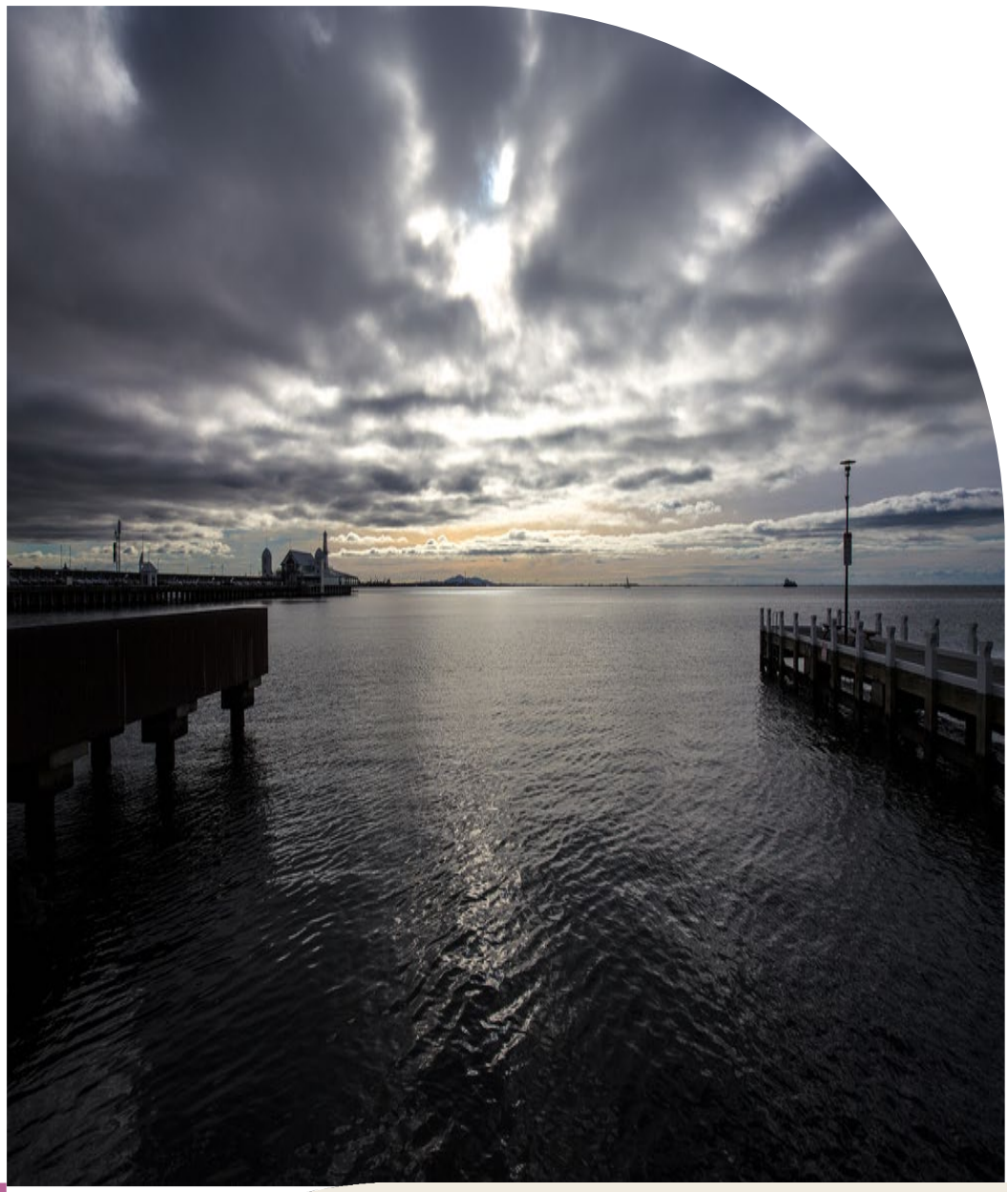


INFRASTRUCTURE VICTORIA

April 2024

Weathering the storm

Adapting Victoria's infrastructure to climate change

About us

Infrastructure Victoria is an independent advisory body with 3 functions:

- preparing a 30-year infrastructure strategy for Victoria, which we review and update every 3 to 5 years
- advising the government on specific infrastructure matters
- publishing research on infrastructure-related issues.

Infrastructure Victoria also helps government departments and agencies develop sectoral infrastructure plans.

Infrastructure Victoria aims to take a long-term, evidence-based view of infrastructure planning, and we inform community discussion about infrastructure provision.

Infrastructure Victoria does not directly oversee or fund infrastructure projects.

Acknowledgement

Infrastructure Victoria acknowledges the Traditional Owners of Country in Victoria and pays respect to their Elders past and present, as well as Elders of other First Peoples' communities. We recognise that Victoria's infrastructure is built on land that has been managed by Aboriginal people for millennia.

Contents

Summary

Adapting Victoria's infrastructure to climate change can keep communities safe and functioning, while also saving governments and businesses money.

The world's climate is changing. This means Victoria will have more severe weather and intense rainfall events, more hot days and bushfires, and higher sea levels. Most of Victoria's infrastructure, such as roads, electricity networks and buildings, was not built to perform in this new climate.

Victoria's infrastructure strategy 2021–2051 recommended the Victorian Government conduct a strategic review of the climate change consequences for infrastructure. In 2022, the Victorian Government published 7 system-based adaptation action plans to help Victoria adapt to climate change.

This report extends that work. It makes recommendations that will allow the Victorian Government to select wise and prudent investments that reduce the risks climate change poses to infrastructure. These investments can help keep people, communities and businesses functioning, and reduce the cost and harm of damaged or destroyed infrastructure.

Governments have traditionally waited until infrastructure fails, and then spent large amounts of money trying to fix it, instead of investing upfront.[1] The Productivity Commission estimates that just 3% of Australian Government spending on disasters is invested in proactive efforts to limit the impact of future events.[2]

What does infrastructure adaptation mean?

Adaptation in infrastructure can involve building, maintaining or renewing physical infrastructure to better prevent, prepare, respond and recover from actual or expected impacts of climate change.

Examples assessed in this report include:

- better flood preparation through water sensitive urban design
- improving the ability of roads to withstand flooding with techniques such as foamed bitumen stabilisation
- using insulated cables to reduce the impacts of high winds for electricity distribution networks.

Climate events can affect many infrastructure sectors at once, which adds to their cost and harm. Between 2007–2016, recovering from extreme weather events cost Victoria an average of $2.7 billion a year.[3] Climate damage might cost Victoria nearly $1 trillion by 2100 if it does not act to reduce emissions and adapt its infrastructure.[4] The benefits of investing in resilient infrastructure can outweigh the costs of repairing and rebuilding it after extreme weather events.[5]

Victorians are already paying the costs of a changing climate. If governments do nothing, Victoria's infrastructure will fail more often, causing harm and cost to people and businesses. Underinvesting in infrastructure resilience leads to higher economic, social and environmental costs over time.[6]

Governments have many options to make infrastructure more resilient to climate change now. Some options cost very little. Governments can build infrastructure in safer, less hazardous locations. They can build infrastructure using materials or designs that minimise the impacts of climate risks. They can change the way they manage infrastructure. For example, they can change the type and frequency of their maintenance activities or retrofit infrastructure to reduce the risk of damage. And they can reduce the severity of climate risks, such as managing vegetation to mitigate flood risks or the chance of trees falling on power lines. This causes less damage, and communities and businesses experience less harm, fewer costs, and can return to normal faster after a serious event.

The Victorian Government already has some policies and guidance about climate change adaptation. But many departments still do not always consider climate risks and take action to adapt their infrastructure. Infrastructure managers told us they do not yet have the obligation, tools or confidence to propose adaptation actions. This report sets out ways they can embed adaptation in their normal activities.

The government can support its asset managers to consider climate change risks during the infrastructure life cycle as part of normal business. This helps them prioritise, coordinate and sequence adaptation activities to produce more value over time as climate change generates more frequent and intense impacts.

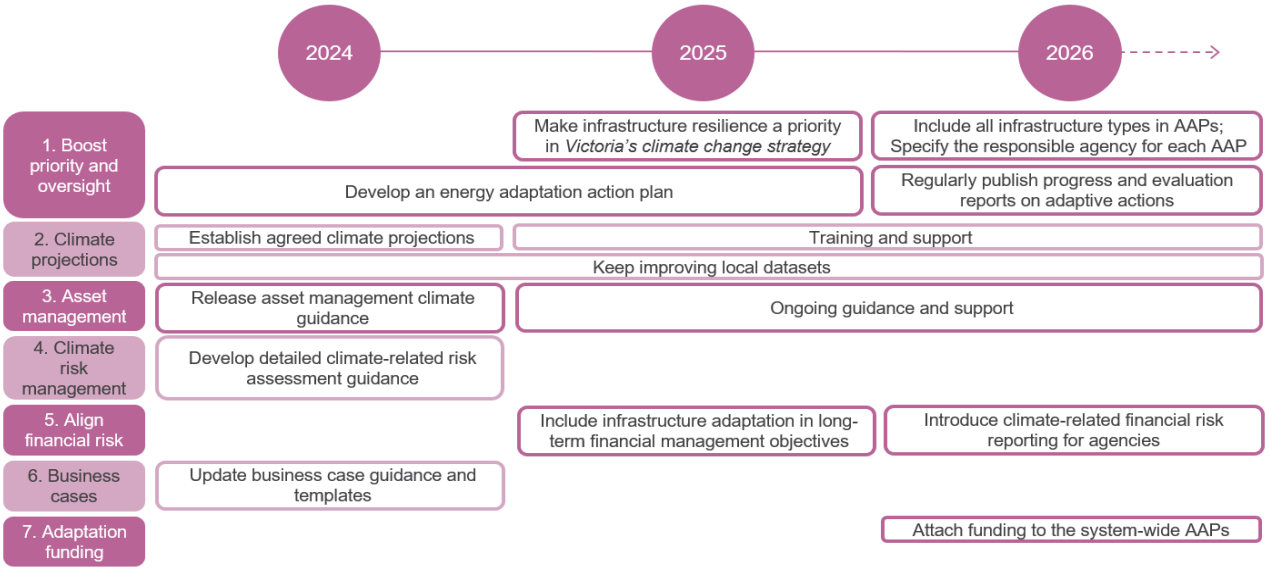
The government might have to invest in adapting high-risk infrastructure to climate change. Infrastructure owners might need to modify or enhance it to withstand more frequent and severe weather events and return to service quickly. This is not a one-size-fits-all proposition. Infrastructure's vulnerability to climate change will be different depending on its type and location. So will the best adaptation options.

Infrastructure managers can select the best adaptation measures by completing site-specific analysis for high-risk locations and infrastructure and determining the most cost-effective response. Infrastructure agencies can audit their infrastructure, prioritise assets at high risk, and identify and prioritise measures to mitigate these risks. During this research, we conducted 3 cost-benefit analyses of specific adaptation measures and demonstrated that some options generate a positive return on investment. Some adaptation proposals can also have unintended consequences. Site-specific analysis can identify these problems.

The Victorian Government can change its systems and requirements for its infrastructure agencies, so they adapt their assets to climate change, and thereby help better protect Victorian communities and businesses, and keep costs down. They can develop contemporary policy settings that give clear direction, and supply asset managers with easy-to-use climate data. They can give infrastructure agencies a suite of tools for professional adaptation analysis that embed adaptation in normal practices, including in asset management, risk management, and financial analysis and disclosure. And they can provide guidance on conducting quality business cases to secure appropriate funding for prudent adaption initiatives.

Our 7 recommendations provide a pathway to better assess and prepare Victoria's infrastructure for the impacts of a warming climate.

Figure 1: Timeline for recommended Victorian Government action on adaptation



Note: AAPs = Adaptation action plans

Recommendations

1. Boost priority and oversight for infrastructure adaptation

- Make public infrastructure resilience a priority in *Victoria's climate change strategy.*
- Develop an adaptation action plan for Victoria's energy system.
- Include all infrastructure types in future adaptation action plans.
- Specify the responsible agency for each adaptation action.
- Regularly publish a progress and evaluation report on adaptation actions.

2. Coordinate and standardise climate projections

- Establish an agreed set of climate projections for use in government infrastructure planning and management, especially projections of extreme weather events.
- Keep improving local level data that infrastructure managers can use for site-specific analysis.
- Deliver training and ongoing support for infrastructure managers to apply the data to climate risk assessments.

3. Use asset management systems to improve resilience

- Release climate change guidance on assessing climate vulnerability and risk, designing for resilience, and adopting preventative maintenance.
- Support agencies to develop the processes, tools and expertise to embed climate considerations in asset management practice.

4. Integrate climate risk into government risk management

- Develop detailed guidance to accompany the Victorian Government *Risk management framework* on how to assess climate-related risks to infrastructure and integrate them into decision-making.

5. Align climate and financial risks to infrastructure

- Include climate adaptation in the government's long-term financial management objectives for infrastructure.
- Require departments and agencies with infrastructure holdings to prepare climate-related financial risk disclosures.

6. Update business case and investment guidance

- Update existing business case guidelines, technical guidelines and templates to include the risks and impacts of climate change.

7. Build confidence that good adaptation measures will receive funding

- Attach funding to the 2026 updates of the system-wide adaptation action plans, to encourage government agencies to evaluate and prioritise assets for adaptation and incorporate adaptation into business cases.

By the numbers

Victoria's climate is already 1.2°C warmer than when records began in 1910. Global average temperatures are expected to increase by 1.5°C by 2030.

Extreme weather events in Victoria between 2007–2016 averaged $2.7 billion in damage a year. Costs associated with Victoria's 2009 Black Saturday bushfires were estimated at more than $4 billion.

Without action, climate-related damage in Victoria could cumulatively cost at least $115 billion by 2030, and more than $986 billion by 2100.

Climate impacts are estimated to cost greater Melbourne local governments $90–$120 million annually. These costs are projected to increase to $210–$300 million annually by 2050 and $400–$540 million annually by 2100.

The Australian Government spends 97% of its natural disaster funding after an extreme weather event, while 3% goes towards proactive efforts to limit the impact of future events.

Canada's national adaptation strategy sets the expectation that 80% of public organisations will factor climate change adaptation into decision-making processes.

Early investment in adaptation action can reduce the costs of future damage. A study of 28 adaptation projects in over 16 countries found a wide range of positive returns on investment. The projects produce benefits that outweighed their cost by between 1.3 to 60 times. The median project saved $6 saved for every $1 spent.

