be a need to be considered prior to reducing the ground level or removing debris.

## Measuring benefit

All types of insulation can help stabilise internal temperatures and greatly improve the energy efficiency in existing buildings. Approximately 20% of heat is lost through a typical roof (ARUP et al. 2011) and 45% of heat gain will be through the roof (Hyde 2000).

Studies on the effects of ceiling insulation and roof ventilation rates on the heating and cooling energy in a moderate climate demonstrate a more than 50% reduction in cooling energy and 75% reduction in heating requirements with effective insulation in place (Hyde 2000). Given the significance of these energy savings, prioritising insulation is important.

The introduction of insulation is key to reducing heat gain and minimising heat loss to provide comfortable internal conditions. This will substantially reduce heating and cooling costs. Comparing energy bills before and after changes should provide data on reduced energy usage. Other site-specific benefits of insulation will include improved noise reduction.

# Roof ventilation

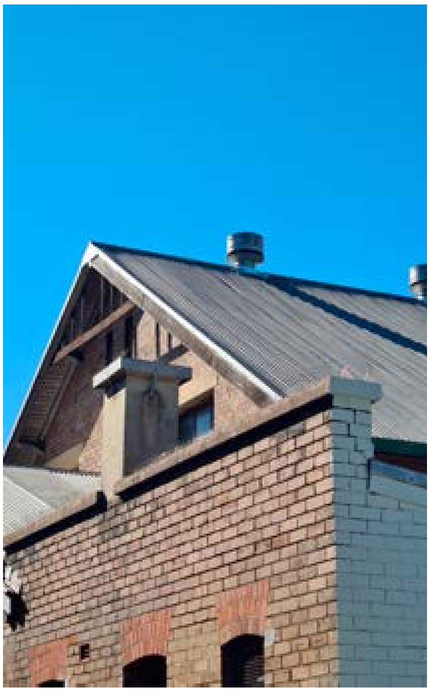
**Related strategies**

Improving natural ventilation

Heating and cooling options

Adequate roof ventilation is important in managing the thermal performance of buildings and providing safe and comfortable conditions for occupants. The benefits of roof ventilation are well understood and were a critical component of climate control in buildings prior to the widespread uptake of insulation and mechanical cooling. The form of roof ventilation varies greatly across heritage buildings in New South Wales, from utilitarian building elements to elaborate architectural statements. Common types of roof ventilation in heritage buildings include roof cowls, louvred gable openings, ridge ventilators and ventilated eaves, through to turrets and spires in larger public buildings.

Maintaining, reinstating or installing additional roof ventilation is a simple and low-cost way to remove excess heat and humidity in a building's roof space and support the longevity and condition of heritage buildings.



Coronation Hall, Newtown showing traditional roof cowls to the ridge connected to internal ceiling registers (Photo: Steven Barry/Transport for NSW)

## Application

Roof ventilation as an energy efficiency strategy is relevant to most buildings.

## Environmental principles

Roof ventilation should be reviewed in conjunction with roof and ceiling insulation and considered as an integrated system. A balance needs to be struck between maximising the benefits of the insulation and roof ventilation. Insulation loses effectiveness when exposed to moisture, so some air flow is important in maintaining the integrity and function of the insulating material; however, air movement through insulation reduces its effectiveness in heat transfer. Where insulation is not present and cannot be included, roof ventilation becomes more critical.

Roof ventilation promotes natural ventilation by allowing the passive exchange of air. The primary purpose of roof ventilation is to regulate the temperature of roof cavities or buildings by allowing hot air to escape in warmer weather and preventing condensation during colder months.

Excessive heat and moisture in the roof space can accelerate the degradation of roofing materials. Roof ventilation extends the lifespan of roofs by reducing the temperature extremes and moisture levels, preserving the integrity of the structure and insulation. Along with ducted exhaust systems, ventilation can help prevent condensation in the roof space that can lead to mould growth and accelerate deterioration of the roof structure.

Where buildings have a roof space, they can become very hot and radiate heat back down into the occupied space below. The inclusion of insulation at the ceiling level or the line of the roof will reduce the heat load in the roof space and the ability of that heat to move into the habitable spaces below. Roof ventilation can assist in removing excess heat, reducing the performance requirement of insulation.

For buildings without a roof space, such as raked internal ceilings or sawtooth roofs on industrial buildings, ventilation towards the top of these spaces that allows hot air to escape is important in preventing the 'stack effect'.

Most original or early roof ventilators in heritage buildings will work on passive airflow. If supplementing or adding new ventilation, low-energy mechanical roof ventilators are available. All roof ventilation needs to be designed and sized appropriately to ensure it will work as intended.

## Heritage considerations

Many heritage buildings have had roof ventilation removed or compromised over time. This could include complete removal during roof replacement or elements of the system being blocked or removed which impact efficient operation of the whole building. Operable louvred openings to the vertical of sawtooth roofs were common but were often replaced with solid panels if the louvres leaked, preventing the escape of hot air.

**Actions**

- Retain and conserve original roof ventilation. Review effectiveness in combination with other environmental performance strategies, such as insulation, and make any necessary adjustments to ensure all elements function together.
- Check site context, original drawings, historic photos and aerial imagery for evidence of the original/early roof ventilation if none is present.
- Include policies in conservation planning documents to promote reinstatement of original/early roofing ventilation where it has been removed or replaced with unsympathetic alternatives or include reinstatement in project scopes

Further practical considerations when planning roofing ventilation to heritage buildings include:

- reconstruct missing roof vents to original details based on available evidence
- if physical or documentary evidence is not available, additional research into roof ventilation to ensure replacement is appropriate to the size, building type and architectural period should be completed to inform the work
- depending on complexity of the building, roof ventilation may require the input of a mechanical engineer to ensure a balanced outcome
- where additional roof ventilation is recommended, avoid primary elevation or significant views if possible. New elements should be of a high quality and be visually discreet while achieving the required environmental performance.

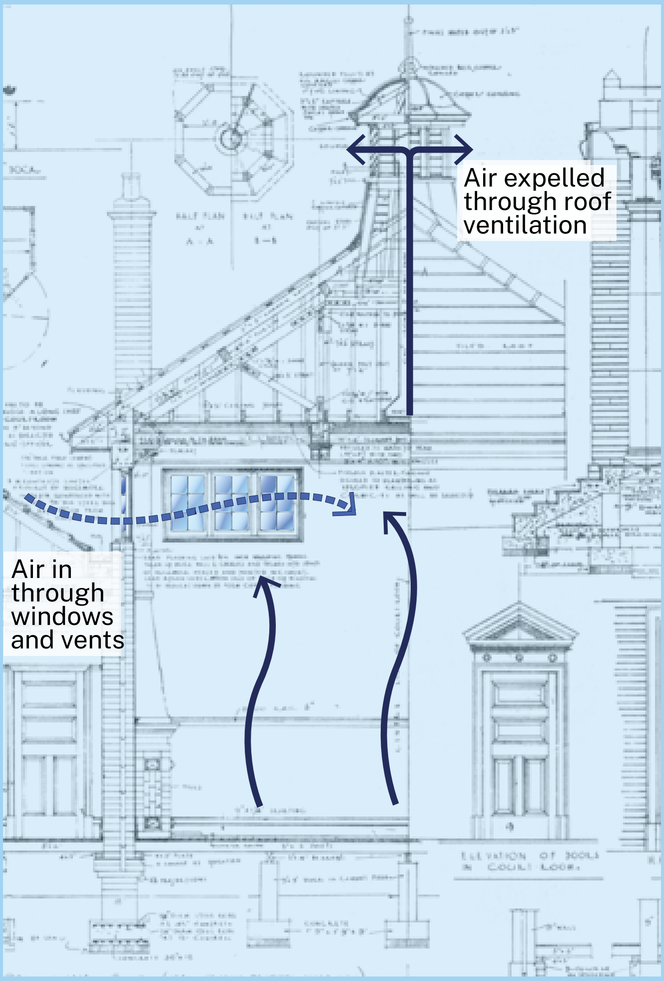
In focus

# Roof ventilation – utility to ornament

A number of examples of roof ventilators are provided below. They serve to illustrate the varied forms that roof ventilators can take, from basic and functional utilitarian building elements to highly ornamented and complex architectural statements.

## NSW courthouses

Designs for early twentieth-century NSW courthouses illustrate the use of roof ventilators over the main court room in almost all examples. Original drawings of Campsie courthouse show the naturally ventilated central court room with central 'turret' or roof ventilator (see illustration and photo below). The cross-sections show a galvanised iron vent tube leading to the louvred 'turret'. Campsie and Bowral courthouses present a more elaborate arrangement for the roof ventilator than other examples. Manly courthouse includes a simple steel roof cowls to ventilate the main space, but the climatic design principles are the same. In both, the upper-level windows allow fresh air into the space and the roof ventilators allow the hot air to escape.




Cross-section of Campsie courthouse showing the naturally ventilated central court room with central 'turret' or roof ventilator with overlay to show air movement (Image: NLA, *Building* magazine, vol 40, No. 229, 11 September 1926)

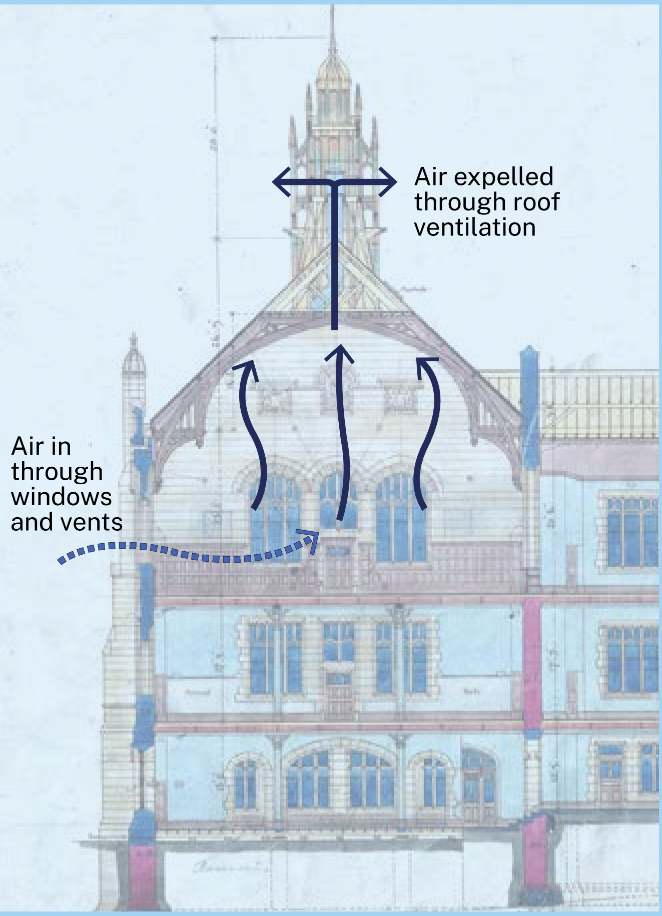

Moss Vale courthouse showing the central 'turret' or roof ventilator over the court room (Photo: Steven Barry/Transport for NSW)

## MacLaurin Hall (former Fisher Library), University of Sydney

As part of additions to the original Fisher Library at the University of Sydney, now MacLaurin Hall, a ventilating fleche was designed and built over the library reading room. The 1902 plans by Walter Liberty Vernon, former NSW Government Architect, show the louvred fleche or spire which is still present today. The drawings show a round duct running up through the centre of the fleche and discharging to the level of the louvres.

The internal ducting would connect to registers or openings in the timber-lined ceiling to the reading room to allow hot air to travel upward and be captured in the ducting before moving horizontally and then upward and out through the centre spire. The section also suggests wall vents at the lower level to allow cooler air at the floor level of the reading room to enter and create the flow of air required to drive the hot air upward.

The design and notations of this elements calling for a ‘ventilating fleche’ reveal a very practical function, but equal (if not more) attention was paid to the design and aesthetic presentation of the spire. Often the aesthetic significance of an element such as this would be highlighted in heritage assessments, but its importance to the climatic response and temperature regulation of the building is less consistently identified, understood and valued. Physical analysis coupled with documentary research is important in identifying and describing such systems.




1902 plan showing the additions to former Fisher Library including ventilating fleche or spire with overlay to show air movement (University of Sydney archives with graphic overlay)

MacLaurin Hall viewed from the Quadrangle showing the copper clad central ventilating fleche with louvres at the upper levels on all sides (Photo: Steven Barry/Transport for NSW

## Measuring benefit

Effective roof ventilation can improve energy efficiency and lead to lower cooling costs. It can also assist in maintaining a comfortable indoor climate and preserve the structural integrity of buildings. Ventilation systems assist in maintaining a healthy indoor environment by preventing the accumulation of pollutants and moisture in the roof space. This contributes to better indoor air quality and reduces the risk of respiratory issues and allergens.

The effectiveness and need for roof ventilation will be influenced by many factors including the interaction with insulation, wind conditions and siting and how exposed the roof is to direct heat gain. Professional input may be required on the determining the need, sizing and location of roof ventilation as well as rejuvenating and integrating existing systems.