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Climate change threatens infrastructure

Infrastructure Victoria did this research to assess the benefits of adapting infrastructure to the changing climate. It examines Victoria's climate policy framework to determine how departments and agencies are assessing resilience and adapting their infrastructure. It follows our recommendation in *Victoria's infrastructure strategy 2021–2051* for the Victorian Government to strategically review the climate consequences for public infrastructure after delivering the adaptation action plans under the *Climate Change Act 2017*.[7] The government published the plans in 2022.

In 2006, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Maunsell Australia and Phillips Fox undertook an assessment of climate risks to Victorian infrastructure.[8] They found that climate change amplifies the risks to Victoria's water, energy, telecommunications, transport and built environment infrastructure. Since then, we have much more information about climate change and its effects on infrastructure.

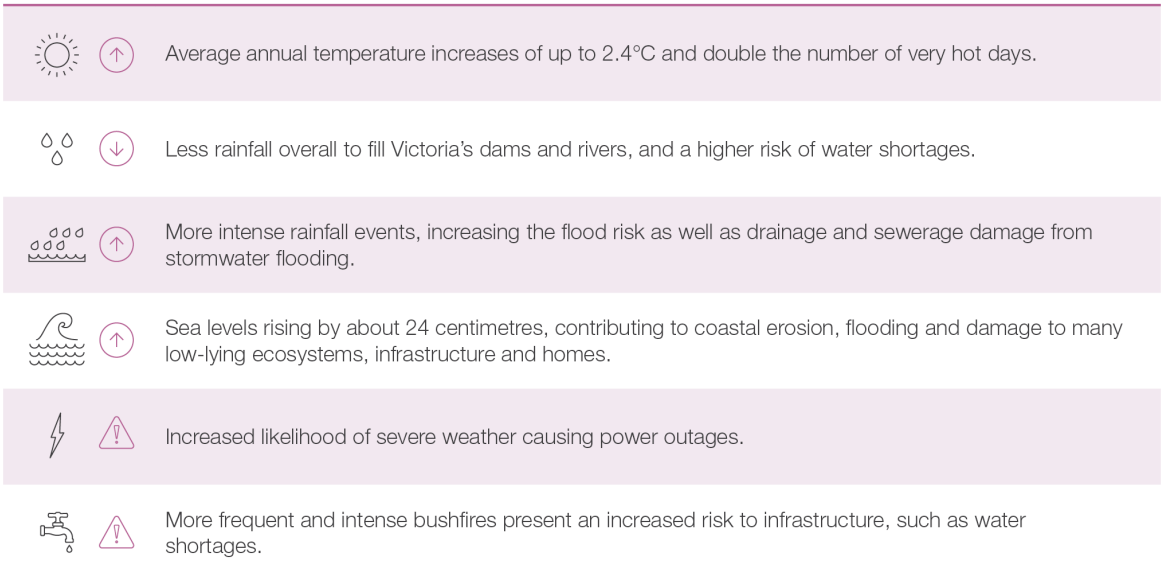
In this research, we used this new information to examine how climate change might affect Victoria's infrastructure. We took a longer-term and statewide view to consider new measures the Victorian Government can take to improve the climate resilience of infrastructure it owns or manages, including how to assess climate risks, determine the return on investment of adaptation measures and fund these measures consistently over time.

Climate change already presents unavoidable risks

Victoria's climate is 1.2°C warmer than when records began in 1910.[9] This has produced a drier climate with more frequent and intense weather events, such as heatwaves, floods, and more dangerous fire seasons.[10] The Intergovernmental Panel on Climate Change (IPCC) finds that current global efforts are not enough to prevent climate change.[11] They predict that climate change is set to increase global average temperatures by 1.5°C by 2030.[12] The extent of the temperature rise depends on ongoing global action to reduce greenhouse gas emissions. The IPCC says governments must make deep, rapid and sustained cuts to greenhouse gas emissions to keep global warming below 1.5°C to limit further damage to health, wellbeing and ecosystems.[13] The risks to these systems increase as global average temperatures rise.

Climate change presents a real and accelerating danger to Victoria's infrastructure. For instance, more frequent bushfires can destroy critical buildings and facilities, electricity and telecommunication cables, mobile phone towers, and block roads and rail lines. Floods can damage buildings and equipment and wash away roads and bridges. Storms, winds and hail can knock down trees onto power lines and roads, tear off roofs and smash windows. Sea level rise threatens coastal infrastructure, which can be washed away during storm surges, flooded, or undermined by coastal erosion. These events will become more frequent and severe as climate change intensifies.

Figure 2: Predicted climate change impacts on Victoria by 2050s under a high emission scenario



Source: Department of Environment, Land, Water and Planning, *Victoria's climate change strategy*, State of Victoria, 2021, accessed 7 August 2023; Infrastructure Victoria, *Victoria's infrastructure strategy 2021–2051*, Infrastructure Victoria, 2021, accessed 8 August 2023; Department of Energy, Environment and Climate Change, 'Power outages', DEECA website, 2023, accessed 8 August 2023.

Climate change will not affect every place evenly.[14] Climate projections vary in different regions of the state. For example, by the 2050s Bendigo, Ballarat and Shepparton might have over 60% more high fire danger days. Melbourne may have around 40% more.[15] But more frequent extreme weather events will have consequences for people all over Victoria. For example, more frequent and higher floods will damage roads which will disrupt movement around Victoria, compromising access to jobs, goods and services. More frequent and intense bushfires can damage electricity transmission and telecommunications, resulting in extended blackouts and loss of internet and mobile phone reception. Damage to critical buildings, like hospitals, can mean people cannot get emergency medical care. All these impacts will endanger lives and disrupt Victoria's economy.[16]

The Victorian Government is acting to reduce greenhouse gas emissions, which will help reduce the global total. But some climate change effects are now unavoidable and cannot be entirely prevented.[17] For example, flooding events in Melbourne and regional Victoria are becoming more frequent, which accelerates the deterioration of roads. This means the Victorian Government will need to repair and rebuild roads more often.

The IPCC calls on governments to act rapidly this decade to adapt at a scale that can prevent the worst consequences for people and nature.[18] The Victorian Government can reduce these unavoidable risks through climate adaptation in local projects and by re-designing its infrastructure systems.[19]

Case study

Storm causes power outages and blocks roads

In June 2021, heavy rain, lightning, and severe winds hit eastern and central Victoria, especially Gippsland and the Yarra Ranges. The storm caused major damage to the electricity distribution network, leaving thousands of homes without power.

Around 297,000 customers had no electricity at the same time.[20] Over 25,000 homes were still without power 5 days later, and suppliers advised 3,000 households that they would be without electricity for up to a month.[21]

Cascading events hampered efforts to reconnect homes to electricity after the storms. For example, fallen trees blocked roads, meaning workers had to wait for road to be cleared before they could reach the damaged power lines.[22]

Later events compounded the storm's effects. Stormwater contaminated the water supply, leaving residents without safe drinking water.[23] The storm also degraded the region's electricity and telecommunications infrastructure. For example, residents of Kalorama, where the storm destroyed 44 houses, suffered 41% more power outages and 31% more internet outages in the year the followed.[24]

Prolonged power outages badly disrupt and distress communities:[25]

- 'At my house no power meant no light, lost food storage, no water, no septic (and untreated sewage leakage!!), no internet, mobile phone was also out, so no communication.'
- 'Our driveway… was blocked by approximately 30 trees. It took us 3 days to be able to cut our way out, so we had no means of communication and no way of getting fuel for our generator.'

After the storm, the Victorian Government commissioned an independent review into the resilience of the electricity distribution network. The review recommended that the Department of Energy, Environment and Climate Action conduct local geospatial analyses in the short term to identify risks and recommended that distribution businesses conduct cost-benefit analyses on investments to improve network resilience.[26]

These short-term recommendations form the basis of the Victorian Government and distribution businesses 5-year *Network Resilience Plan* to roll out network resilience investments across the Victorian electricity network.[27]

Infrastructure damage has costs and consequences

Victoria's infrastructure was not built for frequent and severe climate events.[28] This includes some of Victoria's critical infrastructure such as the road network, electricity distribution network and hospital facilities. Some infrastructure was built in locations now more exposed to bushfire, flooding, landslides and storm surges. At the time, engineers presumed events like high winds, extreme heat, or heavy hail were very rare. A different climate means that those assumptions might not be valid anymore.[29] Climate change will increase the risk of damage to infrastructure and affect its performance.

Damage from extreme weather events already causes large economic costs. These costs will get progressively higher as the climate changes. Extreme weather events in Victoria cost $2.7 billion a year, on average, over the 10 years to 2016.[30] Victoria's 2009 Black Saturday bushfires cost more than $4 billion.[31] The 2022 floods cost the Victorian Government $1.8 billion in immediate relief funding and another $677 million for flood recovery.[32] Other costs can include loss of life, worse health and wellbeing, less safety, and the loss of species and biodiversity.[33]

Communities can have strong expectations that governments should be adequately preparing for climate events. They want governments to ensure that people can stay safe and healthy during and after these events, and that services and economic activity can quickly resume. For example, the Legislative Council Committee inquiry into the 2022 flood event in Victoria was inundated with over 800 submissions. Many people expressed deeply personal stories of loss, trauma and anger. They felt governments had failed to adequately prepare, protect and revitalise their communities.

If humans keep producing more greenhouse gas emissions and Victoria does not adapt to the effects of climate change, climate-related damage in Victoria could cumulatively cost at least $115 billion by 2030, and more than $986 billion by 2100.[34] These figures likely understate the total cost because they only include lower productivity, worse health impacts and losses from land and infrastructure. They do not include many other costs of floods, bushfires, pollution and biodiversity loss.[35]

More extreme weather caused by climate change damages and disrupts infrastructure, costs money to repair, and has extensive consequences for the people and businesses relying on it. For example, extreme wind events can damage electricity distribution infrastructure and result in many thousands of customers experiencing power outages at the same time. Victorians experienced this in June 2021. Heavy rainfall and strong winds damaged power lines, and about 330,000 homes lost electricity, especially in the Dandenong Ranges. About 68,000 customers had no power for more than 72 hours.

People need infrastructure so they can stay safe, well and productive.[36] Infrastructure provides many services. It delivers energy, water and telecommunications to homes and businesses, and gives people transport access to work and other valuable destinations. Facilities provide access to essential services like education, healthcare, and other commercial, community and public services. Vulnerable people especially rely on these infrastructure services to stay healthy and safe.

Much Victorian government-owned or regulated infrastructure is already vulnerable to climate change events.[37] To keep communities functioning and businesses open, Victoria's infrastructure must be able to keep functioning in a warmer, drier climate and during more extreme weather.

Early investment in adaptation action can reduce the costs of future damage. One academic study of 28 adaptation projects in over 16 countries found a wide range of positive returns on investment. The projects produce benefits that outweighed their cost by between 1.3 to 60 times. The median project saved $6 for every $1 spent.[38]

The case study on the next page shows Queensland road adaptation delivered a similar return. More resilient infrastructure can reduce climate-related damage, and consequently reduce recovery costs.[39] This includes the costs of disruption to the economy and reductions in labour productivity.[40] Investing now to adapt infrastructure will allow governments to minimise the costs of recovering from extreme events and reduce the harm to people and the environment. It will enable communities, services and supply chains to resume normal functioning faster.

Case study

Making Queensland roads more resilient delivers savings

Between 2010 and 2013, major cyclones and heavy rain hit Queensland, which caused $6.5 billion dollars of damage to its roads. Over 8,000 kilometres of Queensland Government roads needed to be fully or partially rebuilt after flooding.

The government established the Transport Network Reconstruction Program to deliver long-term disaster repairs to the state-controlled road network resulting from floods and cyclones.

The program commissioned a study to measure the damage caused by extreme weather events to Queensland roads over their useful life. This helped identify the funding needed for more flood resilient roads.

The study used a life cycle costing model to demonstrate that investing in more resilient roads delivers benefits. This work documented the life cycle costs to roads, including the damage itself, its immediate recovery time and cost, its eventual reconstruction and the cost of repairs, community and industry delays, and associated costs.

The researchers selected 7 case studies in 4 representative Queensland regions. These included urban and rural locations that allowed the researchers to compare 3 investment scenarios: the base case of what actually happened, a full resilience scenario and a preventative maintenance approach to road rehabilitation.

The study found that moving to a preventative maintenance strategy for selected roads meant an extra dollar of spending would deliver $6.90 in road user cost savings and produce cumulative life cycle savings of nearly $600 million.[41]

Image below: Volunteers help clean up flooded streets in Brisbane in 2011. Source: Shutterstock.

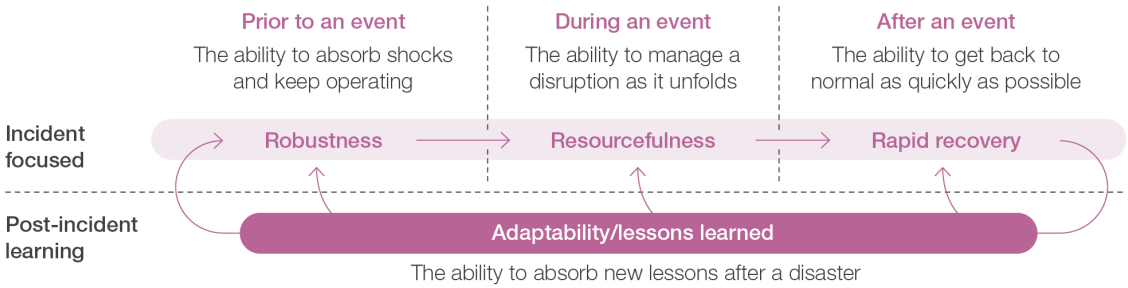
Adapting infrastructure for the future climate

Governments cannot completely eliminate the risk of damage to infrastructure from future climate change events, or the consequences for communities. But they can reduce the risks. Adaptation can make infrastructure more resilient before, during and after extreme weather events, as Figure 3 illustrates.

Infrastructure lasts for a long time, but its designers have typically assumed it will operate in similar climatic conditions as in the past. A different climate that has more frequent and intense extreme weather events means that infrastructure may not function, because it was not built for these conditions.[42] Other factors also affect whether infrastructure can keep performing. This includes its age, condition, design and construction materials, and how essential it is for physical, functional or social requirements.[43] It also means that infrastructure owners must plan, design, build, and operate new infrastructure in ways that account for the future climate change that might occur during its life.[44]

Adaptation comes in many forms. Adaptation measures do not always have to be expensive. In this report, we document different adaptation options to help inform decision-making. Options can include building infrastructure to better prevent and prepare the infrastructure before an event, such as undergrounding of distribution networks to reduce power failures from high winds. They can include actions that reduce the exposure and severity of the event on the infrastructure, such as catchment upgrades to reduce flooding exposure. They can include response measures undertaken during an event, such as traffic management and emergency repairs. Or they can include activities that mean infrastructure can recover and be repaired more quickly after an event, such as bushfire risk management plans which reduce downtime after landslides.