Traditional roof cowls sit behind the new high-performance atrium roof of the Bondi Pavilion. The new central atrium drives natural ventilation throughout the building. The glass roof and skirt trap the sun's heat to provide a buoyancy-driven stack effect within the double height space to drive ventilation to the main atrium space. The timber beams act to filter direct sunlight on the surfaces below to reduce heat load (Photo: Brett Boardman for TZG)

## External shading

### Related strategies

Floor and window coverings

Window upgrades

Natural lighting

‘Unlike the rather austere Georgian character of their British counterparts, Australian terraces were quickly amended by the addition of verandahs to temper the harsh sun and heat.’

(Tanner 2015)

External shading of windows and openings is an efficient means of managing the thermal performance of buildings and providing comfortable conditions for occupants. The type and form of external shading varies greatly across heritage buildings and architectural styles in New South Wales. The inclusion of external shading on buildings in Australia occurred quickly to adapt otherwise unsuitable building styles to the NSW climate. Common types of external shading on heritage buildings are fixed or retractable awnings or hoods, louvres and shutters, external blinds and verandahs or pergolas. Verandahs or pergola also provide the added benefit of shaded outdoor space. The expression of these shading types then varies according to the period and architectural style of the building.

Maintaining, reinstating, or installing additional external shading is an effective means of restricting heat gain before it reaches the building, and can also be effective in managing cooling and heating loss.

Historic photo of the Christian Brothers Training College at Strathfield illustrating a range of traditional external shading devices. The lower-level glazing to the projecting bay is protected by external timber louvres, while the upper-level windows feature external venetian blinds. To the right of the bay the balcony and window are protected by an operable canvas blind (Photo: Arthur Ernest Foster collection, State Library of NSW)

## Application

External shading as an energy efficiency strategy is relevant to all buildings. The strategy is more relevant during warmer weather and in warm climate areas of New South Wales. It may be counterproductive to include external window shading in cold climate areas of New South Wales as this could restrict passive heating so operable options might be more suited. Site analysis and overlay with climate conditions is required to confirm application.

## Environmental principles

Windows and other openings are particularly vulnerable to direct heat gain. See 'Window upgrades' in this chapter for further options to improve the energy performance of windows and doors, particularly where external shading is not present or cannot be accommodated due to heritage significance or other factors.

One of the most effective passive means of restricting heat gain from direct sunlight is by externally shading windows rather than trying to mitigate the impact at the window or internally once the heat gain has occurred. External shading helps to regulate internal conditions and reduce the reliance on mechanical cooling and supports minimising overall energy consumption.

The orientation, angle and size of shading devices are important considerations in making full use of available natural light to minimise electric lighting while avoiding heat gain. The design of external shading devices should restrict sunlight on windows or other openings during the warmer months when the sun angle is more acute and the effects of heat gain are more extreme, but allow sun to enter in the cooler winter months when the angle of the sun reduces and passive heating is desirable.

Some shading devices, such as external venetian blinds or operable canvas blinds, provide adaptability and flexibility to occupants to control the amount of light and heat and adjust with user preferences and time of year. Other shading devices, such as window hoods or integrated design elements, are fixed and have ideally been optimised in orientation, angle and size to provide a year-round balance regarding natural light and heat gain.

For warm climate areas in New South Wales, planting deciduous trees on the east-and west-facing aspects can provide shading in summer and sunlight access in winter to moderate heat gain within the building and minimise energy usage for heating and cooling. See 'Landscape' for additional information.

Rouse Hill Estate is a rural property in south-west Sydney and is managed by Museums of History NSW. The main buildings features external timber shutters to regulate light, temperature and natural ventilation (Photo: Katherine Lu for Museums of History NSW)

Fisher Library at the University of Sydney was completed in 1962 and features deep cantilevered concrete ledges which act as window hoods to the glazing below (Photo: Steven Barry/Transport for NSW)

## Heritage considerations

For buildings that have retained original or early external shading, the conservation priority should be to maintain and repair these existing design features. Repairs should be durable given the exposed positioning of these elements and replacement may be necessary.

If external shading is not present but is desirable the following actions will assist in determining whether the building can accommodate additional elements based on heritage significance and what type of devices may be applicable.

**Actions**

- Check site context, original drawings and photos for evidence of external shading elements that may have been removed.
- Include policies in conservation planning documents to promote reinstatement of external shading elements and removal of any unsympathetic shading elements where aesthetic significance and character are identified as part the heritage significance of a building or include reinstatement into project scopes.

| Approach to external shading where it has been removed or was not part of the original design | |
|---|---|
| If external shading was part of the original design but has been removed | • Where evidence of original/early external shading can be obtained, seek to reinstate according to original details.<br>• Where detailed evidence is insufficient to facilitate reconstruction, additional research of historical records or physical analysis of other similar buildings in the area might be needed to inform fabrication and reinstatement. |
| If external shading was not part of the original design but is desired | • Where there is no evidence of external shading consideration should be given to how it can be sensitively included.<br>• Additional research of historical records including trade catalogues, and physical analysis of other similar buildings in the area comparable in age and architectural style would be needed to inform a proposed design. |

New external shading and canvas awnings were added to the Juanita Nielsen Community Centre in Woolloomooloo (Photo: Katherine Griffiths for City of Sydney)

The deep colonnades to the beach (right) are an iconic feature of the Bondi Pavilion. The renewal (left) interprets this element in a contemporary way for the courtyard, providing shading and shelter to the internal building facades to help manage heat load and improve resilience (Photos: Brett Boardman for TZG)

## Measuring benefit

Maintaining or incorporating external shading in heritage buildings can reduce heat gain and contribute to improved energy efficiency and reduced operating costs, mitigate heat-related issues and create more comfortable internal conditions for occupants.

Effective external shading will allow natural light to minimise electric lighting and glare while eliminating the harsh summer sun and allowing less intense winter sun for passive heating.

External shading is a highly effective passive design strategy; however, maximising energy and cost savings from adaptable external shading requires some user interaction or integration with automation technologies. Operation of blinds, louvres and other shading devices to provide the highest level of thermal comfort requires a basic seasonal understanding of when to close and open the building to maximise results.

Where external shading is reinstated or added, comparing energy bills before and after changes should provide data on reduced energy usage.

### Useful links and resources

Sunshine and shade in Australasia – technical report 92/2, CSIRO Publishing 1992

## Related strategies

General maintenance

Improving airtightness

Floor and window coverings

External shading

'Up to 40% of the heat loss, and up to 87% of the heat gain is associated with windows.'

(Sinko and Moore 2021)

# Window upgrades

Traditional single-glazed windows are generally less insulating than the rest of the building envelope and are considered thermal weak spots. Reducing heat flow through windows is an important aspect for maintaining comfortable internal conditions.

Windows are a visually prominent feature of most heritage buildings, so while upgrading or replacing them can be an effective means of improving energy efficiency, any changes need to be carefully balanced against heritage significance. Timber and steel are the most common material for window frames in heritage buildings, with aluminium framing featuring in more recent buildings. The heritage significance, condition, climate region and exposure to direct sunlight will all inform the decision pathway for window upgrades to individual heritage buildings. Options range from simple low-cost repair, draught sealing and applied films, through to the replacement of windows that are beyond repair.

## Application

Window upgrades as an energy efficiency strategy are very relevant to all buildings.

## Environmental principles

Reducing heat flow or heat transfer is the primary objective when upgrading windows – for example, restricting the flow of heat into a building and cool air out during summer, or of cool air into a building and warm air out during winter.

Heat transfer can occur in 3 ways, and it is important to understand the basic mechanisms as each type requires a different physical response. The 3 mechanisms are radiation, conduction and air infiltration.

**Radiation** plays a role in both heat loss and gain. Heat radiates from objects such as people and electrical equipment in long wavelengths, that cannot pass directly through plain glass; however, some radiant energy is absorbed by the glass and conducted through the glass. Similarly, long-wavelength radiant heat from outside can pass indirectly through the glass into the room. Short-wavelength solar energy, including visible sunlight and near-infrared radiation, is also largely transmitted directly through plain glass.

Heat **conduction** occurs with the direct transfer of heat through the window frame and glass. In aluminium frames without a thermal break, heat conducts up to 6 times more readily through the frame than the glass (ReNew 2013). In winter, conduction from inside to outside creates a convection current on the interior of the window, causing accelerated heat loss. If heating elements are located near windows, it can further increase heat loss.

**Air infiltration** is the result of air leaking through gaps between the inner and outer window frames. Poorly sealed windows lead to high air infiltration rates, reducing thermal efficiency as warm or cool air is transferred. See 'Improving airtightness' for options to address air infiltration.

Addressing these heat transfer mechanisms is essential for improving energy efficiency and maintaining comfortable internal conditions. All transfer mechanisms can be addressed in both warm and cool climate areas through increasingly involved upgrades to the existing windows from minor works such as draught sealing and applied films, through to major upgrades such as secondary glazing systems, double glazing and complete replacement windows. These are discussed in more detail below.

In deciding on the right approach to window upgrades, several performance measures need to be overlaid with climate-specific information. Common performance measures will include whole-window U-value, solar heat gain coefficient and low emissivity. Lower U-values indicate better performance. Windows with a lower U-value have a higher resistance to heat flow in all directions and will contribute to an internal surface temperature on the window that is closer to the desired room air temperature. This can be a complex task and specialist advice will be needed in most cases to achieve an optimal and balanced solution. Where windows are of heritage significance there may be limited opportunities to improve the U-value of the framing and instead options will need to focus on the glass and sealing.

In cool and cold climate areas, improving the U-value will improve overall performance and efficiency, but the correct specification for the solar heat gain coefficient is crucial to ensure the upgraded system doesn't prevent passive heating in winter when it is desired, which may negatively impact energy efficiency overall.

In warm climate areas, the solar heat gain coefficient, low emissivity and restricting the infiltration of hot air will be prioritised.

High-performance windows may achieve a U-value of 2–3, which equates to an R-value of 0.5 (ReNew 2013). It is unlikely that such a low U-value will be achieved by upgrading existing windows, and windows will remain a weak spot in the building envelope, albeit improved. This demonstrates the importance of combining energy efficiency strategies including window coverings and 'External shading' to provide a holistic solution to improving environmental performance.

‘There are many options for improving the thermal performance of windows, depending on the nature and significance of existing installations.’

(ARUP et al. 2011)

## Heritage considerations

Where heritage buildings have retained original or early windows, the conservation priority should be to maintain, repair and improve these existing elements. Any improvements should not distract from the heritage significance of the building but improve the overall energy performance and internal comfort.

**Actions**

- Check site context, original drawings and historic photos to determine heritage significance of existing windows.
- Include policies in conservation planning documents to promote reinstatement of windows that have been removed or infilled or replaced with unsympathetic contemporary windows, where aesthetic significance and character are identified as part of the heritage significance of a building, or include reinstatement into project scope.
- Include installation of insect screens with window upgrades to allow windows and doors to be used to support ‘Improving natural ventilation’.

Window upgrades require some additional consideration to supplement ‘Understanding the context and building’ before making decisions. The upgrade options in this table are discussed in more detail below and range from the least expensive and least impactful through to more expensive and greater potential for heritage impact.

Typical timber sash window in the artist studios of The Gunnery. Refurbishment works focussed on operability and addition of UV and security film to improve the environmental performance (Photo: Katherine Lu for DunnHillam)

The glazed south-west facing bedroom (and living room) windows of the J Tuck House captures views over the adjacent protected bushland, as well as maximising natural light and ventilation. The existing glass was replaced to improve thermal performance and safety. The glass within the existing timber framed openings were replaced with double glazing, and the steel framed windows were retrofitted with a low emissivity laminated glass (Photo: Steven Barry/ Transport for NSW)

Discreet hinged insect screens were added to the steel casement windows supporting natural ventilation (Photo: Steven Barry/Transport for NSW)

| Has the heritage value of the existing windows been assessed? Are they of heritage significance? | |
|---|---|
| If significant | • Maintain and seek to improve the efficiency of the existing windows. Specific options include:<br>• upgrading existing windows<br>• secondary glazing.<br>• If the windows are significant, but are beyond repair:<br>• replacement windows or glazing.<br>• Material (timber, steel, aluminium) and window type (sash, casement, awning) need to inform replacement windows that discreetly incorporate improved energy efficiency. |
| If not significant, and/or original windows have been replaced | • If the windows are in serviceable condition, maintain and seek to improve the efficiency of the existing windows. Specific options include:<br>• upgrading existing windows<br>• secondary glazing.<br>• If the windows are not in serviceable condition OR the decision has been made to replace unsympathetic replacement windows:<br>• replacement windows or glazing.<br>• Check site context for evidence and review drawings and photographs for details of original/early windows.<br>• Where detailed evidence is insufficient to facilitate reconstruction, additional research of historical records or physical analysis of other similar buildings in the area might be needed to inform fabrication and reinstatement. |

## Upgrading existing windows

Upgrading existing windows is the most cost-effective and least impactful means from a heritage perspective of improving energy efficiency.

Window restoration incorporating draught sealing will improve airtightness and restrict heat flow. Specialised companies exist to undertake this work and timber joiners experienced with heritage buildings are able to assist with this work.