Figure 3: Resilience categories



Source: The National Infrastructure Advisory Council, *A framework for establishing critical infrastructure resilience goals*, 2010, in PIARC, *Uniform and Holistic Approaches to Resilience: Climate Change and Other Hazards*, 2023.

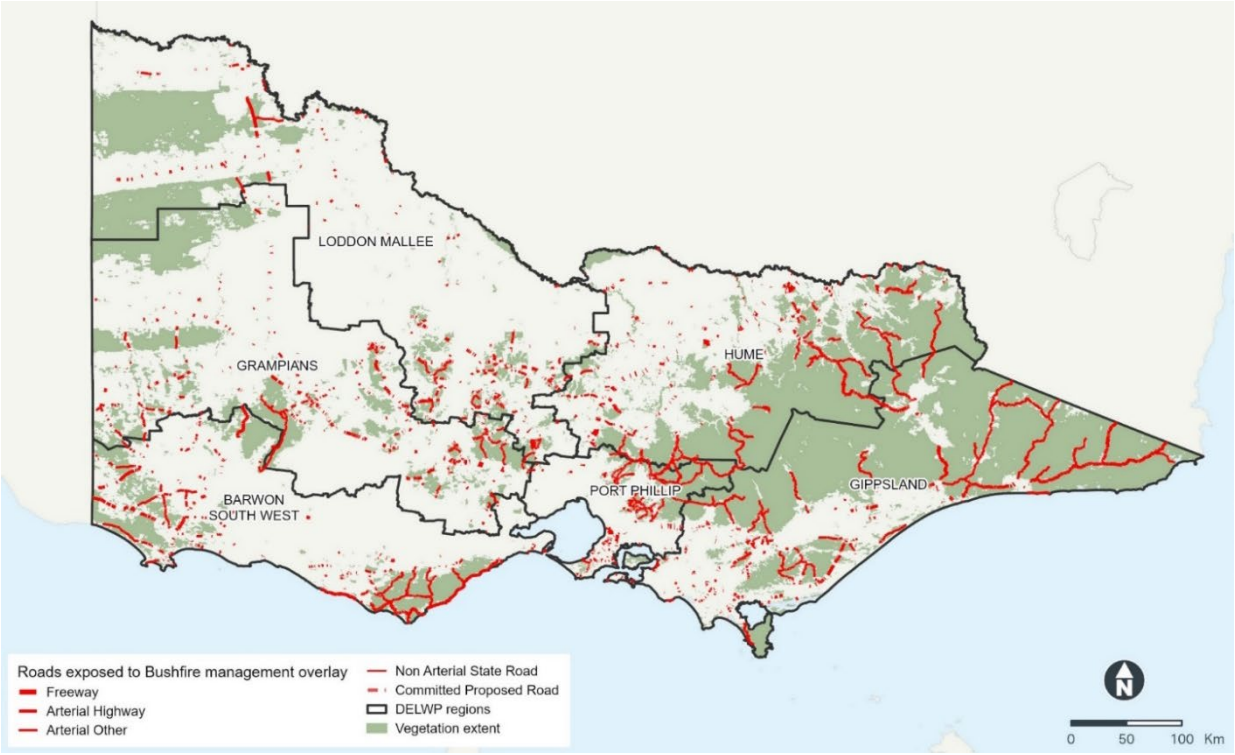
Adaptation increases the robustness, resourcefulness and rapid recovery of infrastructure assets and systems. But making infrastructure more resilient to effects of climate change is not an end in itself.[45] Resilient infrastructure contributes to more resilient communities and economies.[46] It supports communities to withstand, respond to and recover from events linked to climate change, such as a heatwave or extreme flooding.[47] It can give communities early warning information so they can better prepare, provide emergency shelter during extreme weather, enable transport and communications during times of emergency, and support emergency services' response.

Resilient infrastructure allows essential services to keep operating, such as food, water, energy, transport, telecommunications and health care services.[48] It provides venues and access to support services that help communities recover.[49]

Adaptation is not one-size-fits-all

Victoria's climate risks to infrastructure will vary between different asset types and different locations, and different climate change events will occur at different frequencies and intensities. Exposure to extreme weather events varies in different parts of Victoria. Climate projections suggest they will not intensify evenly in different regions. For example, the increase in bushfire risk will rise most rapidly in heavily forested areas. Figure 4 shows the variation in Victoria of road exposure to bushfires. Infrastructure managers can learn from past events, and use scenario planning to examine different possible futures, to assess infrastructure's local vulnerability and risks.[50]

Figure 4: Roads exposed to bushfire risks (bushfire management overlay)



Source: AECOM, *Climate change consequences study*, 2023.

Note that these figures illustrate assets that intersect or are near hazard zones and may therefore be exposed to climate hazards. Further analysis is required at the subregional or site level to determine if assets are actually at risk or are sensitive to these hazards.

Victorian Government agencies routinely manage risks to their service delivery, reputation, finances and people's safety. Climate change introduces new risks for agencies to manage and makes some existing risks more severe. Infrastructure managers can identify assets and locations that might be particularly vulnerable and assess their climate risks. Conducting these climate risk assessments allows infrastructure managers to make informed decisions about adaptation investments that get the best returns.

Infrastructure managers can then select the best priority adaptation measures by undertaking site-specific analysis of the impacts of climate change for vulnerable and high-risk locations. The effects of climate change are different for every location because of their individual socioeconomic, physical, geographic and functional characteristics. For example, site-specific analysis can identify the local impacts on vulnerable people, cultural heritage, biodiversity and ecological health, alongside the likelihood and severity of impacts on infrastructure safety, embodied carbon, and considering the resilience for multiple climate hazards.

Testing individual adaptation measures is also highly site-specific. What may work in one location may not be effective or suitable in another. In this research, we examined 3 asset types in detail:

electricity transmission and distribution infrastructure, public hospital buildings and roads. We identified that extreme weather events have negatively affected each of them and will continue to do so.

The best adaptation measures might be specific to that location. For example, increasing roadside vegetation for stormwater management can reduce flood risk. Vegetation can slow down and absorb rainwater, which reduces flooding and erosion risks. But vegetation can also mask signs of slope instability. In another location, increasing vegetation can be maladaptive. Vegetation can act as a fuel for bushfires, potentially increasing the severity and spread of the fire. This is why infrastructure managers must carefully assess local conditions to decide whether specific adaptation measures are suitable.

Case study

Assessing climate risk for Victorian regional hospitals identifies several themes

In February 2022, the Department of Health released the *Health and human services climate change adaptation action plan 2022–26*. One of the plan's objectives is to make infrastructure more resilient to climate hazards, such as severe weather events.[51] In March 2023, the department commenced a project to assess climate hazard risks to 6 regional hospitals across Victoria. The project analysed their exposure to flooding, extreme heat, grassfire and bushfire. It was delivered in a partnership between the Department of Health and hospitals with funding from Emergency Management Victoria. It included 3 phases:

- Desktop analysis of historic weather patterns for each of the regions surrounding the hospitals. This was mapped to projected trends in increased temperatures and extreme weather to provide site-specific climatic projections.
- Engagement with key stakeholders in water, planning, and emergency services to source data, better identify local risks and existing actions to mitigate and respond to these risks.
- Visits to each hospital to assess infrastructure, meet with hospital staff and workshop the challenges and opportunities the hospital faces in adapting to projected future climate hazards.[52]

While climate risk is specific to the type of asset and its location, several themes emerged across the health services in the study:

- While hospital locations vary, it was generally found that the centralised location of hospitals in towns largely protected assets from the direct impacts of severe weather events.
- Hospital services are at greater risk than infrastructure during climate-related events than hospital buildings. For example, access to and from the hospital by staff and patients and the reliance on external sources for critical services such as utilities and supplies present challenges for the effective delivery of health services during severe weather events.
- Aged care facilities were shown to be more exposed to severe weather events given aged care patients are broadly more susceptible to climate extremes and the inherent risks associated with evacuation.[53]

The study proposed adaptation options to increase the resilience of infrastructure and services. Options included relocation of critical assets (such as electrical switchboards) to increase their protection from severe weather and upgrading buildings components to better manage extreme heat (for example, double-glazed windows).

Service delivery options included reviewing emergency management protocols to address site-specific risks, installing backup communications (such as satellite phones, UHF radios) and strengthening supply chains through stress-testing arrangements and backup options.[54]

The study will assist with embedding climate resilience into the health system in line with the *Health and human services climate change adaptation action plan 2022–26*.

Climate change impacts can be interdependent

Extreme weather events that affect one sector can have flow-on effects to others. These are also known as 'cascading impacts'. For example, blackouts caused by storms in June and October 2021 also disrupted water, sewerage and communication services. The storms also knocked over trees, which closed roads and delayed repairs to electricity distribution lines.[55] This means that even if infrastructure is not directly exposed to a climate risk, it can be indirectly vulnerable from another type of infrastructure failing. For instance, road disruption can cut access to critical locations, such as hospitals, residential areas, or industrial zones. This can also sever access by emergency services or stop businesses operating.

'Compounding impacts' occur when extreme events happen at the same time or in short succession to produce combined impacts that are worse than the individual effects of each event.[56] For example, storms and flooding rapidly followed the 2019–20 East Gippsland drought and bushfires, compounding the effects on those communities.[57]

By identifying interdependencies, infrastructure managers can more comprehensively assess their risks beyond direct damages,and improve resilience in other sectors.[58]

Local area analysis can avoid maladaptation

Climate risk assessments are useful for determining which assets to prioritise, but asset managers will need to analyse local conditions to identify how climate change will affect specific infrastructure assets.[59] This allows them to decide which adaptation measures are effective in terms of planning, performance and cost.

Many different variables determine whether an adaptation measure will be beneficial. Otherwise, infrastructure operators cannot tell what the measure will do when they implement it. The appropriateness of adaptation measures depends on the situation in which they are applied. There are no universally 'good' options. Infrastructure managers must closely analyse the region, area and infrastructure to determine its appropriateness.[60]

If infrastructure managers do not undertake localised analysis, they risk investing in measures that might not be effective for decades or might be ineffective or maladaptive. Maladaptation refers to negative consequences following the implementation of an adaptation measure.[61] This occurs when an adaptation measure, meant to protect the community from climate change, inadvertently increases the vulnerability of a system, sector or social group.[62] Researchers have found that maladaptation is often caused by information gaps, where an adaptation measure has been introduced without fully assessing all the risks and impacts.[63] The next case study shows an example of maladaptation in Fiji floodwall construction. Localised and site-specific assessments can capture detailed data to help decision makers avoid proceeding with maladaptive measures.

This is especially relevant when an adaptation measure might affect other sectors. Infrastructure does not operate in isolation, and ideally adaptation measures should not be maladaptive for infrastructure and services in the same location. Our research found that extreme weather events can have compounding and cascading impacts on electricity and road infrastructure and for hospital buildings. For example, powerlines knocked over by extreme wind can block a road, which could then stop staff and patients accessing a local hospital.[64]

Case study

Fiji floodwall construction shows impact of maladaptation and need for local knowledge

In 2015, government contractors constructed of floodwalls on the Fijian island of Vanua Levu. Rising sea levels were increasingly flooding the low-lying villages of Karoko and Korotasere. But the contractors built them without engaging local people or conducting local assessments.

The contractors built floodwalls that were not long enough to protect the villages from flooding. Flood waters could travel around the floodwall. Worse, the floodwalls made the flooding worse because the villages did not have good drainage systems. The floodwalls prevented water flowing out to the sea, trapping floodwater and heavy rainfall in the villages.[65]

An academic study of the Karoko and Korotasere floodwalls found that the project could have prevented this maladaptation if it had placed the long-term concerns of the locals at its centre. Instead, the project was undertaken as a short-sighted response to recent flooding events.[66]

Building from similar experiences globally, the Intergovernmental Panel on Climate Change identified 4 key factors for successful adaptation:

- ensuring vulnerable communities are included in adaptation planning
- creating an inclusive consultation process that encourages participation
- ensuring that the effects of adaptation are distributed fairly and do not make existing inequalities worse
- creating strong, flexible institutions, which integrate policies into risk management and account for long-term goals.[67]

These factors can help to evaluate the shared benefits and trade-offs between different adaptation responses and reduce the likelihood of maladaptation.

Image below: Savusavu marina and Nawi islet, Vanua Levu island, Fij. Source: Shutterstock.

Victoria has committed to climate adaptation

Victoria's *Climate Change Act 2017* sets out the processes for the government to manage climate risks and transition to net zero emissions. It requires the Victorian Government to develop a climate change strategy every 5 years. This strategy sets out how Victoria will meet emissions reduction targets and adapt to the impacts of climate change.[68]

The government released *Victoria's climate change strategy* in 2021. It sets out priorities for adaptation: addressing current climate change impacts, reducing barriers to adaptation, and laying the foundations for future adaptation action.[69] These adaptation priorities set the direction for Victoria's 7 system-based adaptation action plans. The plans guide Victorian Government adaptation efforts in each sector. The sectors are the built environment, education and training, health and human services, natural environment, primary production, transport, and water cycle systems.[70]

The Victorian Government has also published 6 regional adaptation strategies to guide local action.[71] These regional strategies use local knowledge to set out place-based climate change adaptation actions. To date, the government has allocated $1.5 million to deliver projects identified by them.[72]

The *Climate Change Act 2017* requires the government to update the adaptation action plans in 2026. That is an opportunity to for the government to commit to more tangible and extensive action to adapt infrastructure to climate change.

But Victoria spends little on adapting infrastructure

Victorian Government agencies and infrastructure owners are at different stages in adapting to a changing climate. Some agencies and infrastructure managers still assume that the future climate will be the same as the past climate. For example, they make decisions using historical climate data. This includes decisions about maintenance, asset management, upgrades and possible new projects.