In addition, films can be added to improve the performance of the glass. Films come in many types with specifications that suit different climate regions. For example, if the priority is excluding direct radiant sun, then a low solar heat gain coefficient is needed. Window films are generally better suited to warmer climates and keeping heat out; however, low-e films can help to reduce the whole-window U-value and will benefit cool and temperate climate regions. Films need to be consistent with the appearance of the heritage building – for instance, they should not be highly reflective. Professional installation is also important to ensure a high-quality finish. This is important not only visually but also in terms of performance, warranty and energy certification. Films can be highly effective, excluding up to 80% of the sun's heat depending on the specification.

It may not be possible to achieve basic upgrades in some rare cases, such as lead-light windows where additions of film and the like are not possible. These elements are generally confined to smaller physical areas and focus should be diverted to other improvement strategies.

These strategies can also be applied to external doors with glazed infill panels that are exposed to direct heat gain.

## Secondary glazing systems

Secondary glazing systems can be added to existing windows as second layer of glazing material and are less expensive than replacing with high-performance windows. The secondary glazing layer is often acrylic but can also be glass. The systems are installed to the inside of the existing window frame, have minimal effect on the external appearance of the window and are largely reversible and therefore more readily accepted for heritage buildings where the existing windows are significant.

There are various suppliers and systems which provide various levels of functionality, but all seek to provide an air gap similar to double glazing. Some are removeable and held in place with magnets, while others are fitted in an operable frame which is important in facilitating natural ventilation. The style and articulation of the secondary glazing unit should complement the existing window to minimise the visual impact. Installation options should also consider maintenance of the original window and ease of cleaning.

### Replacement windows or glazing

Before replacing the whole window, replacement glazing can also be considered in some instances as a lower heritage impact and lower-cost alternative when the window framing can be preserved. Depending on the existing window detail, slimline double glazing within the existing frame may even be possible. This minimises the impact on the character of the window, although it may involve the loss of original or early glazing. Consideration will need to be given to the heritage significance of the existing window including framing and glazing, and the required impact to accommodate the additional thickness and weight of the glass.

Where replacement windows are needed due to condition or because unsympathetic contemporary windows have been installed, it is important to consider the window type, framing material and glazing. Where character and aesthetic significance are important, like-for-like replacement with discreet environmental improvements is likely the best approach. The framing material should be selected based on heritage significance. A study on optimal window designs for Australian houses concluded timber performs best for warm climate zones, which is likely compatible with many heritage buildings. Selecting the material of the frame based on heritage character is crucial, and then ensuring it can be manufactured with a thermal break is important to improving efficiency. This is achievable for most materials, including aluminium.

Glazing, whether it be double or triple glazing with air-or gas-filled voids or incorporating interlayered films, is largely climate-dependent and further advice is needed for individual buildings. It is important to note that the frame is going to be deeper, so it is important to consider how this can be accommodated in existing openings without major modification.

Replacement double glazing or new double-glazed windows still require 'External shading' to optimise energy efficiency and comfort outcomes.

## Measuring benefit

The benefits of window upgrades include reducing the energy consumption required for heating and cooling, and thereby also in reduced heating and cooling system sizes, providing a more stable indoor thermal environment and improving occupant health and wellbeing (Sinko and Moore 2021). Comparing energy bills before and after changes should provide data on reduced usage.

Other site-specific benefits of window upgrades will include improved sound reduction through better insulated and better fitting windows. The exact benefit of window upgrades will vary greatly by site based on the extent of upgrade that is feasible, both financially and from a heritage perspective, but also based on how much glazing makes up the elevation. For example, Modern commercial buildings with glazed exterior walls will be much more reliant on window upgrades for energy efficiency, in comparison to a Colonial Georgian house with small openings.


The Clarence Street facades of Sub Station No. 164 were carefully restored, including detailed recording and replacement of the timber and steel windows.

The replacement windows provided the opportunity to improve the performance of the windows with high performance glazing and improved airtightness supporting the objective of improved operational efficiency. The windows also serve to provide natural lighting to the office space, which is supplemented by circadian rhythm lighting and contemporary skylights to service the deep floor plate.

The project's sustainability focus resulted in a 6-star Green Star sustainability rating, and with the Built head office fitout also achieving a WELL Health Safety rating and 6 Star Green Star and WELL Platinum rating (Photo: Toby Peet for Built)

**Related strategies**

Lighting

‘In moderate climates there is an abundance of natural light; the challenge for the designer is to utilise this natural light to avoid electric lighting without heat gain.’

(Hyde 2000)

# Natural lighting

Building elements such as skylights, roof lanterns, clerestory windows and pavement lights were common design elements for many traditional buildings and natural light was a key tenant of Modern architecture. Deterioration of these elements over time has often seen them replaced with opaque or less transparent alternatives that impact the environmental performance of the building and character of the place.

Reinstating natural lighting where it was part of the original design, or sensitively incorporating new natural lighting elements, can contribute to reduced reliance on artificial lighting and energy usage, and improve the appeal and level of comfort for occupants countering the common narrative of heritage buildings being as cold and dark.


An advertisement from 1909 in *Building* magazine for a ventilating skylight illustrating the availability of these technologies in the early twentieth century (Image: NLA, *Building* magazine, Vol. 3, No. 20, 8 April 1909)

## Application

Natural lighting as an energy efficiency strategy is relevant to all buildings.

## Environmental principles

Natural light can reduce the need for artificial lighting during the day and reduce energy usage while improving occupant wellbeing and productivity. It is a good supplementary strategy to contribute to the overall energy efficiency of heritage buildings.

When reinstating or installing new natural lighting elements, it is important to balance the potential heat and cooling lost through the new element. Considering the placement or orientation of new elements to minimise heat gain in warm climate areas is important. South-facing roof elements will provide diffuse natural light with minimal direct heat gain. For cold climate areas, incorporating operable internal coverings can help to minimise heat loss – see 'Floor and internal window coverings'. Investing in high-quality glazing and operation systems as part of reinstating or installing new natural lighting will maximise the effectiveness of this strategy.

Natural lighting initiatives can be optimised at larger scales through 'daylight linking' – see 'Lighting' for further information. Daylight linking of artificial lighting can be achieved with smart control systems. The introduction of natural lighting elements should reduce the need for artificial lighting, which can be monitored by discreet sensors and artificial lighting adjusted for user comfort and maximum environmental performance. See 'Smart technologies' for further detail on zoning and lighting controls.

## Heritage considerations

Natural lighting elements are often a weak point for watertightness, particularly as the system ages and seals deteriorate if not maintained to the level required. In heritage buildings this often means they have been removed and replaced with alternative materials that are easier to maintain. Industrial buildings often included glazing to the vertical elevation of sawtooth roofs and Modern architecture saw the advent of glass curtain walls. Although very different systems, both are susceptible to deterioration, leaking and eventual replacement.

**Actions**

- Check site context, original drawings and aerial imagery for evidence of natural lighting elements that may have been removed.
- Include policies in conservation planning documents to promote reinstatement of natural lighting elements, or include reinstatement into project scopes.

The following case study helps to illustrate this approach that can be scaled to any building.

In focus

# Reinstating skylights to enable daylight linking – Central Railway Station

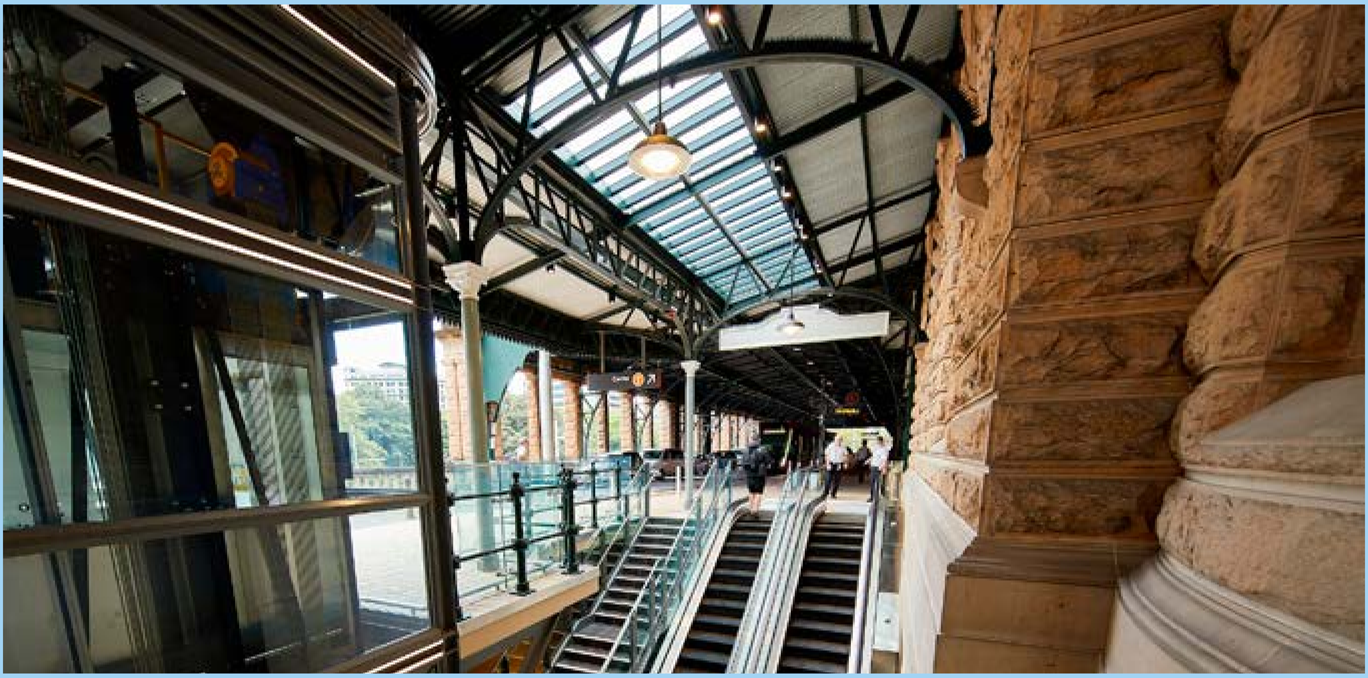
Central Railway Station is a good example of a site where many daylight openings have been removed. These changes often occur incrementally; however, in the case of Central it was a severe hailstorm in January 1947 that destroyed many of the skylights. Skylights were replaced with steel roofing or substantially reduced due to a scarcity of replacement glass at the time. This compromised the integrity of the building design and reduced the amount of natural light.

This also highlights how heritage buildings can be susceptible to the pressures of climate change and worsening weather events and the critical need for heritage buildings to be part of the solution to curb carbon emissions.


Image extract from January 1947 showing extensive damage to the Central Railway Station skylights which was the trigger for extensive replacement in less transparent or opaque materials (Photos: *Sydney Morning Herald*)

Transport for NSW is working to reinstate these elements through specific projects in accordance with the Central Railway Station Lighting Strategy. The intent is to reinstate original design elements while also reducing daytime energy usage by lowering the need for artificial lighting through a principle of 'daylight linking'. Lighting Principle 2.57 Daylight notes that 'in some areas, daylight openings have been closed-such opportunities for architectural modification, reinstating or introducing natural light should be assessed and implemented where appropriate.'


1924 image showing a skylight over the colonnade awning to the north-west corner of Central Station (Photo: NSW State Records)



The awning skylight at Central Station was reinstated as part of a customer accessibility upgrade which included a new lift, stair and escalator. The skylight was reinstated to its original configuration along with reproduction heritage pendants with LED technology, and secondary architectural feature lights (Photo: Transport for NSW)

Glazed and louvred openings are used to provide natural light and fresh air to the Walsh Bay Arts Precinct. Ceiling fans and bar heaters are used to provide additional low-energy environmental control in the outer circulation spaces of the building (Photo: Brett Boardman for TZG)

Further practical considerations when planning new natural lighting elements in heritage buildings where aesthetic significance and character are identified as part the heritage significance include:

- in addition to considering siting and location for heat and cooling loss, the position of new elements should be visually discreet and not detract from the principal views of a building
- consider the set-out in relation to other building elements, symmetry and colour to support a discreet installation
- if the natural lighting element is integrated into the roof, check that the structural capacity of the existing roof is sufficient to take the weight of the new element. If structural strengthening is required, this should be confined to internal structural augmentation and supported by an engineer with experience working with heritage buildings.

## Measuring benefit

Reinstating or installing new natural lighting elements should contribute to reductions in in energy use and costs associated with lighting particularly in areas with high daytime usage. It is critical to consider positioning and shading to avoid unintended increases in energy usage to combat additional heat gain. Comparing energy bills before and after changes should provide data on reduced usage. For more specific data collection temporary or permanent sub-metering can be considered for high energy use areas. Daylight also provides a connection to the outside and can improve wellbeing and productivity.

### Useful links

Your Home – Skylights and roof windows

## Roof and wall colour

> ‘When dark-coloured roof surfaces are exposed to strong sunshine, a high proportion of the heat available in the sun’s rays is absorbed and conducted downwards to the body of the roof.’
>
> *Building* magazine, October 1935

Light-coloured construction materials have well-established benefits for the thermal performance of buildings. ‘Whitewashed cottages’ are recorded as early as 1790 in Sydney and, along with the development of limewashing, these techniques were used extensively as means of protecting building fabric and have the added benefit of minimising solar absorption. Traditional building colour schemes typically leaned towards light and natural tones; however, contemporary taste has shifted towards darker-coloured building materials and finishes. This broad trend extends to heritage buildings.