The government's existing approaches prioritise funding for repair and recovery after the event has already occurred.[73] This is true of most governments.[74] For example, in 2014 the Productivity Commission found that the Australian Government spent 97% of its natural disaster funding after an extreme weather event, but only spent 3% on proactive efforts to limit the impact of future events.[75]

The commission said that state governments also underinvested in risk mitigation, and that natural disaster costs were a growing unfunded liability.[76] The National Emergency Management Agency is also conducting an independent inquiry into Commonwealth disaster funding, including funding arrangements for risk reduction and preparedness, which is scheduled for release in April 2024.[77]

Recent Victorian budgets contained little new funding for infrastructure adaptation to better prepare for events. The Victorian Government says it has provided over $2 billion over several budgets towards climate action.[78] The vast majority of identified spending is for reducing greenhouse gas emissions.

The Victorian Government allocated $166 million in the 2023–24 budget to climate resilience, largely for revegetation projects, waterways management or drought resilience projects for agriculture. [79] We could not separately identify Victorian Government spending on infrastructure adaptation projects.

This funding might feasibly be included as part of other infrastructure spending or maintenance activities, but not separately accounted for.

Our research method

This research uses a mixed methods approach. Our methodology report explains the components of our approach in more detail. The methodology report is published on our website, alongside other technical reports we commissioned for the research.

We consulted with stakeholders throughout the project including Victorian Government departments and agencies, asset managers, academics, regulators and think tanks. For instance, we engaged around 90 participants in our initial risk assessment workshops from a variety of sectors. We also engaged with selected government departments to assess our thinking and recommendations.

We learned from other governments and jurisdictions

We started by reviewing literature about the difficulties governments and policymakers confront to adapt infrastructure to climate change. We also examined reports about successful adaptation.

We assessed climate change adaptation policies and initiatives in other Australian and international jurisdictions. We show some of these lessons using case studies in this report.

We also reviewed the application of Victoria's climate change policy framework to infrastructure adaptation. We considered progress in delivering Victoria's adaptation action plans and regional adaptation strategies, ways to improve future updates to these plans and barriers to taking adaptation action.

We assessed climate change risks for infrastructure

In the early phases of our work, we considered different types of physical infrastructure including energy, telecommunications, transport and water infrastructure, and buildings and facilities. We conducted a first pass risk assessment of climate change impacts in the infrastructure sectors of transport, utilities, and the built environment. We considered the socio-economic, environmental and cross-sectoral impacts of climate change. We then conducted detailed analysis of climate risks in 3 more specific infrastructure sectors – road networks, electricity networks, and public hospital buildings. This helped us identify adaptation actions which could build on those already planned or underway.

We examined the effects of extreme weather events on these 3 sectors in a *Climate change consequences study.*[80] The study included geospatial analysis to identify regions where these types of infrastructure may be exposed to flood and bushfire risk. We used planning scheme instruments such as bushfire management and flood overlays, and urban flood zones to find existing areas of potential fire and flood risk.[81] This analysis was statewide and high level, aiming to identify regions where assets are exposed to climate hazards because of their location, rather than identifying specific assets.

We also identified physical and policy-based adaptation actions relevant to road networks, electricity networks, and public hospital buildings. For these sectors, we identified assets and risks to assess in more detail using a multi-criteria analysis to prioritise risks that:

- had fewer effective controls in place
- had more flow on impacts, including direct and indirect impacts on other sectors

- had limited redundancy, back-up solutions or where recovery would take a long time
- can inform the next 30-year infrastructure strategy and/or the government's adaptation action plans.

We analysed site-specific adaptation costs and benefits

We generated new quantitative and qualitative evidence and analysed possible public policy responses.

We conducted economic analysis of 2 infrastructure sectors, electricity distribution and road networks, to test the potential return on investment for different adaptation measures. This approach demonstrated how economic evaluation can guide adaptation action, by factoring the benefits of risk reduction into investment decision-making.

Figure 5: Building the economic case for adaptation action in 4 stages

We selected 3 climate risks to assess: flooding and bushfire for roads, and extreme winds for electricity distribution. We then examined adaptation measures relevant to these sectors and risks.

Infrastructure adaptation can take many different forms, and for ease of analysis we divided the identified options into 4 categories:

- higher-cost investment options, such as large-scale projects requiring the construction of infrastructure or higher-cost materials
- lower-cost investment options, including nature-based solutions
- maintenance, including increasing periodic maintenance and incorporating preventative maintenance
- hazard management solutions, such as communication and early warning systems, removal of hazards and temporary structures.[82]

To conduct an economic analysis, we created a base case 'do nothing' scenario under current climate conditions. We then projected future climate conditions for 2070 against which we compared the costs and benefits of our adaptation measures.

We examined the cost of implementing and maintaining each adaptation measure, including replacement costs where appropriate. Our analysis also included the embodied carbon emission cost of each adaptation measure.

Our research confirmed adaptation measures can produce a compelling case for investment when direct, indirect and intangible costs and benefits are considered together. It also shows that site-specific analysis is essential for assessing potential adaptation measures, because not all measures generate a return on investment because of their specific location, features or local climate conditions.

The next 3 examples show a summary of each cost-benefit analysis.

Cost-benefit analysis

Adapting the road network for flooding – hypothetical suburban scenario

Our research explored the economic costs and benefits of investing in climate adaptation for a site-specific road network. We did this work in partnership with Arup.[83] Our analysis indicated that damage to roads due to extreme weather events was a high climate risk for the transport network.

We examined how floods might affect a major suburban Melbourne arterial road, and how the costs and benefits of adaptation measures performed against a 'do nothing' base case. Our scenario was based on real world data. It featured a 7-kilometre, 2 lane road, in a flood zone. Eleven thousand vehicles used the road each day.[84]

We created a long list of adaptation measures relevant to the scenario. We then conducted a multicriteria analysis to create a shortlist of adaptation measures. We also considered community impacts during construction and maintenance, recovery time, cost of construction, road service level impact, embodied carbon emission impact, level of net impact on the environment and maladaptation risks.

We assessed the embodied carbon associated with the production and transportation of materials for the adaptation measures. We selected 8 measures to examine:

- using foamed bitumen stabilisation, a road pavement treatment which improves its strength
- upgrading the road grade and improving drainage now to absorb one-in-20-year flood events
- staged upgrading of the road grade and improving drainage now to absorb one-in-20-year flood events, and upgrade in future to absorb one-in-100-year flooding
- building a new raised road viaduct over a floodplain or waterway
- using water sensitive urban design to harness natural infrastructure and systems to capture, treat and manage stormwater runoff from roads
- increasing preventative maintenance to preserve pavement condition and extend the road's life
- programming road rehabilitation involving more frequent extensive repairs and maintenance to improve the overall condition of the road
- using intelligent transport system solutions and rerouting to prevent further damage to roads after flooding.[85]

Our results showed that good adaptation does not have to be expensive

Our analysis showed positive benefits related to low-cost measures such as maintenance activities.

Five adaptation measures produced a positive return on investment in all conditions: foamed bitumen stabilisation, water sensitive urban design, preventative maintenance,

programmed rehabilitation, and optimising the road grade now to absorb one-in-20-year flood events.[86]

Preventative maintenance and foamed bitumen stabilisation produced the highest returns on investment under both current and future conditions. Preventative maintenance produced $5.10 for every $1 spent in current climate conditions, increasing to $8.29 under future conditions. This was shown to extend the lifespan of infrastructure assets, helping to avoid costly repairs and premature replacements.

Foamed bitumen stabilisation showed $2.98 for every $1 spent in current conditions and $4.83 under future conditions.[87]

The viaduct option had a unique outcome. It was resilient to flooding but, for our hypothetical suburban road, it did not show benefits that outweighed the installation costs under current and future climate conditions. It was the only adaptation measure that did not produce positive results under any scenario.[88] However, it may still be an option to consider if a road is deemed critical, such as access for emergency services.

Table 1: Benefit-cost ratio (BCR) for flooding adaptation measures under current (2022) and future (2070, high emission scenario) climate conditions based on a 7% discount rate

Adaptation measure	BCR current conditions (7% discount rate)	BCR future conditions (7% discount rate)
Preventative maintenance	5.10	8.29
Foamed bitumen stabilisation	2.98	4.83
Water sensitive urban design	2.90	4.66
Programmed maintenance	2.51	4.06
Upgrade road and drainage to one-in-20-year flood events	1.26	2.03
Staged road and drainage upgrading to one-in-20-year and one-in-100-year flood events	1.04	1.71
Hazard management solution	0.77	1.26
New raised road viaduct	0.09	0.14

Source: Arup, *Adapting Victoria's infrastructure to climate change: economic analysis of adaptation for roads*, Infrastructure Victoria, 2023.

Planning the implementation of adaptation may produce better results

Our research explored individual adaptation measures compared to a base case scenario. But some adaptation measures that do not produce a high return on investment by themselves may work better when coordinated with other measures or implemented using a staged approach. This is known as adaptation pathway planning.

A pathway approach also allows decision makers to consider new information and adjust their decisions over time to enhance infrastructure and community resilience. This can help with the use of resources and optimises the benefits from specific adaptation measures.

We examined one high-cost adaptation measure with a pathway approach: optimising the road grade and improving drainage now to absorb one-in-20-year flood events, and upgrade in future to absorb one-in-100-year flooding.

This produced a positive return on investment under future climate conditions. Other individual adaptation measures that produced lower results, such as hazard management, may work better when coordinated with other measures.[89]

By considering some adaptation measures together and their sequencing in the future we can help to make infrastructure more resilient as new information becomes available.

Full details of this cost-benefit analysis are in the technical report, *Adapting Victoria's infrastructure to climate change: economic analysis of adaptation for roads*, available on our website.

Cost-benefit analysis

Adapting the road network for bushfires and bushfire-induced landslides – hypothetical rural scenario

We examined the economic costs and benefits of investing in climate adaptation for a site-specific road network. We did this work in partnership with Arup.[90] Our analysis indicated that service interruption of roads caused by bushfires and subsequent rainfall-induced landslides was a highly rated climate risk for the transport network.

We examined how bushfires might affect a regional road in Victoria, and how the costs and benefits of adaptation measures compared to a 'do nothing' base case. Our area was based on site-specific real world data, consisting of a 50-kilometre undivided road carriageway in a bushfire zone. The road connects 3 small towns with a total population of 600 people and provides essential access for residents, freight, tourists and emergency services. Aside from unsealed roads, the surrounding area has few alternative roads.[91]

We examined the extra risk of post-bushfire induced landslides. Bushfires rarely cause direct damage to roads, but they can destabilise the surrounding landscape by causing erosion and creating debris. Bushfire-induced landslides can cause more disruption to the road than a bushfire itself.[92]

We created a long list of relevant adaptation measures. We then conducted a multicriteria analysis to create a shortlist of adaptation measures. We considered community impacts during construction and maintenance, recovery time, cost of construction, level of net impact on the environment and maladaptation risks. We also assessed the embodied carbon associated with the production and transportation of materials for the adaptation measures. This method produced a shortlist of 8 measures to examine:

- remediate 2 high-risk slopes with flexible barriers to protect the road from landslides, debris or rockfalls
- remediate 11 high and moderate-risk slopes with flexible barriers
- fire-resistant plants that do not burn easily from continuous flame or from the first wave of a bushfire
- fire break (vegetation clearance zone from the road) to reduce the rate of spread and intensity of fire
- increased programmed drainage clearing and vegetation management such as clearing or controlled burns
- immediate post-fire responsive drainage clearing for embankments and cuttings along slopes following a bushfire
- post-fire erosion protection and slope stabilisation using seeding, matting and drainage clearance
- risk management plan including intelligent transport system signage alerts, disaster response planning procedures for inspections, maintenance and rehabilitation.[93]

Table 2: Benefit-cost ratio for bushfire and landslide adaptation measures under current (2022) and future (2070, high emission scenario) climate conditions based on a 7% discount rate

Adaptation measure	BCR current conditions (7% discount rate)	BCR future conditions (7% discount rate)
Programmed drainage clearing and vegetation management	5.88	11.52
Post-fire erosion protection and slope stabilisation	0.73	1.37
Risk management plan	0.71	1.07
Post-fire responsive drainage clearing	0.57	1.07
Fire-resistant plants	0.42	0.82
Remediate 2 high-risk slopes with flexible barriers	0.19	0.58
Remediate 11 high and moderate-risk slopes with flexible barriers	0.19	0.28
Fire break (vegetation clearance zone from the road)	0.17	0.32

Source: Arup, *Adapting Victoria's infrastructure to climate change: economic analysis of adaptation for roads*, Infrastructure Victoria, 2023.

Programmed drainage produced over 5 times the return on investment

Our analysis clearly demonstrated that, in this scenario, increasing programmed drainage and vegetation management would produce a large return on investment. At a 7% discount rate, increasing programmed drainage under current climate conditions would return $5.88 for every $1 spent. For future climate conditions, this increases to $11.52 in benefits for every $1 spent.[94] Increased programmed drainage would increase flood resilience, reducing the effects of post-bushfire landslides without more expensive interventions.

Higher cost does not equal the best return on investment

Lower-cost investments such as maintenance measures and hazard management showed the largest positive return on investment. Their lower upfront initial expenditure makes these measures a 'no regrets' adaptation measure.

Immediate post-bushfire erosion and drainage clearing produced positive returns on investment under future climate scenarios.[95] The results also showed that some adaptation measures can be combined, enhanced and sequenced when implemented in a certain order. For example, improving soil erosion control and vegetation restoration before undertaking infrastructure upgrades can help stabilise slopes and minimise erosion impacts. These results suggest that these types of adaptation measures may be worth investigating for application for roads in Victoria soon.

Our results suggest that the most cost-effective solution to this scenario is through increased maintenance and hazard management options. Neither of the high cost slope

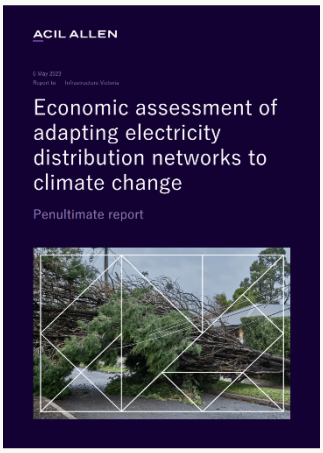
remediation measures produced a positive return on investment under a 7% discount rate, although remediating the 2 high-risk slopes had a neutral result under future climate conditions at a 4% discount rate.[96]

The low-cost fire-resistant planting measure did produce a positive return on investment for future climate projections but only at a 4% discount rate.[97] Fire breaks received a lower result in this analysis due to the high costs associated with their establishment and maintenance in this particular exemplar for roads. Fire breaks can be an effective measure, with cost differences across regions based on environmental constraints and terrain, scale of treatment and purpose of protection.[98]

Our result emphasises the importance of place-based approaches to prioritising investments in infrastructure resilience. The full details of this cost-benefit analysis can be found in the technical report on our website, *Adapting Victoria's infrastructure to climate change: economic analysis of adaptation for roads*.