The renewal of heritage buildings provides an opportunity to reinstate historical materials and finishes and potentially improve the thermal performance of the external building envelope. This opportunity arises when the chosen replacement material or finish not only aligns with the building’s heritage significance but also has the potential to achieve a lighter external appearance.


The Street’s Ice Cream factory in Turrella with light-coloured external walls demonstrates understanding of building colour and thermal performance – particularly important in keeping ice cream cold (Photo: Arthur Ernest Foster Collection, Mitchell Library, State Library of New South Wales)

## Application

Roof and wall colour as an energy efficiency strategy is relevant to all buildings. The strategy is more relevant during warmer weather and in warm climate areas of New South Wales.

## Environmental principles

Light-coloured building materials and finishes can make an important contribution to the energy efficiency and climate adaptation of heritage buildings.

Light-coloured materials with high reflectivity help in maintaining cooler indoor temperatures by reflecting a larger portion of sunlight. This reduces the heat load on a building and the need for air conditioning or other mechanical cooling, ultimately improving energy efficiency.

The reflectivity of materials is measured by the Solar Reflectance Index (SRI) or solar absorption (SA). Light-coloured materials generally have a high SRI and low SA, indicating their ability to reflect solar radiation. These properties help in keeping the surface of buildings cooler. As the climate changes, with higher average temperatures and extreme weather events increasing in frequency, the use of light-coloured building materials, where aligned to a building's heritage significance, can assist in adapting heritage buildings to different climate patterns.

The Building Code of Australia (BCA) mandates the maximum SA value for roofing and other building materials. Adhering to the BCA and other relevant ratings will ensure compliance with minimum standards, but taking opportunities to exceed the minimum where possible will help to further improve energy efficiency, cost and occupant comfort.

These principles extend beyond the building envelope to adjacent materials such as ground treatment and paving.

## Heritage considerations

Where aesthetic significance and character are identified as part the heritage significance of a building, and the roof or wall colour are to be changed during renovations or major works, the new material and colour palette should support the heritage values of the site and implement opportunities for light-coloured materials where these objectives align. Roof replacement is an ideal opportunity to assess natural ventilation of the roof. See 'Roof ventilation' for further detail.

### Roofs

Slate, corrugated steel and tiles are the most common roofing materials for heritage buildings in New South Wales. The different materials offer varying levels of opportunity to affect change when it comes to colour selection during replacement. For example, slate roofing has a high solar absorption but is likely to be a significant heritage element, so the opportunity to change this for a material and colour with a lower solar absorption is limited. Similarly, traditional terracotta tiles have a medium to high solar absorption but opportunities to change this for thermal performance alone are also unlikely to be supported. In cases where a material and colour change cannot be actioned to improve the thermal performance of a roof, other strategies – mainly roof insulation – will need to be deployed to manage heat gain.

**Actions**

- Check site context, original drawings, historic photos and aerial imagery for evidence of the original/early roofing material if it has been replaced.
- Include policies in conservation planning documents to promote reinstatement of original/early roofing material where it has been replaced with unsympathetic alternatives or include reinstatement in project scopes.

Roof material and colour requires some additional consideration to supplement 'Understanding the context and building' before making decisions.

| Has the heritage value of the existing roofing been assessed? Is it of heritage significance? | |
|---|---|
| **If significant, and in serviceable condition** | • Maintain and seek to improve the thermal efficiency of the roof through insulation (if not already present). |
| **If significant, and in poor condition requiring replacement** | • Confirm the roofing type is original/early and that like-for-like replacement is appropriate.<br>• Explore opportunities with the replacement material to sensitively incorporate materials or finishes with a higher SRI. |
| **If not significant, and in poor condition requiring replacement** | • Check site context for evidence and review drawings and photographs for original/early roofing material.<br>• Where evidence of original/early roofing can be obtained seek to reinstate while achieving the highest SRI possible for the material required. |

Further practical considerations when planning roofing replacement to heritage buildings include:

- painting corrugated iron roofing is a common practice to extend the life of the material. If painting is being considered, explore heat-reflective paints. Heat-reflective paint technologies are emerging from a range of suppliers and are a particularly important consideration where a dark finish is required to support heritage objectives
- galvanised corrugated iron is a very common roofing material for a broad range of heritage building types and has a light to medium solar absorption rating. Seek to reinstate raw galvanised corrugated iron roofing where it was the original roofing material and finish – this should achieve a positive heritage outcome and provide a good solar absorption value
- use of Colorbond steel roofing in place of traditional galvanised iron roof sheeting should be avoided for heritage buildings due to the differing profile depth and visual outcomes. It can be justified where environmental factors such as proximity to marine environments or industrial emissions would prevent manufacturer warranties for galvanised roofing. Colorbond Windspray is a close match to galvanised steel and achieves a high SRI.

## Walls

Similarly to roofs, the different materials used in external wall construction offer varying levels of opportunity to effect change when it comes to colour selection during replacement or repainting.

Unpainted masonry, including brick and stone, should remain unpainted and the SRI for those elements is largely fixed. In these cases, external shading and supplementary landscaping might be used to protect exposed walls and reduce solar absorption. The possibility of selecting lighter colours that are aligned to heritage significance primarily applies to timber weatherboard, painted masonry and steel or sheeted buildings.

**Actions**

- Check site context, original drawings and specifications and historic photos for evidence of the original/early paint schemes.
- Consider commissioning a paint scrape analysis in conjunction with the documentary research noted above to better understand the original/early paint schemes. Note this analysis is only effective where repainting hasn't removed all previous paint layers.
- Consider light-coloured paint schemes where they align to the heritage significance and architectural period of the building.
- Include policies in conservation planning documents to promote reinstatement of original/early paint schemes.

Restoration works to the Parliament of NSW reinstated the original Georgian-inspired colour scheme. This lighter colour scheme enhances the heritage values of the place while also increasing the solar reflectance of the building helping to maintain thermal comfort (Photo: Steven Barry/Transport for NSW)

## Measuring benefit

> 'Light coloured roofs are estimated to reflect up to 70 per cent of summer heat gain – around 50 per cent more than a dark roof.'
>
> (Australian Government 2014)

Incorporating light-coloured roof materials and wall finishes where they align with heritage significance can significantly reduce heat absorption and subsequent energy use in cooling. These materials contribute to improved energy efficiency and reduced operating costs, mitigate heat-related issues and create more comfortable internal conditions for occupants.

Careful selection of material colour, including roofs, walls and pavements at a site-specific level, has the potential to contribute to broader objectives that are becoming increasingly important for climate adaptation. Research from Western Sydney University suggests broader positive benefits related to urban heat mitigation through site-specific responses, noting that ambient temperatures in suburban areas can be reduced by 2–10 °C through the inclusion of light-coloured roofs.

### Useful links

Ian Evans, Clive Lucas and Ian Stapleton (1992, reprinted 2008) – *(More) colour schemes for old Australian houses*

## Key actions checklist – energy efficiency fabric upgrades

| Strategies | Key actions |
|---|---|
| Energy efficiency fabric upgrades (overall) | ☐ Professional input and specifications from a range of disciplines including heritage, architecture and engineering are required for many of the strategies in this chapter given the complexity and interaction with building fabric and systems. Targeted input and key times and will help to optimise energy efficiency and building outcomes.<br>☐ Installation of upgrades should be undertaken by licensed tradespeople and certified installers and should be informed by a heritage specialist. |
| Insulation | ☐ Review existing insulation (if any) to determine the R-value and condition if renewed or new insulation is required, determine the correct R-value and insulation type based on the climate zone<br>☐ Prioritise roof insulation, followed by floor and finally wall insulation if budget constraints require a staged approach. |
| Roof ventilation | ☐ Retain original/early roof ventilation where present<br>☐ Determine the existing ventilation rate (normally measured in air changes per hour) and the optimal rate – too little and it won't be an effective strategy, too much and it can increase heating costs in cool climate areas<br>☐ Where additional roof ventilation is required, research appropriate types seeking sufficient information to reconstruct missing features or supplement with discreet, high-quality contemporary options. |
| External shading | ☐ Retain original/early external shading where present<br>☐ Where additional external shading is required, research the building for previous evidence or appropriate types seeking sufficient information to reconstruct missing features<br>☐ Where external shading was not part of the original design, but is desired, continue research to support sympathetic inclusion. |
| Window upgrades | ☐ Determine heritage significance of existing windows<br>☐ Identify opportunities to reinstate windows that have been removed, infilled or replaced with unsympathetic contemporary windows<br>☐ Select the window upgrade strategy based on heritage significance and budget<br>☐ Include installation of insect screens with window upgrades to promote use and natural ventilation. |
| Natural lighting | ☐ Identify opportunities for reinstatement of natural lighting and daylight linking to reduce artificial lighting needs<br>☐ Where natural lighting was not part of the original design, but is desired, new elements should be carefully located from an environmental performance and heritage point of view<br>☐ Where the new element is in the roof, structural capacity should be checked by an engineer. |
| Roof/facade colour | ☐ Research original/early colour schemes for buildings of the same type and period<br>☐ A paint scrape analysis may be commissioned for some sites.<br>☐ Where reroofing and/or repainting is proposed identify opportunities for a colour palette that aligns with the significance of the building while also being lighter and having better SRI<br>☐ Where dark colours are part of the original/early scheme it may be appropriate to explore heat-reflective paint technologies. |

Case study

# The Gunnery

DunnHillam have conserved and transformed The Gunnery at Woolloomooloo as a renewed home for Artspace.

The Gunnery has been home to Artspace for the past 30 years and has been comprehensively transformed. The NSW State Heritage Register listed building has undergone a major upgrade to included expanded exhibition spaces, increased artist studios, multi-use spaces for education and improved accessibility, and better connection to the neighbourhood and foreshore.

Central to the project was the careful conservation and restoration of the former bond store. Through the process of removing decades of non-original building elements, the new layout and building program for the contemporary art facility was woven through the robust masonry and timber heritage fabric.

Enabling the ongoing use of The Gunnery creates value for the community and ensures the building is cared for and maintained. Particular attention was paid to maintenance and repair, upgrading services, fabric upgrades and onsite renewable energy generation in delivering a facility that will support and provide a backdrop to the ongoing success of Artspace.


The main entrance was reoriented to the Forbes Street Plaza giving the building a more generous approach. The parapet conceals the solar photovoltaic system that helps power the building (Photo: Katherine Lu for DunnHillam)

'The transformation of The Gunnery is a remarkable way of imagining a new future for artists and audiences in the iconic Gunnery building here in Woolloomooloo.' Alexie Glass-Kantor, Executive Direct, Artspace

## Quick facts

**Project type:**
Public

**Client:**
Create NSW/Artspace

**Heritage listing:**

- NSW State Heritage Register
- Local heritage list

**Project team:**
Architecture – DunnHillam

Builder – FDC Building

Heritage Consultant – GML Heritage

Structural Engineering – John Carrick Pty Ltd

Services Engineering – JHA Engineers

Fire Engineering – Minerva Group

Town Planning – SJB Planning

BCA and Access – Group DLA

Quantity Surveying – MBM Consulting

Security – SCG

**Location:**
43–51 Cowper Wharf Road, Woolloomooloo

**Year:**
2023

The key environmental performance upgrades delivered as part of the project include:

- adjusting the building program to respond to thermal comfort and energy use where changes to the fabric could not be achieved. For example, the unprotected west elevation is subject to higher heat gain and, as such, was planned as the location of transient spaces where people move through quickly
- refurbishing the existing timber windows to be operable throughout the building to supply fresh air and natural light. Works included the addition of UV and security film to improve overall performance
- installing mixed-mode heating and cooling to the offices and artist studios with fresh air supplied from the refurbished windows. New efficient mechanical ventilation was provided to the remaining areas of the building
- replacing the roof, which had reached the end of its functional life, and capitalising on the opportunity for inclusion of increased roof insulation and thermal breaks. The roof also supports a 30 kWh solar photovoltaic system concealed behind the masonry parapet
- integrating the mechanical systems on a building management system with demand response control to manage peak electricity loads
- selecting energy-efficient LED lighting, electric hot water supply and water-efficient fittings throughout the project.

Material selection for new elements focused on longevity, avoiding petrochemicals, maintenance requirements and minimising the addition of embodied carbon. For example:

- a steel-framed lift shaft with screw piles was selected to reduce weight and the need for concrete, resulting in a less carbon-intensive option
- the mixed-mode ventilation strategy reduced the amount of insulated ducting required
- careful reticulation of cabling and services to reuse existing penetrations reduced wastage and significantly reduced new cabling.

The ground floor exhibition space provides a visual connection to Sydney Harbour. Operable windows to the gallery space provide natural light and ventilation (Photo: Katherine Lu for DunnHillam)

**Heritage significance and history**

The Gunnery has seen many uses since its construction in the early twentieth century. Starting out as a bond store for Fairfax newspapers, it was repurposed as a naval training building at the end of World War II as a gunnery instructional centre. The name 'The Gunnery', has stayed with the building despite further changes in use which saw the building occupied as an artist squat for 30 years, and eventually designated for community use in the 1980s.