Cost-benefit analysis

Adapting electricity distribution lines for extreme wind events – hypothetical urban scenario



We examined the economic costs and benefits of investing in climate adaptation for electricity distribution infrastructure with ACIL Allen (pictured).[99]

Electricity distribution networks transport electricity from the high voltage transmission network to homes, businesses and industrial premises. They include poles and wires, substations, transformers and switching equipment.[100]

Our analysis indicated that damage to, or degradation of, assets due to extreme weather events were a high rated climate risk for electricity transmission and distribution infrastructure.

We examined how extreme winds may affect a typical metropolitan Melbourne area, and how the costs and benefits of adaptation measures compare to a 'do nothing' base case. Our area was based on real world site-specific data, rather than an actual location, consisting of a service area of 2,000 customers.[101]

We created a long list of adaptation measures but found only a handful had moderate to high effectiveness for this scenario. After considering community acceptance, financial costs and maladaptation risks, we selected 4 measures to examine:

- undergrounding distribution cables, existing overhead distribution infrastructure is replaced with the same underground infrastructure
- insulated cables, existing overhead conductors are replaced with overhead insulated cables
- replacement of large trees that have potential to damage overhead distribution infrastructure with lower growth trees
- grid-forming inverters, electricity customers that install solar and battery systems to also install inverters that can operate on their own or as an island system in the event of a grid outage.[102]

Our findings from the cost-benefit analysis were mixed

We found that all 4 adaptation measures reduced electricity outages and helped to adapt distribution networks to the effects of extreme wind but only one adaptation measure, insulated cables, delivered a positive return on investment.[103]

We also assessed the present value of embodied emissions associated with manufacturing and construction emissions required for specific adaptation measures. For example, emissions from manufacturing new capital items, such as cables, and construction

emissions, such as from installing new insulated cables or trenching for underground cables.

Embodied carbon costs were found to be less than 2% of the total capital cost for the base case, undergrounding and insulated cable. For tree replacement, the embodied carbon of this measure was higher, at about 4% of the total capital cost of the measure.

Further research can strengthen the evidence base for future investment

Our analysis pointed to several research gaps and complexities that influenced our findings. These included the amenity benefits of undergrounding electricity distribution power lines.

We analysed the costs and benefits of undergrounding power lines. Undergrounding is expensive and we found that it is not a cost-effective way to adapt electricity distribution networks to the likely future effects of extreme wind in this example.

However, undergrounding can deliver major amenity benefits, including a better streetscape and more tree cover. Studies in other parts of Australia suggest that undergrounding can deliver a positive return on investment when amenity benefits are included in the analysis, but we did not consider that these estimates could be extended to Victoria.[104]

The effects of climate change on future generations

The decision-making process can capture future benefits and avoid maladaptation by identifying where adaptation options fit in a pathways approach to climate resilience. But benefits that occur a long time into the future can be difficult to capture in a cost-benefit analysis.

Analysts use discount rates to compare benefits that occur at different points in time, and the choice of discount rate affects the value placed on future benefits.

Our study used the Victorian Government's recommended approach in selecting discount rates, but other methods are available that might be more appropriate for analysis over very long periods. More research and guidance can help address these uncertainties for future analysis.

The full details of this cost-benefit analysis can be found in the technical report, *Economic assessment of adapting electricity distribution networks to climate change*, available on our website.

Image below: Melbourne's distribution network is vulnerable to damage or degradation due to extreme weather events. Source: Shutterstock .

Victoria can better manage climate risks to infrastructure

Boost priority and oversight for infrastructure adaptation

If governments do not act to adapt to new climatic conditions, Victoria's infrastructure will fail more often. Infrastructure failure causes real harm to people and businesses. It is also expensive for governments to repair, especially urgently, in affected communities with potential worker and materials shortages.

The Victorian Government cannot reduce the risk of climate-related disruptions to infrastructure to zero.[105] But successful adaptation can reduce, manage or avoid many adverse effects of climate change.[106] Governments with strong policy frameworks can make better, more informed and cost-effective decisions to adapt infrastructure. The government can better manage or reduce risks by considering climate risk when planning for new infrastructure, maintaining or retrofitting existing assets.

Victoria already has the policy architecture for climate change adaptation. Victoria's *Climate Change Act 2017* requires the government to produce a climate change strategy, including 7 sector-based adaptation action plans and 6 regional adaptation action plans. These plans set out adaptation actions, which can include specific changes to make infrastructure more resilient.

Despite Victoria having a policy framework to guide adaptation action, asset managers told us they do not feel empowered to assess climate risk or suggest adaptation measures. The Victorian Government can strengthen its policy structures and requirements to direct infrastructure managers to assess climate risk, act upon it, and demonstrate how their assets are more resilient.

Recommendation 1: Boost priority and oversight for infrastructure adaptation

- Make public infrastructure resilience an adaptation priority in *Victoria's climate change strategy.*
- Develop an adaptation action plan for Victoria's energy system.
- Include all infrastructure types in future adaptation action plans.
- Specify the responsible agency for each adaptation action.
- Regularly publish a progress and evaluation report on adaptation actions.

Make public infrastructure resilience an adaptation priority in Victoria's climate change strategy

Victoria's *Climate Change Act 2017* has 5 policy objectives. One of them is to build the resilience of Victoria's infrastructure, built environment and communities through adaptation and disaster preparedness.[107] But *Victoria's climate change strategy* does not reproduce this specific legislative objective. It details 16 adaptation priorities to guide Victoria's 7 adaptation action plans, but none prioritise making public infrastructure more resilient.

The Victorian Government should specify a new priority to make infrastructure more resilient in the next version of *Victoria's climate change strategy*. The next version is due by 31 October, 2025. Updated adaptation action plans, due in 2026, should have actions to achieve this new priority.

Develop an adaptation action plan for Victoria's energy system

The government has no specific adaptation plan for Victoria's energy sector. The built environment adaptation action plan includes some elements of the energy sector, but it does not mention other elements. It has few actions that apply to improving the resilience of energy infrastructure.

Most other adaptation action plans identify energy as critical to services due to interdependencies across many other sectors such as health, transport, and education. Victoria's storms in June and October 2021 illustrate the disruption that occurs when energy systems fail. Almost 300,000 Victorians were without power following the June storms, and over 525,000 lost power in October's extreme winds.[108]

Energy assets are largely privately owned and operated. But the Victorian Government helps shape energy policy by regulating energy consumer rights and safety. It issues planning approvals for energy infrastructure. The government is also now preparing to be an energy market participant via the State Electricity Commission.[109] The Victorian Government can use its different regulatory, funding, and producer roles to improve energy infrastructure resilience.

The *Climate Change Act 2017* requires the Victorian Government to produce new adaptation action plans by 2026. The 2026 update should also include a new adaptation action plan for Victoria's energy system. This can build on the work of the *Electricity distribution network resilience review*, completed in 2022. The energy system adaptation plan should aim to clarify the respective roles of private businesses, governments, regulators and local communities in strengthening resilience.[110] This recommendation is in line with section 34 of the *Climate Change Act 2017* which allows other adaptation action plans to be developed, provided they are prescribed in regulations.[111]

Include all infrastructure types in future adaptation action plans

Victoria's 7 adaptation action plans guide government action to manage climate change risks and opportunities across the built environment, education and training, health and human services, natural environment, primary production, transport, and water cycle systems.[112] Collectively, they contain around 125 actions to build capability, improve tools and information to support decision-making, strengthen frameworks and coordinate activities.

The plans cover most infrastructure, but not all. For example, the plans do not mention justice and community safety infrastructure, and do not mention some telecommunication infrastructure, such as telecommunications towers, poles and wires, and VicTrack's telecommunications network.[113] These omissions mean there are no clear actions to adapt some infrastructure types to climate change.

The Victorian Government should include all infrastructure it owns, manages or regulates in its adaptation action plans.

Specify the responsible agency for each adaptation action

Each adaptation plan has a lead department, but the plans do not identify which department, unit or agency is responsible for individual actions. Some plans cover multiple portfolios and agencies. This can make it difficult to tell which area of government is accountable for delivering each action, particularly as departmental responsibilities change over time. For example, the Department of Transport and Planning leads the *Built environment climate change adaptation action plan*, but the Department of Energy, Environment and Climate Action is responsible for energy policy, which this plan contains. The government should assign all adaptation actions to the department or agency

responsible for delivery. This will strengthen the line of sight between ministers, agencies and their adaptation responsibilities, and allow them to monitor progress. These arrangements should also be clarified following any machinery of government changes.

The government could further clarify agency responsibilities in responding to climate risks to infrastructure by issuing ministerial guidelines under the *Climate Change Act*.[114] These can show agencies how to incorporate the Act's policy objective to build Victoria's infrastructure and community resilience and the guiding principle of risk management in policy and decision-making.[115]

Regularly publish a progress and evaluation report on adaptation actions

The Victorian Government can help infrastructure managers make better decisions in the face of the uncertainties of climate change by more effectively monitoring and evaluating the actions they take to adapt. These processes can also generate the evidence that allows practitioners to learn from past efforts and adjust future programs to perform better.[116]

One purpose of the *Climate Change Act* is to improve clarity and accountability through information collection and reporting.[117] The Victorian Government publishes a report every year on progress towards reducing Victoria's greenhouse gas emissions. But it does not track progress on climate change adaptation efforts.[118]

The Act requires the government to report on the implementation and effectiveness of previous adaptation action plans in each update.[119] This commits government to a 5-yearly reporting cycle. Each adaptation action plan flags that a monitoring and evaluation framework will be developed to guide implementation. The government is yet to publish a framework for any of the system plans and there is no publicly available monitoring on adaptation actions and outcomes. We could not identify progress on implementing infrastructure adaptation actions from publicly available information. As climate change is fast-moving and dynamic, waiting 5 years in between cycles to assess progress is too slow, and we will miss opportunities to learn and adapt.

Best practice adaptation requires reporting and assessment mechanisms to determine whether adaptation is progressing and is effective in building resilience.[120] The Victorian Government should develop a monitoring and evaluation framework to guide ongoing improvement of adaptation plans, and report results mid-way and at the end of each 5-yearly adaptation cycle. The framework should cover:

- Monitoring individual adaptation actions in each system plan. System-focused monitoring and evaluation should be undertaken by the lead department for each adaptation system, overseen by a clearly designated part of government such as the Department of Energy, Environment and Climate Action or a central agency.
- Whole-of-system, statewide adaptation progress to build knowledge of Victoria's resilience to climate change over time, including infrastructure. This should consider collective progress on adaptation plans and the overall effectiveness of Victoria's adaptation framework. Whole-of-system reporting can be undertaken by the Department of Energy, Environment and Climate Action or a central government agency. Alternatively, an independent agency can monitor government progress in building resilience.[121]

Monitoring implementation of Victoria's adaptation action plans and evaluating their collective effectiveness can demonstrate successes and find areas for improvement. Reporting at the action, system and statewide level can build evidence of what works and guide future investment decisions. It can identify and address gaps and areas for improvement, particularly in addressing shared or cross-system climate risks where departmental accountability is less clear.[122]

Case study

Incremental progress towards climate resilience

The United Kingdom has a well-established policy framework to reduce domestic emissions and promote adaptation action.

Their *Climate Change Act 2008* commits the UK to reduce its greenhouse gas emissions by 100% of 1990 levels (net zero emissions) by 2050. The legally binding emissions reduction target was the first of its kind.[123]

The Act also set up an independent Climate Change Committee to advise government on emissions targets and report on progress in reducing emissions and preparing for climate change. It requires the UK Government to produce a Climate Change Risk Assessment and a National Adaptation Programme every 5 years.

The risk assessment shows the hazards and opportunities the UK faces from climate change and provides evidence that informs the development of adaptation actions. The third assessment was published in 2022.[124]

The adaptation program is the government's response. The latest report sets out the actions that government and others will take to adapt to the impacts of climate change from 2023 to 2028.[125]

The UK's 5-yearly cycle to review and update its adaptation program provides transparency on the actions taken to build resilience. The progress reports assess each sector's efforts.[126] Every 2 years the progress towards achieving effective adaptation is reported to Parliament.[127] This approach helps keep attention on climate change policy and means that sectors can make changes and improvements over time as new evidence becomes available.

Despite the strong policy framework, adaptation is still challenging to implement. The most recent progress report on adaptation found that the scale of action is not enough to prepare the UK for the climate risks it faces. It recommended a step change to fully embed adaptation in government policies and decision-making.[128]

Image below: Mechanical diggers on a construction site in Cornwall, UK, repair coast defences and sea walls with rocks from a quarry after rising sea levels caused erosion and damage. Source: Shutterstock.

Coordinate and standardise climate projections

Climate change means that historical data is no longer a reliable indicator of future weather patterns and events.[129] Climate projections can help infrastructure managers determine how their assets are likely to perform in a future climate and how current infrastructure might be adapted.

Some infrastructure sectors, such as in water infrastructure planning, have begun to incorporate climate projections into decision-making about infrastructure management and new investment. But people in many other sectors do not feel equipped to do this. They report that they do not have the requisite skills to interpret the data, or that the data is not available in a form that they can easily apply to their infrastructure assessment tools.

Climate projections generally follow global standards set by the IPCC.[130] But they are complex to use. Future climate projections produce a variety of outcomes, often expressed as range of possibilities, because they are constantly evolving with new information.[131] Understanding how to interpret them with confidence is difficult because they rely on highly technical datasets, containing multiple models and emissions scenarios. It is not obvious to infrastructure managers which data to use and for what purpose. Climate scientists recommend using multiple scenarios to account for the uncertainty surrounding Victoria's future climate (for example, high and low future emissions scenarios).[132] Stakeholders told us that they struggle to interpret and apply climate data when assessing risks, developing policies and making investment decisions.[133]

The Victorian Government has developed reports and climate projections data to provide insights into how Victoria's climate is changing. For example, *Victoria's climate science report 2019* provides a statewide summary of available evidence.[134] The Victorian Government and CSIRO have also developed *Victoria's future climate tool*, an interactive website that contains local area climate projections (to a spatial resolution of 5 kilometres) to make it easier for policy makers to visualise how the latest projections show climate change affecting Victoria.[135] Full datasets are available from the *Climate change in Australia* website.[136]

These tools are valuable, but public servants need more support to use climate data properly in infrastructure planning. Climate projections model how different aspects of the climate are likely to change in the future, but they do not predict how extreme weather events will affect particular locations.[137] For example, average rainfall projections might indicate changes in flood risk. But actual flooding will depend on how intense storms are, detailed local geography and topography, and how much water can be absorbed by drains, land and waterways in different areas. Translating climate projections into sensible estimates of the frequency of hazards requires specialist knowledge that asset managers and policymakers typically do not have.

Victoria's future climate tool includes multiple climate models. Users are advised to use as many models as possible to explore the range of possible futures, or to carefully select the model that best suits the task at hand.[138] This involves a level of judgement, potentially leading to different models being applied to similar analyses or inappropriate data. Different infrastructure business cases may rely on different climate models and assumptions, making it difficult to compare costs and benefits for different proposals.

Ireland's meteorological service has developed a national set of standardised future climate projections to aid decision-making in multiple sectors, such as transport, energy and water. This is detailed in the case study: Ireland's Translate project helps people 'speak the same climate language' (p.36).

Recommendation 2: Coordinate and standardise climate projections

- Establish an agreed set of climate projections for use in government infrastructure planning and management, especially projections of extreme weather events.
- Keep improving local level data that infrastructure managers can use for site-specific analysis.
- Deliver training and ongoing support for infrastructure managers to apply the data to climate risk assessments.

Establish an agreed set of climate projections for use in government infrastructure planning and management, especially projections of extreme weather events

To make climate projections easier to apply, the Victorian Government should determine which climate models to use for different variables as standard to inform infrastructure decision-making across government. This should include work to translate these into standard parameter estimates for climate hazards and impacts. The government can regularly update the projections to incorporate new evidence from climate science as it becomes available.

For example, the government should produce standard projections of increases in the frequency and intensity of bushfires, storm events, flooding, and coastal inundation. These should include a central estimate of the parameters, which can be supplemented by a range of scenarios to indicate uncertainty. This is like the approach taken with official state projections in *Victoria in future* for populations and households.[139] It can remove the judgement currently required and improve consistency in assessing climate risks.

Keep improving local level data that infrastructure managers can use for site-specific analysis

The Victorian Government should keep improving local area climate projections. This will enable agencies to conduct site-specific risk assessments on the assets they manage and give government a clearer picture of priority locations and assets for infrastructure adaptation. The government should develop the data in collaboration with the National Partnership for Climate Change Projections so it is consistent with the *Climate projections roadmap for Australia*.[140]

Deliver training and ongoing support for infrastructure managers to apply data

The government should accompany this with training and ongoing support for the relevant government staff to incorporate climate risks into asset management processes and investment decision-making. Sharing examples of risk assessments and business cases can assist them to learn and apply them consistently.

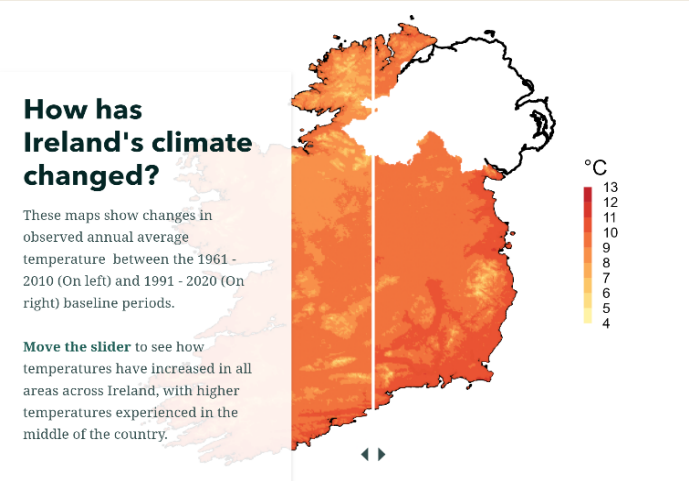
The next update to *Victoria's climate science report* is due by October 2024.[141] This will be a timely opportunity to focus on the tools and support for Victorian Government agencies to incorporate climate data in asset management and investment decision-making (see also recommendation 4: integrate climate risk into government risk management and recommendation 6: update business case and investment guidance). The government can also review resourcing and governance for climate modelling, to determine whether there is merit in a dedicated body to develop and guide the use of climate change data in government decision-making.

Case study

Ireland's Translate project helps people 'speak the same climate language'

Communicating complex scientific information in a way that can be understood and actioned by policy and decision-makers is an issue shared around the world, particularly for climate change.[142] To meet this challenge, the Translate project has developed standardised climate projections for Ireland alongside climate services that meet the information requirements of decision-makers.[143]

Translate delivers a dataset to support Ireland's climate adaptation and mitigation efforts. Climate services communicate the data and information into products, such as risk assessments and uncertainty estimates, that are tailored to meet the needs of different stakeholders and sectors. For example, road managers are using Translate data to 'stress test' the rural road drainage system using future surcharge and flooding conditions. This will facilitate adaptation of vulnerable or exposed roads.



Ireland's Meteorological Service has developed a tool to communicate the impacts of climate change on the island's weather. Source: Met Éireann,

Image below: Silverstrand beach in Galway, Ireland. Source: Shutterstock.

The project's aim is to deliver climate projections, information and services that are easily accessible to all users.[144] Translate released its first climate projections in June 2023. A follow-on project will build upon these results to develop more climate products and services for Ireland.[145]

Use asset management systems to improve resilience

Adaptation measures do not have to be expensive or involve large rebuilding or retrofitting of infrastructure in projects. We explored many different adaptation options focusing on physical adaptation measures to infrastructure, including improving maintenance, nature-based solutions and asset management standards. Managing existing assets so they still are fit for purpose for changing climatic conditions is cheaper than building new infrastructure. But much of Victoria's existing infrastructure might need to be maintained, managed differently, or retrofitted, to increase its climate resilience and keep critical services and communities functioning.[146]

Climate risks to new infrastructure can be managed from the planning and design stages, well before building begins.[147] Managing climate risks means rethinking how and where infrastructure is built in the future to be more resilient to the effects of climate change.[148] For example, the Insurance Institute for Business and Home Safety is working with James Cook University in Australia to improve resilience of buildings from wind and rain events.[149]

Victoria cannot build its way out of the problems posed by a changing climate. Building new assets will generate more greenhouse gas emissions, including from the materials and processes used in constructing it.[150] This means better using the infrastructure that already exists and planning for alternatives for networks, for example alternative evacuation routes. When rebuilding is unavoidable, *Victoria's infrastructure strategy 2021–2051* recommends rebuilding priority public infrastructure to more resilient standards or in less vulnerable locations.[151]

Increasing the resilience of infrastructure using better asset management practices minimises repairs.[152] It reduces disruptions to people and communities. It also helps prevents shocks to businesses and freight supply chains, which helps Victoria maintain its productivity. But international studies have found that governments often overlook management of their existing assets.[153] A 2019 audit found that many Victorian Government agencies should improve their asset management practices.[154]

The *Asset management accountability framework* is the government's policy framework for asset management.[155] The framework requires departments and agencies to assess their asset management maturity levels. Their 2020–21 self-reported assessments indicate that some areas of government can develop better knowledge of the performance of their full asset portfolio.[156]

Good portfolio asset management involves organisations knowing the infrastructure they hold, the purpose it serves, the risks it faces, a strategy to manage each asset, and regularly reviewing the plan so it stays relevant.[157] Organisations can integrate climate adaptation into asset management practices using site-specific data and qualitative information as part of existing functions and processes to make infrastructure more resilient to a changing climate.[158]

Recommendation 3: Use asset management systems to improve resilience

- Release climate change guidance on assessing climate vulnerability and risk, designing for resilience, and adopting preventative maintenance.
- Support agencies to develop the processes, tools and expertise to embed climate considerations in asset management practice.

Release climate change guidance on assessing climate vulnerability and risk, designing for resilience, and adopting preventative maintenance

Asset management maturity levels vary in different Victorian Government departments and agencies for different infrastructure types. Less mature practices focus on operational asset maintenance, where asset managers are still developing data and knowledge about the condition and performance of their assets. A more integrated approach builds infrastructure resilience to risk exposure such as climate change.[159] Asset managers told us they find it challenging to detect the vulnerability of their assets to climate change and to choose an appropriate adaptation response.[160]

A step change can better incorporate resilience planning into Victorian Government asset management practices. Achieving this requires:

- using vulnerability and risk assessments to identify locations and infrastructure vulnerable to climate risks
- designing infrastructure facilities to be more robust to future climate impacts
- programming maintenance cycles and preventative maintenance so existing infrastructure can better withstand these impacts
- adjusting operations to prepare for and respond to extreme events.

Asset managers must have systems with sufficient maturity and the right information to conduct this type of analysis. Without such systems and information, it proves difficult to make the decision-making case for adaptation and overcome the hurdles and challenges that exist to incorporate resilience into asset management practices. Some private companies, such as insurance companies, might have better developed systems and data to conduct this analysis. Governments might be able to learn from these practices or access this data.

The Victorian Government does not clearly allocate responsibility for taking action to adapt infrastructure.[161] The *Asset management accountability framework* requires agencies to manage their assets effectively and efficiently.[162] The Department of Treasury and Finance is preparing to provide additional guidance on how climate risks to infrastructure can be assessed or managed, but this is yet to be published.[163] All infrastructure owners and operators must rapidly increase their asset management maturity to comprehensively consider climate change in their practice. This change is becoming more urgent because climate change effects are already occurring and will accelerate.[164]

The government should release its planned accountability framework climate change guidance to build knowledge and capability to manage climate risks. The guidance should clarify responsibilities and demonstrate approaches to manage climate risks, including advice on standardised climate models and datasets (see also recommendations 2 and 4) The guidance should support asset managers to consider climate change and resilience at each stage of the asset management life cycle, which includes during asset planning, acquisition, operation and disposal (see recommendation 6: update business case and investment guidance).

Support agencies to develop the processes, tools and expertise to embed climate considerations in asset management practice

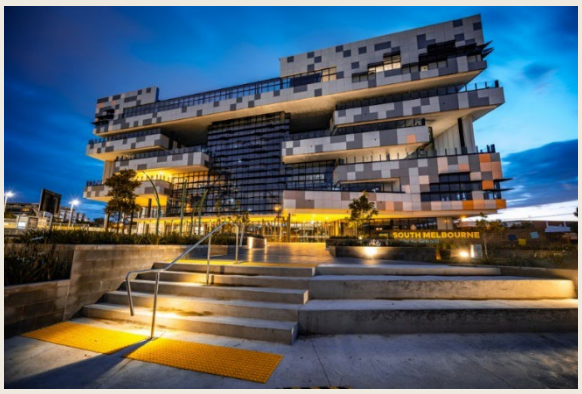
When the government releases new climate change guidance, it should also consider methods that assist asset managers to follow it. The Victorian Auditor-General found that the government can give more support and clarity to agencies to interpret and apply accountability framework requirements, and that agencies should keep investing in developing staff skills and their asset management systems to improve their performance.[165] Agencies will face similar challenges to incorporate climate considerations into asset management.

The government should deliver targeted training and support on adopting the new guidance. For example, it should develop further processes, tools and standards, and facilitate knowledge sharing and good practice between agencies, so staff can better understand the methods that can improve their asset management.[166]

Case study

Collaboration and preventative approach better supports school asset management

Victoria's school buildings asset base includes over 1,500 schools, 27,000 buildings, land and other assets valued at over $20 billion.[167] The Department of Education identified a $420 million maintenance backlog in 2012. A 2017 audit attributed the backlog to government underfunding, a lack of attention to maintenance by schools and differences in school leaders' asset management capability.[168]



The Asset Management Reform program helps Victorian schools better manager their buildings and other assets. Source: Shutterstock.

Victorian Government schools adopted a devolved governance model in the 1990s which put individual schools at the centre of decision-making, including for asset management. But the devolved model did not support the skills and systems development to keep pace with changes in asset management practice.[169] The department has since shifted towards more central support for schools, offering oversight and more resources to develop shared systems and processes.[170]

The department established the Victorian Schools Building Authority in 2016 to oversee school design, construction and upgrades. It refreshed its asset strategy in 2018 and launched a new shared responsibility model. Individual schools remain responsible for asset condition, but the building authority offers school principals more support to grow their asset management capability. This includes a centralised IT system, consistent processes in the education system, and targeted training.

The new approach recognises that schools can be well-managed locally as principals and school communities understand their unique needs. The centralised IT system allows the department to monitor of the physical condition of its assets and it can use that information to advise on maintenance tasks, allocate central funding for high-priority maintenance, and inform capital funding allocations.

The Asset Management Reform program aims to move from reactive and backlog-driven maintenance to a more preventative approach. The department considers the program integral in reaching full compliance with the *Asset management accountability framework* and is rolling it out to schools progressively over the 5 years to 2023.[171] The reforms are not specific to climate adaptation, but they offer lessons for other government agencies with devolved service models seeking to strengthen asset management practices and capabilities.

The department has identified climate adaptation for future improvement.[172] The Asset Management Reform program places it in a much stronger position to act. The department can consistently assess portfolio data and assets. It has the tools and processes to embed climate resilience in school buildings.

Integrate climate risks into government risk management

Not every piece of Victoria's infrastructure must be adapted, and of that which does, it cannot all happen at once. The Victorian Government can prioritise the infrastructure exposed to the highest priority risks. It can sequence adaptation actions by prioritising assets or combinations of actions by their potential exposure to the effects of climate change, their location and their value to the communities they support. This report helps identify some high-level infrastructure risks, barriers to adapting to them, and methods to select economically feasible infrastructure adaptation measures.

Evaluating what infrastructure is most vulnerable to climate change, and which is most critical, allows decision makers to prioritise actions. The challenge is for each department and agency to conduct their own climate risk assessments for their infrastructure. This should include detailed local assessments of assets to document their potential exposure and sensitivity to climate change effects. They can then identify measures and prioritise adaptation actions.

Risk assessments can use up-to-date climate projections to estimate how climate change might affect infrastructure and consider the likelihood and consequence of events. Incorporating climate projections into risk assessments allows infrastructure managers to assess the potential impacts of climate change, any emerging risks, and which risks the asset is exposed to. Decision makers can also use critical asset lists, alongside climate risk assessments, to prioritise what to focus on in a detailed evaluation of adaptation measures.

We documented numerous climate risks to government-owned and regulated infrastructure in our research, including electricity supply failure due to storms, extreme rainfall damage or disruption to roads and flood damage to hospitals.[173] Some local governments in Victoria have begun similar work by analysing climate damage and risks to their assets. The Eastern Alliance for Greenhouse Action has calculated that climate hazards cost greater Melbourne local governments $90 to $120 million annually. The same research projects that, without adapting infrastructure to climate change, this will increase to $210 to $300 million annually by 2050 and $400 to $540 million annually by 2100.[174] Local governments can use these estimates as a baseline assessment for their cost-benefit analyses of adaptation measures.