The resident artists fought for the heritage listing of the building to prevent demolition, and the building was refurbished in 1992 as a visual arts centre. The recent transformation at The Gunnery represents an ongoing commitment to the arts and cultural scene of Sydney and provides Artspace a home that is fit for purpose now and for many years to come.

Photo: Steven Barry/Transport for NSW

# 4 Renewable energy

## Incorporate appropriate renewable energy technologies

The renewable energy options set out in this chapter explore on-site and off-site opportunities. Site suitability, heritage impacts and cost may limit opportunities for on-site renewable energy generation. The viability of on-site generation should be thoroughly evaluated before moving to the purchase of renewable energy from the energy grid or off-site generation, which are viable alternatives for some heritage buildings. It is important to strike the balance between heritage and broader environmental outcomes.

Lowering energy demand through the implementation of all relevant improvement strategies in Chapters 1–3 will reduce the size of the renewable energy system required and the embodied carbon of producing that system. Once energy efficiency has been optimised, the next step of the process is confirming an appropriate renewable energy technology and system size for on-site applications.

Incorporating on-site renewable energy technology in heritage buildings must meet 2 criteria – the application must be sympathetic to the heritage values of the building and must meet standard feasibility requirements. The technical feasibility assessment to confirm whether on-site renewable energy technology is viable should follow the same principles for heritage buildings as those applied to all other buildings and consider site suitability, including orientation and shading, financial, and life cycle assessment.

Renewable energy technology will have a short service life compared to heritage buildings so installations should take a reversible approach with minimal impact to building fabric and discreet design and installation to enable removal and ongoing replacement as the technology evolves. As the efficiency of new generation systems increase through technological improvements, the size and type of installation needed to achieve a building's required energy generation will continue to change and may shrink, allowing the system to be refined and reduced in physical size and potential heritage impact overtime.

This chapter covers 4 key areas of renewable energy. Table 6 outlines the potential impact of each of these across energy savings, heritage impact, upfront costs and maintenance difficulty.

> 'Demand reduction through energy efficiency must be considered the first priority in any building as it includes a large number of strategies offering significant operational carbon reduction potential. Maximising onsite low carbon energy supply, and then offsite supply, of renewables should be the subsequent options to meet the remaining energy demand. '
>
> (Prasad et al. 2022)

**Table 6** Impact summary – renewable energy

| | Carbon savings | Heritage impact | Upfront costs | Maintenance |
|---|---|---|---|---|
| Solar photovoltaic panels | ●●● | ●●○ | ●●● | ●●○ |
| Small-scale wind | ●●○ | ●●○ | ●●○ | ●●○ |
| Battery storage | ●●○ | ●●○ | ●●● | ●●○ |
| Off-site renewable energy | ○○○ | ○○○ | ●○○ | ○○○ |

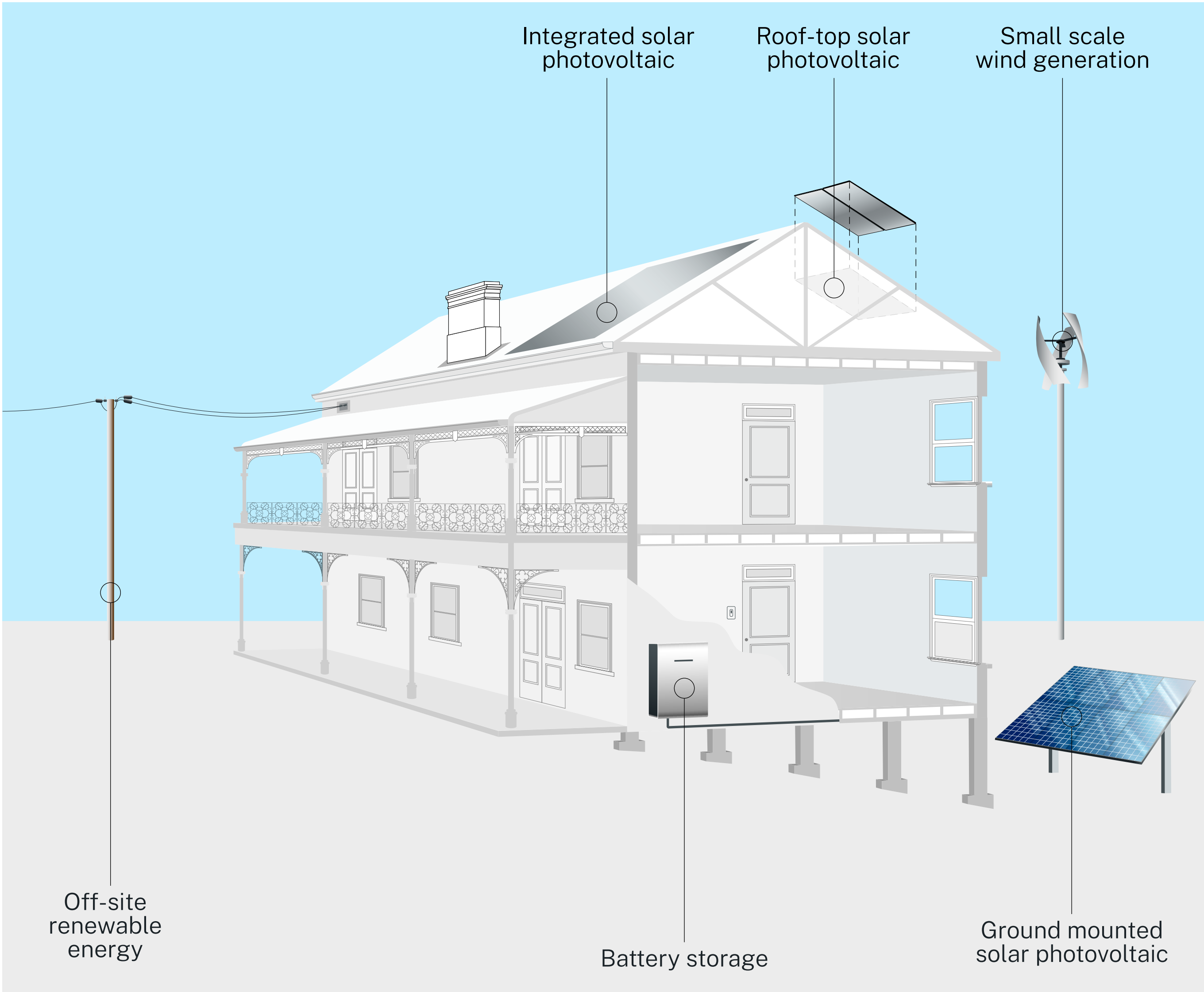



**Figure 7** Diagram illustrating a summary of the energy reduction strategies under renewable energy

# Solar photovoltaic systems

'Australia has the highest uptake of solar PV systems globally.'

Clean Energy Regulator, Australian Government

Solar photovoltaic panels (also known as solar PV) accounted for 6.5% of the total electricity generated in Australia in 2020, with 20% of NSW homes having solar energy installations (Clean Energy Council 2023). Solar PV systems can provide substantial energy cost savings and significantly reduce reliance on non-renewable energy sources supplied through the energy grid, mitigating variable energy pricing and overall carbon footprint.

Solar PV system installations are increasing at a rapid rate and will continue to make up an important part of Australia's renewable energy supply and contribute to emissions reduction targets.

59a Reynolds Street, Balmain is within a heritage conservation area and won the 2023 Marrickville Medal for Conservation. This oblique view of the house shows a discreetly located solar PV system set well down from the ridgeline in a dark colour. Coupled with neat installation this results in a balanced outcome from the street (Photo: Saskia Wilson for SAHA Architects).

The visual impacts of solar PV systems on heritage buildings have led to some difficulties in the uptake and approval of new installations. With increasing awareness of the changing climate and the improved technical efficiency resulting in less solar panel area for the same or greater energy output, along with improved finishes and quality, the concerns that have historically caused resistance to installation on heritage buildings are reducing and there is support for well-designed, visually discreet installations where the heritage impact can be minimised.

Approval processes for solar PV systems have also been streamlined in New South Wales through inclusion in the State Environmental Planning Policy (Transport and Infrastructure) 2021 as exempt development. Many local councils are following with simplified approval processes for solar installations for heritage items and heritage conservation areas. These changes further highlight the importance of the technology in the NSW energy landscape. It is important that heritage buildings are given the best possible opportunity to make use of solar PV systems to reduce energy costs and offset rising energy and maintenance costs.

Energy performance is becoming an increasingly important indicator, particularly for commercial properties, so it is important that heritage buildings can achieve comparable ratings to newer buildings to continue to be attractive and viable options in the marketplace to support ongoing use.

## Application

Solar photovoltaic panels as a renewable energy option are broadly applicable to all buildings subject to site feasibility, heritage assessment and statutory approvals.

## Environmental principles

Solar PV cells convert sunlight into DC (direct current) electrical energy. A solar inverter converts this electricity into AC (alternating current) power for use in buildings instead of drawing electricity from the energy grid (Clean Energy Council, 2020).

### System options

Solar PV systems can be set up in a few different ways to suit how and when a building is being used. Given the reliance on sunlight to generate electricity it must be consumed as it is being generated, stored in batteries or excess exported to the energy grid. Understanding how and when a building is being used is critical in determining the appropriate size and system setup to optimise the performance of the installation. For example, a business with standard operating hours and low overnight energy usage may not benefit from battery storage, while a home where energy use peaks in the late afternoon and evening might benefit more from battery storage.

The systems are generally described as follows.

- **Grid-connected** – energy produced by the solar PV system will be used to power the building, including fixtures, appliances and processes as the priority. Any excess electricity is fed back or exported to the energy grid. If the energy produced by the system is insufficient to meet demand, additional power will be drawn from the energy grid to make up the shortfall.
- **Grid-connected with battery back-up** – a variation on grid-connected that adds battery storage to the setup, allowing electricity to be stored during the day to be used at night when the solar system is not generating electricity. For more information on incorporating batteries in a renewable energy setup see Battery storage below.
- **Stand-alone** – not connected to the energy grid for exporting excess or to make up for shortfalls in energy supply. These systems are more common in remote areas where connection to the energy grid is not possible. Battery storage or generators are needed to store and supplement energy supply.

### Load shifting

Combining physical improvement strategies with specific timing changes to align with solar PV systems can have significant impacts on system selection and reliance on the energy grid. Behaviour change can help maximise the efficiency and use of solar PV systems in a process termed load shifting, to move peak demand to match times of solar generation. 'Load shifting means adjusting the timing of energy use to better align with renewable generation. Load shifting can be very dynamic, such as shifting energy demand on a very hot day, or permanent, such as always running water heaters in the middle of the day' (Energy Efficiency Council 2023). Examples of load shifting include running washing cycles during the daytime, or pre-warming or pre-cooling spaces during the day when renewable energy from solar is available, ready for the evening.

### Solar PV panels

The output from a solar PV system is influenced by the angle or tilt, orientation, shading and efficiency of the PV cell. There are 2 main forms of solar panels, polycrystalline and monocrystalline. The blue-coloured polycrystalline panels are cheaper but less efficient. Monocrystalline panels are darker and offer greater efficiency, improved performance in cloudy and hot conditions and a longer lifespan (Whitehouse et al. 2018). As monocrystalline panels are more efficient, fewer panels are required for the same energy output, which helps to resolve challenges for heritage buildings relating to location and spacing. In addition, they are visually more refined and better suited to the neat and unobtrusive installation outcome that heritage buildings will need to achieve.

The technology and efficiency of solar PV panels is always improving, so it is important to research available certified options at the time of planning an installation.

### Embodied carbon

A common question around solar PV systems is whether they generate sufficient energy to outweigh the embodied carbon produced through the manufacture, transport and installation. The 'solar lifecycle test' published in ReNew (2009) and authored by Andrew Moore determined that the average energy payback period on the embodied carbon was 2 to 3 years. This assessment was based on a 30-year service life for the panel and 15 years for the inverter. It also assumed a north-facing roof with a 20-degree angle and no additional shading. Less optimal conditions and reduced energy generation will impact the energy payback period to some degree.

## Heritage considerations

In considering the opportunity for on-site energy generation, the feasibility of minimising heritage impacts will vary by site. A heritage specialist and renewable energy advisor will need to weigh up factors such as heritage significance and character on one side, and site orientation, broader environmental context and usage requirements on the other in determining the feasibility of proceeding for any given site.

In some instances, it may be concluded that a heritage building cannot support a solar PV system without adverse heritage impacts, or that only a smaller system can be accommodated that offsets some but not all site energy demand. In those cases, alternative opportunities for achieving on-site energy generation or off-site purchasing will need to be explored. These are discussed in the section on off-site renewable energy below.

There are several options for installing a solar PV system. The options are described in the following section along with the key challenges and strategies to consider when planning a solar PV system at a heritage site.

## Rooftop solar

Rooftop solar PV systems are the most common installation type. They involve fixing a supporting frame to the existing roof structure that the PV panels are then secured to. The frame sits over the existing roof covering such as corrugated steel, tiles or slate.