Climate change has relevance for several state-significant risks for Victoria, including the risk of harm to the economy, community, environment and government due to the physical effects of a changing climate.[175] The *Climate Change Act 2017* requires departments and agencies to consider climate risk when developing policies or making decisions.[176] Risk management is a guiding principle of the Act, but the government has not offered detailed advice on what this means for specifically managing climate risks to government assets.

The Victorian Government *Risk management framework* sets out the steps government agencies must take to manage risks effectively.[177] Agencies can tailor their approach to suit their organisational context, provided it is consistent with Australian Standard *AS ISO 31000:2018 Risk management – guidelines*.[178] The framework does not give examples of specific risks, including climate risks. It points instead to the Victorian Managed Insurance Authority for practical guidance.[179] Despite the severity of risks created by climate change, the *Risk management framework* does not necessarily prompt agencies to reflect them or show how to specifically address climate risks.

Some asset managers told us they do not know how to assess climate risks and develop appropriate responses. This compromises their ability to proactively plan for climate change and misses opportunities to identify cost-effective adaptation measures they can implement.[180] Because they have scarce funding, time and resources, asset owners and managers may focus only on immediate operational issues. This might not change unless agencies elevate their obligations to manage climate risks and have ready access to appropriate resources, information and tools.

Case study

Nangak Tamboree project increases university resilience to drought and flooding

In 2018, La Trobe University conducted new flood modelling of their university campuses. The modelling showed that climate change increases the risk of severe weather events impacting the Bundoora campus. The university's analysis showed that the best way to reduce climate-related risks to students and staff was to restore the waterway which runs through the campus.

La Trobe engaged with stakeholders to develop a 10-year plan for the renewal of the waterway to absorb flooding rains and protect the university.[181] The university also acknowledged the significance the waterway holds for the Traditional Owners, the Wurundjeri people.

The waterway was named Nangak Tamboree (a Woiwurrung phrase meaning respecting, sharing, and looking after the waterways) in a collaborative process with Traditional Owners.[182] The university collaborated with Traditional Owners Melbourne Water, Darebin Creek Management Committee, and the Wurindjeru Woi-wurrung Cultural Heritage Aboriginal Corporation, First Nations Elders and community groups to lead the rehabilitation process through multiple projects, incorporated into the *Nangak Tamboree vision*.[183]

The Wurundjeri Woi-wurrung Cultural Heritage Corporation reintroduced local land management practices such as cultural burning. The burns cleared invasive species from the waterway and revitalised native plant life. Following burns in 2021, the critically endangered Matted Flax-lily began growing in Nangak Tamboree. The plant can be found in grassy woodland, but it was previously unrecorded in the area. Its emergence shows the wetlands are returning to health and are more resilient to drought and flooding.[184]

Image below: The Nangak Tamboree waterway has increased the university's resilience to drought and flooding, led by First Nations knowledge. Source: La Trobe University.

Recommendation 4: Integrate climate risks into government risk management

- Develop detailed guidance to accompany the Victorian Government *Risk management framework* on how to assess climate-related risks to infrastructure and integrate them into decision-making.

The government should develop information to guide departments and agencies through the steps involved in undertaking climate risk assessments for infrastructure and incorporating these into investment decision-making. These can align risk assessment processes with international standards specific to climate change, such as *ISO 14090:2019 Adaptation to climate change – principles, requirements and guidelines* and *ISO 14091:2021 Adaptation to climate change – guidelines on vulnerability, impacts and risk assessment*.[185] These climate standards can help departments and agencies to prioritise, develop and implement adaptation measures that respond to the climate challenges they face.[186]

The new guidance can extend the Victorian Managed Insurance Authority's Climate Change Risk Management service, which includes introductory resources to help practitioners address climate risks.[187] The guidance should integrate with existing government policies and frameworks so that climate risk management becomes embedded in the usual business of government. This is like the approach taken in the New South Wales Government's Climate risk ready NSW guide.[188]

We recommend that the guidance expands its scope to include approaches relevant to infrastructure, including aspects required for an economic assessment of climate adaptation (see also recommendation 6: update business case and investment guidance.[189] This can include information on:

- prioritising where to undertake site-specific climate risk analysis
- establishing a sensible base case to compare changes under different climate scenarios
- identifying potential infrastructure adaptation measures and shortlist priority interventions
- methods to assess the potential risk reduction from adaptation measures.

Alongside the proposed guidance, the government should consider changing the Victorian Government *Risk management framework* to incorporate clear examples of the type of risks agencies face. The framework describes minimum risk management requirements for agencies, but it does not reference climate change or any other state significant risk. Other jurisdictions take a different approach. For example, the New South Wales Government's *Risk management framework* lists climate and cyber security risks as examples of emerging risks that agencies should assess, and points to practical information on how to manage them.[190]

This will complement recommendation 3: use asset management systems to improve resilience and recommendation 6: update business case and investment guidance by integrating considerations of climate change and adaptation into existing government policies and practices.

Case study

New South Wales climate risk process offers 4 practical steps to manage climate risks

The New South Wales *Internal audit and risk management policy for the general government sector* is a mandatory policy similar to the Victorian Government *Risk management framework.*

It extends beyond basic requirements to give examples of best practice.[191] The policy adopts Australian Standard AS ISO 31000, the same as Victoria, and flags climate-related risks as emerging risks that agencies should address.

The *Climate risk ready NSW guide* details how agencies should do this.[192] It draws on the international standard on adaptation to climate change (ISO 14091:2021) alongside AS ISO 31000 to use a 4-step process to achieve a consistent approach to climate risk assessment and management.

Outline of the Climate risk ready NSW process aligned to AS ISO 31000. Source: *Climate risk ready NSW guide*. Photo below: Sydney Harbour Bridge during a red dust storm. Photo: John Byrne

The guide has actions and objectives for agencies at each step of the process. It makes recommendations on data and information sources to use in climate risk assessments and offers tools to help agencies put the process into practice. It links into other New South Wales Government policies and guidance so that climate risk management becomes embedded in agency operations.

Training is available to help agencies assess, treat and monitor climate risks and embed these practices into existing risk management systems.[193] Victorian Government agencies would benefit from something similar.

Reduce financial risks and target funding

Align climate and financial risks to infrastructure

The Victorian Government spends billions of dollars responding to emergencies, and helping communities recover afterwards. The Melbourne Sustainable Society Institute estimates that climate damage in Victoria will cost nearly $1 trillion by 2100 without action to reduce emissions and adapt infrastructure.[194]

Climate change creates financial risks for government, including the cost of repairing damage to government assets. Our research identified over 40 high-level climate-related risks to Victoria's infrastructure.[195] If these risks are realised, communities will expect the government to spend more to restore critical infrastructure and services. Insurance premiums might also cost more as climate events intensify.[196] The Organisation for Economic Co-operation and Development recommends that governments invest more to prevent risk. This can reduce the financial losses from climate events.[197]

The Victorian Government does not document the financial risks of climate change in its financial reporting or financial management objectives. The *Financial Management Act 1994* and supporting legislative instruments set out public financial administration processes and allocate financial management responsibilities for government agencies. The Act directs government agencies to manage the state's financial risks, including risks to infrastructure, but it does not refer to climate change.[198]

The Act requires the government to document its long-term financial objectives based on sound financial management principles. These include considering the financial effects of government policies on future generations.[199] The government's most recent financial objectives include building new infrastructure and fostering a resilient economy. They do not mention infrastructure or community resilience to the effects of climate change. This means that climate adaptation objectives do not explicitly influence the government's financial policy, priorities or practice.[200]

The government has several major policy frameworks relevant to infrastructure adaptation, made under the Act, including:

- the Victorian Government *Risk management framework*
- the *Asset management accountability framework*
- the *Resource management framework*.

These frameworks do not reference climate change or specify integration of climate considerations.[201] The government will not have direct knowledge of its financial exposure to climate-related risks if it does not compel agencies to assess the financial risks of climate change on the assets they manage.

Recommendation 5: Align climate and financial risks to infrastructure

- Include climate adaptation in the government's long-term financial management objectives for infrastructure.
- Require agencies with infrastructure holdings to prepare climate-related financial risk disclosures.

The government should manage the financial risks of climate change by including infrastructure adaptation and climate resilience in its long-term financial management objectives. This will help make the financial costs of climate change explicit.

The government should know more about its climate-related risks to infrastructure so it can assess the financial implications. The government can do this is by requiring departments and agencies with infrastructure holdings to prepare climate risk disclosures each year to provide more financial rigour for the Victorian Government climate-related risk disclosure statement.[202] This reporting offers a regular process to regularly review climate-related financial risks to infrastructure.

Internationally, many companies must already make climate-related risk disclosures, including some with an Australian presence. Government might adapt some practices and lessons from these companies in their own disclosure processes. Agencies might need more resources to implement these new reporting requirements.

Recommendation 3: use asset management systems to improve resilience, recommendation 4: integrate climate risk into government risk management and recommendation 6: update business case and investment guidance, also reinforce this recommendation.

Climate-related financial risk disclosures

In 2015, the International Financial Stability Board created the Task Force on Climate-Related Financial Disclosures to improve reporting of climate-related financial information.

The task force developed consistent disclosure guidance for companies and banks, so that investors can better assess their climate-related risks and opportunities.[203]

The Australian Government has committed to introducing standardised reporting requirements for large businesses and public sector entities to make climate-related disclosures on governance, strategy, risk management, targets and metrics.[204]

Other countries have introduced mandatory climate-related disclosures or are developing new requirements, including the United Kingdom, New Zealand and Singapore.[205]

Climate-related financial risk disclosures were developed for private businesses, but they can be applied to the public sector.

The Victorian Government prepared a climate-related risk disclosure statement in 2022.[206] Other jurisdictions are considering similar measures. For example, the New South Wales Government completed a pilot for 3 public sector organisations to produce climate disclosure statements in 2022.[207]

The government can potentially extend this mechanism to clarify how its departments and agencies are managing climate-related financial risks and opportunities, including risks to infrastructure.

Governments also use other mechanisms for this. For example, the Australian and New South Wales governments assess long-term budget risks, including climate change risks, by producing intergenerational reports.[208]

These reports project 40 years into the future to estimate how global and local trends might affect the economy and budget. The Victorian Government does not do this.

Update business case and investment guidance

More resilient infrastructure can reduce future costs of climate change.[209] Our research confirms that climate change poses increasingly severe risks to infrastructure. It also shows that infrastructure managers could find adaptation measures that can reduce the long-term economic, social and environmental costs of extreme weather events.[210] But current government practices do not seek, identify or select these measures.[211] In part, this is because they do not routinely assess the costs of climate change, use them for making investment decisions, or disclose them in business cases for budget funding.

The financial costs of climate change go beyond the direct cost of infrastructure damage. This research also examined the indirect impacts of climate change. These include disruptions to services and supply chains, loss of productivity and lower incomes in disaster affected areas.[212] For example, we analysed a bushfire affected road in a regional area. We found the disruption to freight and passenger vehicles was the single largest indirect cost and exceeded the cost of damage to the road itself.[213]

Adaptation measures can also have costs other than their financial costs. For example, we measured the cost of embodied carbon emissions of each adaptation measure we tested.[214] Infrastructure produces embodied emissions by using materials that generate greenhouse gas emissions in their production and transportation, and by releasing greenhouse gases during construction. Adaptation assessments should measure embodied emissions because infrastructure projects can generate many greenhouse gas emissions. For example, we measured greenhouse gas emissions for different adaptation measures for roads prone to flooding. Building a road viaduct provides strong resilience to flooding. But we found that building a viaduct would produce 5 times more carbon emissions than the next most carbon intensive option, because it used a large volume of materials and required heavy construction.[215]

Infrastructure operators should fully account for the costs of climate change and factor them into their operational costs and any business cases for adaptation action. This includes calculating the embodied emissions inherent in some adaptation measures and calculating their differential costs against the base case.

But because the government does not require infrastructure managers to include these costs, and does not give clear direction on their measurement, they make fewer investments in adaptation planning, preparation and resilience.[216] Stakeholders told us that they are unsure how to use risk assessments to identify investment proposals. They said they struggle to quantify the costs and benefits of adaptation action. They are also unsure how to assess potential adaptation measures and build a case for investment.[217]

Measuring climate costs and incorporating climate science into business cases can be difficult. The effects of climate change are difficult to quantify, and the impacts are not immediate.[218] The benefits of adaptation can be hard to calculate because they are not solely financial savings. For example, adaptation measures can have positive impacts on the environment and can improve community resilience to climate change.[219]

These factors make it difficult for infrastructure managers to proactively plan for and invest in adaptation measures when they face competing priorities for resources and funding. Assessors must consider and quantify as many costs and benefits as possible to produce a rigorous investment analysis for decision makers. Decision makers also have to consider other strategic objectives, including achieving net zero emissions, among other social, environmental and economic outcomes.[220]

Our work demonstrates how infrastructure operators can capture both quantifiable and unquantifiable factors, and where further research can support decision makers.

Case study

Implementing climate change adaptation in decision-making and guidelines

Many European road authorities find that climate change has large effects on their assets, operations and services.

They have developed frameworks to assess the impacts of climate change, but some find fully embedding these frameworks challenging. This is because staff do not know how to use these frameworks in their ordinary work to build the case for adaptation. They also have challenges in identifying appropriate data, capacity and resources.

The Conference of European Directors of Roads has initiated the ICARUS project. It identifies current barriers and gaps in the application of resilience assessments and makes suggestions on ways to overcome them.[221]

The project uses the key performance indicators of road authorities and some of their other policies. It shows how adaptation measures can work within an organisation's existing policies and processes to build the case for adaptation.

It aims to produce:

- a baseline for climate change resilience assessments, resilience evaluation and the use of cost-benefit assessments for climate change adaptation
- a report on the use of impact chains of direct and indirect impacts
- guidelines on defining and using optimum service levels for evaluating resilience and adaptation options
- guidelines that show and explain adaptation measures that can be applied to the specific processes road authorities use
- a demonstration report showing how evaluations of adaptation measures include their wider benefits
- a report showing the factors associated with successfully delivering nature-based solutions
- resource training for different target audiences to ensure implementation of output.[222]

This work seeks to better implement resilience into existing asset and maintenance guidelines and decision-making processes. Victorian Government agencies would benefit from similar measures embedding resilience into business cases and decision-making processes.