Where aesthetic significance and character are identified as part the heritage significance of a building, the location of solar PV system should seek to minimise visual and physical impacts resulting from their location, scale, form, colours, reflectivity and installation.

### Location

Considering all possible locations for rooftop solar PV systems is an important first step.

The first preference in heritage management is to avoid any adverse impact, so it will need to be confirmed that the heritage building/s is the only viable location. Consider secondary structures which may be of lesser heritage significance or less visually prominent, such as ancillary buildings, garages, carports or sheds.

See 'Ground-mounted solar PV systems' below for further information to avoid rooftop installation if an appropriate location cannot be found.

If the main heritage building is the only viable option, the following criteria apply in refining the location:

- solar PV panels should not detract from the principal views of a building
  - avoid complex and/or small street-facing roofs where the solar PV system is broken down into irregular panel configurations
  - side and rear elevations are preferred where these provide necessary solar access and are not subject to overshadowing. The Clean Energy Council notes that 'north facing is optimal, but not essential'. East–west arrangements could be just as effective depending on building use and ability to use load shifting to optimise efficiency
  - set solar PV panels down within a valley roof or a behind a parapet wall to avoid visibility where possible
  - set solar PV panels as far back on the building as possible so they are less visible from the street
  - well-designed and appropriately sized solar PV systems may be possible on simple street-facing roofs
  - avoid placement on verandahs and dormer roofs.

**Design**

Design refinement can play an important role in further reducing the visual impact of a solar PV system and must consider set out, symmetry, colour, contrast and framing:

- panels should be mounted at the same angle as the roof plane and as close to the roof surface as feasible for a streamline appearance
  - flat roof installations may require a tilt frame to achieve a viable angle. Where required this should be set back from the edge of the roof and ideally concealed from view by a parapet wall or similar.
- the principal roof form should remain intact and readily legible
  - roof elements such as chimneys, ventilators and parapets should not be impacted to accommodate solar PV systems
  - solar panels should be parallel to the slope of the roof face
  - solar panels must not extend beyond the edge of the roof plane and should be offset evenly from the ridge, eaves and roof edge. The minimum offset should be determined on a case-by-case basis determined by the scale of the roof. The purpose of the offset is to ensure that enough of the roof remains visible to be legible
  - panels should be evenly spaced between roof features such as chimneys, skylights and clerestory windows.
- panels should be arranged in neat rows and paired. If there isn't sufficient space to maintain a paired layout the system size should be reduced by a panel
- supporting framing is generally available in a number of colours, including black or natural silver. Select the least obtrusive colour to complement the roof covering and panels.

**Installation**

Once the visual impacts are mitigated as far as practicable through options analysis and design, the physical impacts associated with installation need to be considered and managed:

- confirm the existing roof covering is in good condition, weathertight and accessible to allow installation and ongoing maintenance such as cleaning, which is important in maintaining optimum efficiency of solar PV panels
- ensure replacement roofing material is readily available should any be accidentally damaged during installation
- check that the structural capacity of the existing roof is sufficient to take the weight of the new equipment. If structural strengthening is required, this should be confined to internal structural augmentation and supported by an engineer with experience working with heritage buildings

- solar PV systems should be optimised to meet site energy demand requirements and limit the number of fixing points required through the roof covering
  - care and attention to detail is needed to ensure that the framing installation is waterproof in order to avoid water ingress to the roof space and building. Requirements will vary by roofing material
- compatibility of all roofing materials and new equipment needs to be checked to avoid galvanic corrosion, which can lead to accelerated deterioration of fabric
- mounting frames should be trimmed of any excess and finish at the panels and clips
- new cabling containment for the connections between the solar PV panels and inverters should be neat and discreet
- see 'Equipment' below for further information on location and installation of associated elements.

Walsh Bay Arts Precinct incorporates a large-scale solar PV system across the State Heritage Register–listed site. On the visible roof planes, the panels are neatly and symmetrically arranged around the clerestory windows and offset from the eaves and ridge evenly. The low profile and uniform installation maintain legibility of the roof form. The internal valley roofs of Pier 2/3 and Wharf 4/5 also support solar panels, which are not visible from ground level (Photo: Richard Crookes Construction)

### Ground-mounted

In situations where rooftop solar PV systems are not feasible, or heritage buildings sit in an expanded or rural setting, a ground-mounted solar system might be a viable alternative. Panels and equipment are fixed to a frame and can be set at an optimised angle and orientation.

Further practical considerations when planning ground-mounted solar PV systems include:

- visual impacts of a ground-mounted solar PV system still need to be considered. The system should not be visible in significant views of a building or garden setting. Opportunities for screening the system with landscape measures might be considered, but should not overshadow the panels
- archaeological constraints may arise from the need to excavate for the cabling to run from the solar PV system back to a building distribution board. Alternative routes should be explored to avoid archaeological features
- site analysis needs to confirm that the system will not be in shade as this would reduce the efficiency and output of the system
- vandalism and security needs to be considered given the accessibility of the solar panels and equipment.

### Roof/surface-integrated

To mitigate the visual impacts of rooftop solar, the renewable energy industry has invested in the research and development of roof-or surface-integrated solar PV technology. This can take the form of thin film solar technology in glass or full integration into replacement slate and terracotta roofing. This technology is in development and has been undergoing trials. Given the technology is still in its infancy, it is more expensive than traditional systems and has a longer payback period (Whitehouse et al. 2018).

Thin film solar PV integrated in glass will change the material character and transparency of the glass. Glazing shouldn't be replaced to integrate thin film solar PV if the glazing is original or significant. If glazing needs to be replaced, the change in visual character from introducing thin film solar needs to be carefully considered.

Similarly, roof-integrated technology relies on the replacement of the existing roofing material. This should only be considered when the existing roof is at its end of life and needs replacement, and the heritage significance of the place cannot accommodate a rooftop solar PV system. The replacement solar PV tile material would need to match the existing or original roofing in all aspects, including size and colour.

### Equipment

In addition to the solar PV panels, other equipment is necessary to complete the system, including inverters and possibly batteries. This equipment will need to be in proximity to the existing electrical distribution or fuse board.

Where equipment is proposed to be fixed to the wall of a building, the number of fixing points should be minimised. Although fires associated with solar PV equipment are rare, there is an opportunity to use of a fire-resistant board or aluminium frame system for mounting to provide isolation.

Equipment must be positioned to avoid impacting or covering building elements such as windows or decorative elements. The same principles of neat symmetrical installation should be applied to associated equipment.

## Measuring benefit

Solar PV systems will provide substantial cost savings through energy bills. Integration of solar PV systems will also contribute to emission reduction targets and reduce reliance on the electricity grid. Solar PV systems will provide substantial reductions in greenhouse gas emissions where the energy grid is supplied by fossil fuels such as coal.

Climateworks Centre (Armstrong et al. 2023) notes that Australia risks overspending on energy grid transmission upgrades if improved efficiency and renewable energy are not incorporated as part of a national renovation wave. Retrofitting for energy efficiency and incorporating renewable energy can have a broader benefit to the energy grid through 'peak demand reduction'. The energy grid needs to be able to supply the maximum load and generation from on-site solar PV can help reduce peak demand and thereby contribute to reducing the need for expensive broad-scale upgrades that would otherwise proceed to prevent unplanned power outages.

## Useful links

ReNew – Solar feasibility calculator

Clean Energy Council – Solar guide for residential

Clean Energy Council – Solar guide for businesses

## Small-scale wind

Wind generation was the leading source of renewable energy in Australia in 2020 accounting for 9.9% of the total electricity generated and 35.9% of total renewable energy (Clean Energy Council website). Small-scale wind generation is a growing renewable energy technology in Australia, particularly in rural and remote areas for on-site generation. Small-scale wind turbines are generally rated at 10 kW or less and consist of a turbine, tower and inverter. While small-scale wind uses the same technology and principles as large-scale wind farms there are additional challenges relating to site suitability, cost and local planning controls which will impact broad-scale uptake for buildings and individual sites.

The Energy Efficiency Council (2023) highlights the economies of scale that come from utility-scale windfarms, noting that utility-scale generation and storage have a lower cost per customer than small-scale wind turbines and household storage. Ongoing development in small-scale wind turbine technology, including improved efficiency and noise reduction, may support increased adoption over time.

### Application

Small-scale wind is most relevant to non-urban areas where the technical requirement for smooth, strong winds is more likely to be met. 'Urban areas are not suitable for wind turbines because the winds are usually turbulent, and most jurisdictions do not allow turbines in urban areas' (Australian Government 2023).

### Environmental principles

Wind turbines work by capturing wind energy within the area swept by their blades. The spinning blades drive an electrical generator that produces electricity. For small-scale wind generation, the turbines are smaller than utility-scale wind turbines and are designed to meet on-site energy needs.

To maximise efficiency of small-scale wind generation the turbines need to be positioned in areas with smooth and reasonably strong (4–6 m/s) winds. This can be achieved with a naturally elevated position to avoid interruption from buildings and trees, or by placement on a tower.

Towers can range in height, but as height increases wind speed usually increases and the wind is smoother, which improves the efficiency. Small-scale wind turbines on towers will need footings and space for maintenance access, and this needs to be factored into decision making.

Like solar PV systems, small-scale wind can be set up in configurations to suit how and when a building is being used, including grid-connected, grid-connected with battery back-up and stand-alone configurations. See 'System options' under 'Solar photovoltaic systems' for further information on each of these configurations.

In locations where small-scale wind generation is technically suitable it is often integrated with other renewable energy sources, such as solar PV systems and battery storage, to create mixed-mode renewable energy systems that help to provide more reliable and consistent energy supply.

## Heritage considerations

The technical requirement for smooth free-flowing air mean that small-scale wind installations are likely to be visually prominent. Where heritage buildings sit in an expanded or rural setting a small-scale wind system may be possible. This context gives the best opportunity for selecting a location away from buildings and trees, which is of mutual benefit to heritage value and the likely efficiency of the system.

Further practical considerations when planning small-scale wind systems include:

- visual impacts of a small-scale wind system need to be considered. The system should not be visible in significant views of a building or within an associated landscape. Site analysis needs to confirm that the wind conditions, topography and obstructions will not affect the efficiency and output of the system. The technical feasibility needs to be overlaid on the heritage sensitivity of a site to determine overall feasibility for the system
- archaeological constraints owing to the need to excavate for the cabling to run from the small-scale wind turbine back to a building distribution board.

## Measuring benefit

Small-scale wind systems may provide cost savings through energy bills. This will depend on the efficiency of the system in specific locations. While not impacting energy usage directly, these systems provide an overall reduction in emissions through a viable alternative where energy grid is supplied by fossil fuels such as coal, contributing to emission reduction targets.

### Useful links

Wind resource potential – Global wind atlas

# Battery storage

Battery storage is increasingly being integrated into renewable energy systems. ARENA anticipates that due to the technology's versatility and falling costs, the use of batteries for renewable energy will increase over the coming years. The transition to renewable energy and falling costs are further driving the integration of battery storage. Battery storage serves a crucial role in providing stability to the energy grid, managing the intermittent nature of renewable energy sources by storing excess energy when production is high and releasing it during peak demand periods.

As part of a low-carbon future, battery storage is being deployed at various scales, from individual properties through to community-scale batteries and large-scale off-site storage integrated in the electricity grid.

> Battery storage is just one form of the renewable energy storage technologies that will be required to meet energy reduction targets. The CSIRO Renewable Energy Storage Roadmap outlines electrochemical (batteries), mechanical, thermal and chemical as the four key areas of development which will need to be considered and factored into future updates of the guide.
>
> 'Storage of renewable energy is essential to ensure access to secure, reliable and affordable energy as Australia transitions to net zero.' (CSIRO 2023)

## Application

Integrating battery storage with renewable energy generation is broadly applicable to all buildings subject to site feasibility, heritage assessment and statutory approvals. Initial purchase and installation costs are falling, making batteries more viable for many buildings. Site feasibility, energy usage periods and payback period should inform the suitability of battery storage on-site. Feasibility outcomes may change quickly in the near future as battery options and pricing evolve.

## Environmental principles

Batteries are an energy storage technology that uses chemicals to absorb and release energy on demand. Coupling battery storage with renewable energy generation allows energy to be stored during times of peak production and low demand and released at times of peak demand, ensuring maximised utilisation of the renewable energy generation.

Lithium-ion batteries are currently the most common battery chemistry type. The choice of battery depends on various factors including the site-specific application, the scale of energy storage required, cost considerations and available technology. A renewable energy consultant can assist with selecting a battery of appropriate capacity and type based on energy consumption, the capacity of any coupled renewable energy sources and expectations around usage during power outages.

There are several scenarios that are likely to improve the viability of integrating battery storage, including:

- buildings with regular low daytime energy use and high evening demand
- buildings that have critical energy requirements which require a constant and reliable power source, such as cold storage
- sites where connecting to the energy grid is cost-prohibitive
- buildings located in areas with greater energy instability.

Where sites meet one or more of the above criteria, assessment of battery installation is strongly recommended.

## Heritage considerations

As with all technology, the lifecycle of battery storage systems is very short compared to heritage buildings. Modern services, including battery storage systems, must be installed to upgrades or replacement without damage to building fabric. Installations should also be visually discreet.

Further practical considerations when installing or renewing battery storage systems in heritage buildings include:

- battery storage should be unobtrusive, avoiding primary views and minimising visual impact
  - consider secondary structures that may be of lesser heritage significance or less visually prominent such as ancillary buildings, garages, carports or sheds
  - if visible, the scale of the battery storage system should reflect the scale of the building. For example, a small residential installation should adopt a compact system, whereas a commercial building will have more opportunity to incorporate a larger system
  - the battery storage system should not be placed in front of or obscure views of building elements such as windows or openings.
- installation should be carefully planned to avoid damage or removal of significant elements:
  - engage certified installers adopting best practice guidelines to manage associated risks
  - services reticulation should be discreet and neat.

### Electric vehicles – ‘vehicle-to-grid’

An alternative to consider for small heritage buildings, mainly single residences, is battery storage through a ‘vehicle-to-grid’ setup to reduce the extent of additional infrastructure that needs to be installed to support the system. The Energy Efficiency Council notes that electric vehicles could ‘potentially offer lower overall cost storage than stationary batteries, due to larger economies of scale and the distribution of the costs of an EV between home energy storage and transport.’ In this setup, electric vehicles store excess energy and make it available when it is needed, serving as an alternative energy storage system to the batteries discussed above.

### Community batteries

An alternative energy storage solution where on-site batteries are not currently suitable is participation in a community-scale battery scheme/program. Community-scale batteries are an emerging area that can help overcome some of the technical, scale and cost constraints of installing battery storage for individual buildings.

ARENA notes ‘that community-scale batteries have the potential to play an integral role in Australia’s transition to a decentralised grid’ and that there is ‘widespread interest in shared storage and in community energy more generally, from industry, governments, new entrants, and the community at large’.

Centrally located within precincts, participants can choose to have excess energy stored in the community batteries for use later or sale to others who are connected. Participants do not have to have renewable energy generation to make use of community-scale batteries. Community-scale batteries allow for economies of scale to be realised with reduced costs for equivalent storage capacity.

Community-scale batteries offer an opportunity to avoid heritage impacts to buildings where a suitable location that balances heritage and technical requirements cannot be found, while still providing the benefit of access to renewable energy storage. Installing community-scale batteries in heritage conservation areas or in proximity to heritage buildings will, however, trigger similar considerations. Physical impacts to contributory elements such as landscape and street furniture should be avoided. The visual impacts and character setting are equally important given the likely location in the public domain. Locations should be sought that provide the technical requirements, but that don’t impact views to significant or contributory buildings.

### Battery energy storage system (BESS)

A battery energy storage system or BESS can be linked with renewable energy generation and battery storage. The software works in much the same way as a building management system, but for release and use of energy. Implementation is likely to be feasible for larger-scale sites and commercial applications. BESS collects and stores energy from renewable and non-renewable sources and stores it in batteries. It then releases the energy in an optimised way to respond to weather conditions, peak demand, power outages and balancing grid usage.

## Measuring benefit

Battery storage systems integrated with renewable energy technologies may provide cost savings through energy bills; however, this needs to be weighed against the payback period for the battery itself, which is still estimated to be up to 10 years. While not impacting energy usage, battery storage can provide reductions in greenhouse gas emissions when the battery is charged by renewable energy and the energy grid is supplied by fossil fuels such as coal. ARENA notes that one of the key benefits of battery storage is the flexibility it offers as part of an integrated renewable energy system. Batteries can provide households and businesses greater energy independence, reduce the need for load shifting to make full use of renewable energy generation, and balance energy generation when it does not align with on-site generation.

In the same way that solar PV systems can improve 'peak demand reduction', integration with battery storage offers additional potential to reducing the need for expensive broad-scale upgrades to the energy network to prevent unplanned power outages.

## Useful links

YourHome – Residential battery storage

ARENA – Community scale batteries

# Off-site renewable energy

The NSW energy sector is undergoing a transformation with a strong shift toward renewable energy. This process is outlined in the NSW Electricity Infrastructure Roadmap with the overarching goal of 'cheap, clean and reliable' energy. Approximately 53% of the total energy generation capacity of New South Wales is already being supplied by renewable energy generation (NSW Climate Energy and Action website n.d.).

The Energy Efficiency Council notes the importance of developing and 'keep[ing] the grid as clean, reliable and affordable as possible to incentivise people to stay connected'. Economies of scale can be achieved at the larger scale of the central energy grid and provide overall reliability that can't necessarily be achieved at the scale of individual buildings and sites. In a changing and complex energy system, individual buildings and sites connected through community sharing and trading will form a part of the energy mix; however, staying connected to the central energy grid and supporting renewable energy through the consumer options outlined in this chapter support growth of the sector to put downward pressure on pricing and reduce the greenhouse emissions of the energy grid at the rates required to affect a changing climate.

## Application

Off-site renewable energy is a relevant strategy for all buildings. It is most relevant for buildings where it has been determined that on-site renewable energy options cannot strike the required balance with heritage outcomes, or where the system size cannot meet all on-site energy demand. It allows any outstanding energy needs to be filled by clean energy instead of fossil fuel-based sources, reducing carbon emissions as far as practicable and supporting the renewable energy sector.

## Environmental principles

Where on-site generation is not feasible, there are options for consumers in New South Wales to access renewable energy from the central energy grid. As more of the energy generation in New South Wales shifts to renewable energy, energy companies are offering customers the option of opting into carbon neutral electricity, sometimes at no extra cost. Residential customers, businesses and larger organisations can access renewable energy directly from most suppliers, but for additional assurance GreenPower is a useful check.

### GreenPower

GreenPower is a national program supported by Federal and state and territory governments that certifies renewable energy products offered by electricity providers in Australia. GreenPower independently audit electricity providers to ensure that the selected portion of the electricity consumed by customers comes from approved renewable sources.

Consumers can choose the level of renewable energy they wish to purchase through an electricity suppliers GreenPower product. This can range from 10% through 100% of their electricity consumption. This flexibility allows individuals and businesses to align their energy choice with their sustainability goals and circumstances.

Almost 30,000 businesses and over 330,000 households around Australia purchase GreenPower Accredited renewable energy (GreenPower n.d.). Choosing GreenPower helps reduce greenhouse gas emissions and supports the transition to a more sustainable and low-carbon energy sector.

## Heritage considerations

The purchase of off-site renewable energy does not result in any change to the receiving building, so there are no heritage considerations for individual buildings or sites.

Large-scale renewable energy projects, such as solar and wind farms and transmission projects, are assessed and managed through environmental impact assessment processes.

The Eryldene Environmental Sustainability Action Plan recommended switching electricity suppliers to support renewable energy and decarbonise energy use. This approach was deemed the most suitable for the site considering the heritage significance of the place and visual impacts that would likely result from on-site renewable energy options (Photo: Lindy Kerr for the Eryldene Trust)

## Measuring benefit

Switching to off-site renewable energy does not provide the same energy and cost savings as the other strategies outlined in this guide; however, it will contribute to reduced greenhouse gas emissions and broader public benefits to the energy infrastructure network.

NSW Climate Energy and Action (2023) reports that ‘renewable energy is now the cheapest form of new power generation in Australia, which helps place downward pressure on electricity prices’. As the total percentage of renewable energy increases energy prices should trend downwards, at which point cost savings at an individual level can be realised. Switching to off-site renewable energy is a low-cost way of reducing (or eliminating) greenhouse gas emissions associated with electricity usage quickly, easily and with no heritage impact to the building.

Selecting renewable energy helps drive demand and development for the renewable energy sector, which is an important part of reaching emission reduction targets to curb the impacts of climate change. It also supports the transition of jobs away from traditional energy generation sectors and into supporting renewable energy, particularly in regional New South Wales.

### Useful links

GreenPower

In focus

# Co/Tri generation

Cogeneration, often referred to as combined heat and power (CHP), is a highly efficient energy generation process that involves the simultaneous production of electricity and useful thermal energy from a single energy source. The energy source is typically natural gas; however, recent developments have seen the energy source transition to renewable gas alternatives such as hydrogen.

This integrated approach of cogeneration minimises energy waste by utilising the heat generated during electricity production for heating or cooling purposes, such as space heating, hot water or industrial processes. Cogeneration systems can be implemented in various sectors, including residential, commercial and industrial settings, providing a more sustainable and cost-effective energy solution compared to traditional separate generation methods.

Trigeneration extends the concept of cogeneration by adding a third component to the energy production process – chilled water or air conditioning. In a trigeneration system, electricity, heat and cooling are generated simultaneously from a single energy source. This additional capability makes trigeneration particularly suitable for applications where both heating and cooling needs exist, such as in large buildings, hospitals, data centres and industrial facilities. Trigeneration enhances overall energy efficiency and environmental sustainability by optimising the use of resources and reducing greenhouse gas emissions.

There have been several projects that have integrated trigeneration in heritage buildings in New South Wales including Central Park, Sydney (the former Carlton United Brewery). These technologies are best suited to larger sites with complex and varied energy needs. As the technology transitions to renewable energy, cogeneration and trigeneration can be explored for heritage buildings where the technical requirements are aligned.

For further information see the Australian Government Department of Climate Change, Energy, the Environment and Water factsheet for Co/Tri-generation.

The former Kent Brewery adaptively reused to house the trigeneration equipment and cooling towers for Central Park, Sydney (Photo: Steven Barry/ Transport for NSW)

## Key actions checklist – renewable energy

| Strategies | Key actions |
|---|---|
| **Renewable energy (overall)** | ☐ Determine the best-fit renewable energy option for the building that balances environmental and heritage requirements<br>– this may require the input of a renewable energy consultant and heritage specialist depending on the complexity of the building and site<br>☐ Have baseline energy data available to inform system sizing and potential for battery integration<br>– ideally this data will reflect optimised energy use achieved through implementation of all applicable strategies discussed earlier in this guide<br>– temporary sub-metering may provide useful information about energy use and time of day to better inform the system requirements. |
| **Solar photovoltaic systems** | If a solar PV system has been determined the best-fit renewable energy option:<br>☐ Select the system setup that best suits your needs (e.g. grid-connected with battery back-up)<br>☐ Select a location based on the technical requirements and established heritage criteria in this guide (e.g. roof-mounted)<br>☐ Optimise the size of the system to match consumption where visual impacts need to be managed<br>☐ Refine the design consistent with established heritage criteria in this guide<br>☐ Obtain all necessary planning and heritage approvals<br>☐ Solar PV systems need to be installed by licensed tradespeople and follow the principles of neat and discreet installation for heritage buildings<br>☐ Australian Standard AS/NZS 5033 recommends solar PV systems be inspected annually<br>☐ Ongoing maintenance and cleaning to ensure maximum efficiency. The angle of installation will impact how effectively the panels will 'self-clean', which will inform the required frequency of cleaning. |
| **Small-scale wind** | If small-scale wind has been determined the best-fit renewable energy option or as part of a hybrid strategy:<br>☐ Undertake a detailed survey to determine suitability for wind speed and turbulence and heritage constraints. This may require further input from a renewable energy consultant and heritage specialist<br>☐ Select a location based on the technical requirements and established heritage criteria in this guide<br>☐ Obtain all necessary planning and heritage approvals. |

| Strategies | Key actions |
|---|---|
| Battery storage | If the renewable energy setup is 'grid-connected with battery back-up' or 'stand-alone':<br>☐ Select a location based on the technical requirements and established heritage criteria in this guide<br>☐ Optimise the size of the battery to match consumption where visual impacts and/or space constraints need to be managed<br>☐ Obtain all necessary planning and heritage approvals<br>☐ Battery storage systems need to be installed by licensed tradespeople and follow the principles of neat and discreet installation for heritage buildings. |
| Off-site renewable energy | ☐ Visit GreenPower website for accredited suppliers<br>☐ Review energy usage and decide on the overall percentage of renewable energy required<br>☐ Update energy plan to incorporate a GreenPower product or switch suppliers to effect the change to renewable energy. |

Case study

# Bondi Pavilion

## Quick facts

**Project type:**
Community/Recreation

**Client:**
Waverley Council

**Heritage listing:**
- National heritage list (Bondi Beach)
- NSW State Heritage Register (Bondi Beach Cultural Landscape)
- Local heritage list (Bondi Pavilion)

**Project team:**
Architecture – Tonkin Zulaikha Greer

Heritage – TZG Heritage

Landscape – JMD Design

ESD – Arup

Structural Engineering – SDA Structures

Builder – Buildcorp

Photographer – Brett Boardman

**Location:**
Bondi Beach, NSW

**Year:**
2023

Tonkin Zulaikha Greer (TZG) guided the comprehensive renewal of Bondi Pavilion securing the building as a community landmark and delivering a 5-star Green Star sustainability rating.

Bondi Pavilion has been a central part of life for residents and visitors to the iconic Bondi Beach for over 90 years. The Bondi Pavilion has undergone major renovations to secure the future of this much-loved asset following a decade of planning and community pressure.

The project delivered a renewed theatre, music studios, community spaces, expanded pottery studio, food and beverage tenancies and upgraded amenities. Detailed heritage conservation is paired with considered contemporary interventions to deliver this complex building program.

The project demonstrates a far-sighted commitment to this building and precinct through high-quality repair and robust new elements. The focus on sustainability has been rewarded with a 5-star Green Star sustainability rating and was underpinned by prioritising retention of the existing building, repair, making full use of the coastal context for natural ventilation, upgrading services and on-site renewable energy.

Aerial view of the Bondi Pavilion within the iconic Bondi Beach cultural landscape. The dark cement tile concrete roof tiles were replaced with a cordova pattern terracotta tile roof reflecting the original design (Photo: Brett Boardman for TZG)

‘Central to community life, this revitalised building will be home to a vibrant mix of cultural, community, recreational and commercial uses for many decades to come.’ (Tonkin Zulaikha Greer Architects)

The project retained over 80% of the structure, which secures the embodied carbon of the material as well as preserving the heritage significance and character of the site. This decision underpins the sustainability focus of the project.

In achieving a 5-star Green Star building the project delivered innovative environmental performance upgrades including:

- integrating new internal colonnades to the courtyard to provide shading and shelter to the internal facades. The new concrete colonnades reference the original colonnade facade of the outward facing elevation but in a contemporary way
- introducing new openings in walls facing the courtyards to allow for cross-ventilation with ceiling fans to support the natural air flow and enhance the sea breeze
- use of energy-efficient LED lighting, mechanical heating and cooling, and water-efficient fittings throughout the project
- redesigning the central atrium with new precast concrete columns that support a glazed roof. The timber beams filter the direct sunlight to reduce the heat load on the surfaces below. This new heart of the pavilion is now open, allowing natural ventilation throughout the building. The glass roof and skirt trap the sun's heat to provide a more buoyancy-driven stack effect within this double height space
- incorporating 271 solar photovoltaic panels to the inward facing roofs of the pavilion. This supplies 70% of the building's energy requirement. The internal positioning of the panels mean they are not visible from the exterior of the building and do not impact the Bondi Beach Cultural Landscape.

View across the renewed landscaped courtyard to the internal colonnade and solar photovoltaic system. The solar panels are neatly grouped and aligned to the roof. Offsets are provided to the key building elements and space between the groupings allowing the form of the roof to be understood (Photo: Brett Boardman for TZG)

**Heritage significance and history**

In 1928, Robertson and Marks won a design competition for a new Bondi Pavilion, which included amenities including Turkish baths and shops. The Esplanade, a restaurant-cabaret, opened in the new Pavilion in 1929 and the pavilion supported various activities prior to World War II. During the war the Pavilion suffered damage from an unsuccessful explosive operation. Later in the war it housed an American officers' club and the American Red Cross. In 1948, it obtained a liquor licence, but by the 1950s its popularity had declined with changing swimwear trends. By 1959, the building was deteriorating. In 1973, the Bondi Theatre Group proposed converting the Palm Court Ballroom into a theatre, marking the Pavilion's transition into a cultural and community centre. The latest round of renovations secures the future of the Bondi Pavilion as a cultural institution and backdrop to the world-famous Bondi Beach.


Photo: National Trust NSW

# Supporting Information

## Glossary

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| **Adaptation** | Defined in the Burra Charter as changing a heritage place to facilitate compatible new uses. This could involve alterations and additions to suit an existing use or meet current expectations of comfort and function, or the upgrading of a building or site to respond to new needs and procedures associated with an existing function. |
| **Burra Charter** | The Australia International Council on Monuments and Sites (ICOMOS) Charter for Places of Cultural Significance 2013.<br>Burra Charter definitions have been adopted for this guide. |
| **Character** | The combination of the particular attributes, characteristics and qualities of a place. |
| **Conservation management plan** | A document outlining what is significant about a place and how to manage changes over time to ensure the significance is retained. |
| **Cultural significance** | Defined by the Burra Charter as the aesthetic, historic, scientific, social or spiritual value of a place for past, present, or future generations. Cultural significance is embodied in the place itself, its fabric, setting, use, associations, meanings, records, related places and related objects. (See also 'Heritage significance'.) |
| ***Heritage Act 1977 (NSW)*** | The statutory framework for identifying, protecting and managing heritage items in New South Wales. |
| **Heritage conservation area (HCA) or heritage precinct** | An area that has historic significance and (usually) also a distinctive character of heritage significance, which it is desirable to conserve. A heritage conservation area is more than a collection of individual heritage items – it is an area in which historical origins and relationships between the various elements create a sense of place that is worth keeping.<br><br>Heritage conservation areas are listed on local environmental plans, while heritage areas of State significance are listed as heritage precincts on the NSW State Heritage Register. While the majority of properties will be contributory items, the area may also contain individually listed heritage items. |
| **Heritage item** | A place, building, structure, work, archaeological site or relic, garden or landscape, movable object, Aboriginal place or other place of heritage significance. Heritage items are listed on a statutory instrument such as the State Heritage Register or in a local environmental plan. |

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| Heritage significance | This term is used in New South Wales to encompass the 7 criteria used by state and local government to describe the heritage value of a place. It is used interchangeably with the Burra Charter term 'cultural significance'. |
| Illuminance | The luminous flux, or level of light, arriving at a surface divided by the area of the illuminated surface. Measured in lux (lx). |
| Livability | The 'liveability' of a place, which captures usefulness, comfort, and pleasure. A building's amenity is affected by its design, access to sunlight and views, and access to facilities and services. Expectations of amenity and comfort change over time. |
| Low emissivity | Emissivity is the amount of radiation emitted or absorbed from a surface. Low emissivity (low-e) refers to the ability of a material, such as glass, to reduce the transport of heat or cold through the material. |
| Maladaptation | In a building context, maladaptation refers to poor or insufficient adaptation actions, intended to reduce the impacts of climate change, but which inadvertently create more risk and vulnerability. |
| Passive cooling | Passive cooling refers to a set of design principles and techniques used to manage the temperature and conditions inside buildings. It involves utilising building design choices and materials to control heat gain and heat loss, creating a comfortable indoor environment without the need for mechanical cooling systems. Passive cooling is particularly useful in hot and humid or hot and dry climates. |
| Purge ventilation | Purge ventilation is the introduction of intermittent, rapid ventilation into a habitable room to maintain or restore a pleasant living environment. It is usually achieved with operable windows or external doors. The purpose of purge ventilation is to aid in the removal of high concentrations of pollutants and bring fresh air into a building.<br><br>Purge ventilation can be achieved through natural means, such as operable windows, or through mechanical means, such as fans. |
| Retrofit | The upgrading of a building to enable it to respond to the imperative of climate change. Retrofit may involve repair, renovation, refurbishment and/or restoration of the building, providing the aim is to mitigate against climate change and ensure the building is well adapted for our changing climate. |

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| Resilience | Resilience in a building context involves designing and constructing/retrofitting buildings and infrastructure that can withstand and recover from disruptive events and remain comfortable and useable places in a changing climate, ensuring the continuity of essential services and minimising the social and economic impact of hazards. |
| Reticulated services | Reticulated services refer to the installation and management of various pipework, flues and ducts that provide essential services such as air conditioning, water, gas, refrigeration, steam, compressed air and other similar services in commercial and industrial buildings. |
| Stack effect | The stack effect refers to the movement of air into and out of buildings, chimneys, flue-gas stacks or other containers, resulting from air buoyancy. This movement occurs due to a difference in indoor-to-outdoor air density resulting from temperature and moisture difference. Controlling the stack effect is important to maintain comfortable conditions for occupants. |
| Sub-metering | Sub-metering allows for a more detailed assessment of energy use. These can be applied at various scales from tenancies right through to individual appliances. It provides visibility of energy use and performance, allowing building and facility managers to identify opportunities for energy conservation and cost savings. |
| Thermal bridges | Thermal bridges are weak points in a building envelope that allow heat to pass through more easily. They occur where materials which are better conductors of heat are allowed to form a 'bridge' between the inner and outer face of a construction. This commonly happens where there is a gap in the insulation layer, or where an element such as a joist penetrates through the construction. |
| Thermal breaks | A thermal break, or a thermal barrier, is a component or material with low thermal conductivity that is inserted between members of high conductivity to reduce or prevent the flow of thermal energy. Thermal breaks are used to minimise heat transfer between conductive materials, such as steel, concrete and aluminium, in order to improve energy efficiency and reduce heating and cooling costs. They are commonly used in windows, doors and wall systems, to minimise thermal bridging and enhance energy efficiency. |
| Typologies | A classification based on general type of building, and based on use, age and significance. |

## Relationship to existing legislation and policies

### Climate Change (Net Zero Future) Act 2023

The *Climate Change (Net Zero Future) Act 2023* legislates NSW's approach to addressing climate change. It legislates whole-of-government commitments to climate action to deliver net zero by 2050 through establishing guiding principles, confirmed emissions reduction targets, commitment to building resilience to climate change and establishing an independent, expert Net Zero Commission.

#### NSW Net Zero Plan Stage 1: 2020–2030

The Net Zero Plan Stage 1: 2020–2030 (DPIE 2020) sets out how the NSW Government will deliver on the objectives of the *Climate Change (Net Zero Future) Act 2023* over the next decade. The action plan identifies the positive contribution that heritage buildings can make in achieving the overall goals.

#### NSW Sustainable Buildings SEPP

The new State Environmental Planning Policy (Sustainable Buildings) 2022 established requirements for certain large commercial and state significant development to achieve net zero now or to establish adequate space, infrastructure and ventilation to convert to net zero by 2035 and to report this through a net zero statement.

The net zero statement applies to non-residential development over $5M capital investment value and alternations and additions to non-residential development over $10M capital investment value, unless exempt under Chapter 3.1 of the Sustainable Buildings SEPP. This means that some developments considered in this guide, may also be impacted by the Net Zero provisions in the Sustainable Buildings SEPP – particularly for heritage developments relating to education, health, cultural buildings, hotels or offices as these are called out within the policy.

Refer to the *Net zero statement technical note* (DPE 2023) for more information.

All building types (residential and non-residential) should also check how the energy and embodied emissions requirements of the new policy impact proposed development.

### Better Placed

The *Sustainable heritage buildings guide* is aligned to the Better Placed framework and the *Design guide for heritage* to enhance the focus on improving the environmental performance of heritage buildings.

The Better Placed framework was developed by the NSW Government Architect and establishes NSW Government expectations for good design and effective processes around all built environment projects in New South Wales. Better Placed defines 7 objectives for good design. Objective 2 relates to 'Better performance' and is an important reference point when improving the environmental performance of a heritage building.

## Design guide for heritage

The *Design guide for heritage* supports Better Placed and was developed by the NSW Government Architect and Heritage Council of NSW. The guide details the Better Placed design objectives in the context of heritage and identifies the processes and principles that ensure good design supports the significance of heritage places.

Objective 2 of the *Design guide for heritage* provides an overview of how heritage places positively contribute to a sustainable built environment and how sensitive adaptation can further integrate heritage buildings into contemporary life.

This guide is intended to support implementation of the Better Performance principles on enhancing performance, retrofitting for sustainability and retaining and reducing embodied energy.

The *Design guide for heritage* provides 6 key design considerations for achieving Better Performance in heritage places that will be further detailed and cross referenced through the guide:

### Key design considerations

1. Analyse the opportunities and constraints of existing structures, environmental systems, and site organisation in terms of sustainability, durability, and adaptability.

2. Identify existing effective passive design systems. Rejuvenate them if possible. Consider removing additions that compromise environmental performance.

3. Sensitively integrate new environmental initiatives where appropriate to improve environmental amenity and sustainability performance.

4. Retain and recycle original fabric and materials to preserve embodied energy, where possible.

5. Maximise passive heating and cooling and waste and water management in the design of any new work or additions.

6. Select new building materials and systems to enhance energy efficiencies.

## Heritage Council of NSW, climate change and heritage

The Heritage Council of NSW and Heritage NSW are developing resources to help owners and managers of heritage places manage the impacts of climate change. The Heritage Council of NSW endorsed climate change principles in 2023 which support development and implementation of the guide.

Embodied energy in heritage places and the potential contribution of adaptation measures to greenhouse emissions should be considered.

## The Burra Charter

Australia ICOMOS (International Council on Monuments and Sites) is a non-government, not-for-profit organisation of cultural heritage professionals formed as a national committee of ICOMOS. Australia ICOMOS promotes best practice as a peak cultural heritage conservation body. *The Burra Charter: the Australia ICOMOS charter for places of cultural significance* (ICOMOS 2013)and the associated series of practice notes provides a nationally recognised framework for best practice management of cultural heritage places in Australia.

The practice notes provide practical advice on the Burra Charter and its application. Practice note – 'Heritage and sustainability 1: built heritage' (ICOMOS 2019b) is applicable to development and implementation of this guide.

### Burra Charter practice note – Heritage and sustainability 1: built heritage

The *Heritage and sustainability 1: built heritage* practice note 'relates to the conservation of existing buildings and improvements to their environmental performance'. Several principles relate specifically to this guide, with most relevant being:

> Incremental improvements, rather than wholesale change, should be an acceptable path to achieving sustainability outcomes, aligning with the Burra Charter approach of 'doing as much as necessary and as little as possible' (as outlined in the Preamble to the Burra Charter).

The practice note also sets out improvement strategies that could be explored.

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## Legislation

Climate Change (Net Zero Future) Act 2023 (NSW)

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