Recommendation 6: Update existing business case guidance

- Update existing business case guidelines, technical guidelines and templates to include the risks and impacts of climate change.

Infrastructure managers told us that difficulty securing funding prevents them from investing in infrastructure adaptation.[223] They said fiscal constraints are further hampering climate change adaptation efforts, as Victoria is still recovering from the financial cost of the COVID-19 pandemic, supply chains are recovering from disruptions, and inflation is high.[224]

The Victorian Government's *Investment lifecycle and high value high risk guidelines* help agencies to develop investment proposals, inform government investment decisions and monitor project delivery.[225] The *Investment management standard* also supports this.[226] These guidelines direct agencies to consider climate adaptation and resilience when developing infrastructure investments, but do not give practical advice on how to assess climate vulnerability or consider climate risk when developing investment proposals.

A technical supplement guides the economic evaluation of investment decisions for infrastructure, but it does not cover physical risks from climate change.[227] The *Sustainable investment guidelines* give advice on incorporating sustainability into project planning and delivery, but they are not detailed enough to guide asset managers in justifying adaptation options for investment decision-making.[228] If project proponents do not have clear guidance on how to incorporate climate considerations, they will not be included in infrastructure decisions.

Victorian Government agencies can benefit from practical guidelines and worked examples of incorporating climate change into cost-benefit analyses and business cases. The government should clarify in the *Investment lifecycle and high value high risk guidelines* and the *Long form business case template* how agencies can incorporate climate change into investment decision-making. For example: [229]

- Revise questions in the checklist for business case developers and assessors that discourage proactive action on climate adaptation (for example, in the investment case section: 'Does the problem need to be addressed now and by this government?').
- Add climate risk and vulnerability assessment to the list of tasks agencies should undertake when considering a new investment (section *2.1 '*How long-term planning relates to this stage').
- Incorporate climate change scenarios in the investment base case (section 2.5.1 'Defining the base case – the first response option').
- Require agencies to undertake a climate risk assessment when building the business case for all high value infrastructure investments and point to our recommended climate risk assessment guidance (see recommendation 4: integrate climate risk into government risk management). This can be added to section 2.6 Step 4: 'Project options assessment of the *Investment lifecycle and high value high risk guidelines – business case'.*
- Update the *Long form business case template* to require agencies to record the options they considered to embed resilience, their recommended approach, and the financial implications of each.[230]

The government should update the *Economic evaluation for business cases: technical guidelines* to include consideration of climate risks.[231] These should direct agencies to incorporate climate risk assessments into infrastructure cost-benefit analysis and give examples of how this can be approached, linking with other relevant guidance. Updates will offer the government an opportunity to review its current preferred discount rates to determine whether the current approach

appropriately accounts for the long-term effects of climate change and adaptation action (see Discount rates and climate change below for further details).

The updated business case guidance will work with our recommendations to use asset management systems to improve resilience (recommendation 3) and integrate climate risks into government processes (recommendation 4) to guide agencies in how to consider climate change risks throughout the infrastructure lifecycle.

Discount rates and climate change

Discount rates convert future costs and benefits to current values

Analysts use cost-benefit analysis to assess the relative merits of different policies and proposals, including infrastructure investments.[232] Discount rates allow them to compare costs and benefits produced at different points in time.[233]

The Victorian Government recommends using a discount rate of 7% when an analysts can easily translate proposed benefits into monetary terms, such as for housing and roads. They recommend a rate of 4% when benefits are more difficult to quantify, such as in public health and education.[234]

Higher discount rates devalue future costs and benefits

The discount rate affects the value of costs and benefits produced at different points in time. For example, they will affect the assessed value of avoiding future costs in a climate adaptation project.[235]

Projects usually have large upfront costs but produce accumulated benefits in the future. When a project produces benefits in the distant future, a higher discount rate places less value on those future benefits. This means that analysts will calculate a lower ratio of benefits to costs for that project. Higher discount rates favour benefits for present generations over future generations. This means that adaptation projects might not compare favourably against projects that deliver more immediate benefits.

The government can review its discount rate guidance

Policy and investment decisions acting on climate change will have large impacts many generations from now.[236] Decisions that do not appropriately factor in the long-term costs and benefits of climate change will have far-reaching consequences if they contribute to poor future resilience.

Other jurisdictions are starting to do things differently. For example, New South Wales lowered its standard discount rate from 7% to 5% in 2023.[237] The United Kingdom uses discount rates that decline over time to evaluate long-term projects, starting at 3.5% for years 0 to 30, falling to 3% for years 31 to 75 and 2.5% for years 76 to 125.[238] Analysts can also conduct sensitivity tests to different discount rates to show their effects.

Build confidence that good adaptation measures will receive funding

The Victorian Government has not attached dedicated resources or funding to its adaptation action plans. They instead entwine adaptation funding with broader climate action funding, including for reducing greenhouse gas emissions and recovering from emergencies. This means funding for adaptation and resilience measures can easily be overlooked in the budget allocation process. For example, the 2023–24 Victorian Budget included over $2 billion for climate action, nearly all of which was directed to emergency management and recovery, skills development, transport emissions reduction and $1 billion towards new renewable energy projects.[239]

Infrastructure adaptation measures can sometimes need upfront investment. In some cases, the government might need to fund new infrastructure to better protect communities from more frequent and intense weather events. It might need to adapt current infrastructure systems, including energy and transport, to function in more variable future weather conditions or return to service quickly after extreme events. The government might also need to retrofit some public buildings to stay safe and comfortable during more intense heatwaves and other extreme weather.[240] Government agencies can fund some infrastructure adaptation measures from existing maintenance budgets. Other measures will need extra funding to implement change or for major capital works.[241]

Infrastructure managers report that they are not confident that the government will fund even the best adaptation projects. The government has limited resources over and above existing budgets for new adaptation projects. But conducting risk analysis, vulnerability assessments, and cost-benefit analysis takes time and resources. Infrastructure managers are hesitant to do this work if they believe that adaptation projects will not be funded afterwards.

Carefully chosen infrastructure adaptation projects can deliver benefits that outweigh the costs of repairing and rebuilding infrastructure following catastrophic events.[242] Our cost-benefit analysis shows examples of specific adaptation measures that demonstrate a positive benefit over time.[243] For example, we identified 16 priority adaptation measures to adapt roads against the impacts of floods and bushfires. Most of them outperformed the base case (the scenario of ‘taking no action’) and produced a positive return on investment. For example, foamed bitumen stabilisation and water sensitive urban design have the highest return on investment under both current climate conditions in 2022 and future climate conditions in 2070 under a high emissions scenario, even when using different discount rates.

The availability of government funding will affect the extent of adaptation action.[244] But governments still prioritise funding for emergency response and repair over proactive investments in resilience, despite the potential benefits. The Productivity Commission estimates that the Australian Government spends just 3% of its natural disaster funding on preventative measures.[245] If governments keep underinvesting in resilience, they will produce higher economic, social and environmental costs over time.[246] A temporary increase in government spending can help break the cycle of low upfront investment and high repair and recovery costs.[247]

The United Kingdom’s Climate Change Committee identified unreliable and inconsistent funding as a major barrier to improving infrastructure’s resilience.[248] Stakeholders confirmed this during our research.[249] Agencies are unlikely to allocate resources towards infrastructure adaptation if it is not a funding priority for government.

Recommendation 7: Build confidence that good adaptation measures will receive funding

- Attach funding to the 2026 updates of the system-wide adaptation action plans, to encourage government agencies to evaluate and prioritise assets for adaptation and incorporate adaptation into business cases.

The Victorian Government can signal to agencies that the release of the 2026 adaptation action plans will include funding for adaptation actions with strong business cases. The Victorian Government should establish a Climate Adaptation Fund for the 2026 update. This will allow agencies to bid for funding for adaptation projects that they cannot fund from existing budgets and give confidence that priority projects will be considered. This can encourage government departments and agencies to incorporate adaptation in their business cases. To do this, they would first conduct appropriate risk and vulnerability assessments and have rigorously selected high-performing adaptation measures.

Agencies should audit the infrastructure in their portfolio, prioritise assets at high risk of being affected by climate change and identify adaptation measures to mitigate these risks. The next adaptation action plans should include concrete adaptation measures for assets facing near-term climate risks that can also demonstrate a return on investment. Community and stakeholder consultation on the draft plans can help further prioritise potential adaptation actions and inform likely funding requirements.

The Victorian Government has previously established climate adaptation funds. For example, it allocated dedicated funding for adaptation in the Supporting Our Regions to Adapt program, which funded Victoria's regional adaptation strategies and initial implementation of priority projects.[250] Other jurisdictions have established targeted funds for infrastructure adaptation, such as the New Zealand Transport Agency's NZ$419 million Transport Resilience Fund. This invests in preventative resilience projects on state highways and local roads to better protect the transport network.[251] The Canadian Government also supports adaptation with dedicated financial resources. Since 2018, it has invested CA$3.86 billion in more than 80 projects, as the next case study shows.

Similarly, the Greener Government Buildings program allows government agencies to secure funding outside routine maintenance requirements. It funds energy efficiency initiatives for existing government buildings.[252] It is self-funded through operating cost savings from lower energy use. The proposed Climate Adaptation Fund will not be self-funded, but more resilient infrastructure can deliver substantial savings over time including lower repair and recovery costs from extreme weather events and improved social and economic outcomes.

Case study

Canada links infrastructure financing to climate risk

Climate change is already costing Canadians billions of dollars each year. Over the last 5 decades, the costs of climate-related disasters have risen from tens of millions to billions of dollars each year.[253]

The Canadian Government launched its national climate adaptation strategy in 2023, to reduce risks from extreme weather events and limit the impacts of global warming.[254]

The government recognises it should scale up adaptation and build resilience into infrastructure. This is reflected in its adaptation strategy, which specifies that climate resilience will be factored into all new Canadian government funding for infrastructure from 2024.

The strategy sets the expectation that 80% of public organisations will factor climate change adaptation into decision-making processes by 2030, supported by robust guidance covering climate risks for infrastructure systems.[255] This is a significant step to integrating climate considerations into infrastructure planning and decision-making throughout Canada.[256]

The Canadian Government is supporting adaptation with dedicated financial resources. Since 2018, it has invested CA$3.86 billion in more than 80 projects, most to address flood and wildfire risks. It has also established a CA$200 million Natural Infrastructure Fund, Canada's first fund dedicated to nature-based solutions.[257] Both funds help manage the risks and impacts of climate change while generating other benefits such as enhancing natural habitats or increasing green space for communities.[258] Adaptation measures can therefore have benefits in addition to reducing climate risk.

Image below: The Parliament of Canada, located on Parliament Hill, Ottawa, Ontario, Canada. Source: Shutterstock.

Sequencing adaptation responses can help manage uncertainty

Adapting the right infrastructure, in the right order, can achieve better results. It is possible to create flexibility in planning for future climate change events by staging the implementation of adaptation measures as more information becomes available. This is known as an adaptive pathway approach and can help determine how likely different future climate change scenarios are, or decide what the consequences are from decisions made today.[259] This approach allows consideration of multiple possible futures to test the likely effect of different adaptation options.[260] It provides the flexibility to adapt to changing circumstances and future uncertainties.

Adaptation pathways also recognise that different adaptation measures can have complementary effects and build on each other over time. Options can be sequenced as a long-term plan.[261] This can be adjusted and updated as new information becomes available or as climate conditions evolve.[262] By adopting this approach, decision-makers can make best use of limited resources and achieve a higher level of overall resilience over time.[263]

Our cost-benefit analysis of road network adaptation explored sequencing to respond to increasing climate hazards over time. In this example, a staged approach allows the resilience of the road to be reassessed after the first adaptation measure has been implemented and defers the cost of large road upgrades until the benefit of further action in the future is justified as more information emerges.[264]

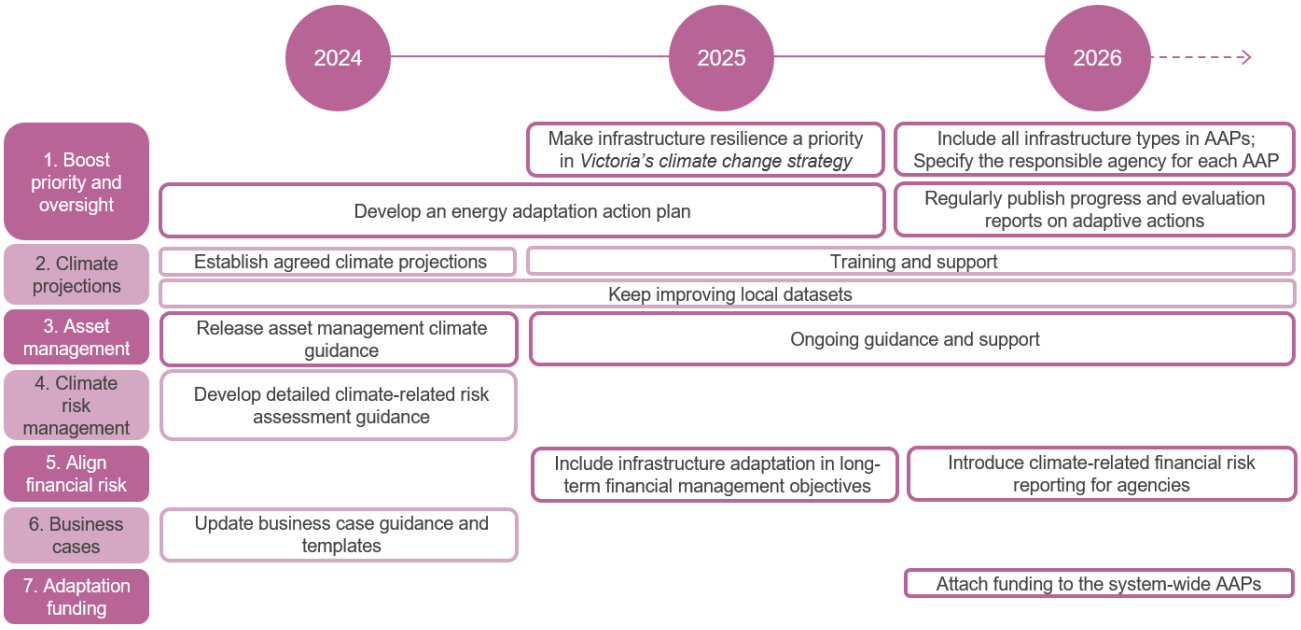
The combined impact of multiple adaptation measures can be more effective. It encourages a coordinated approach to adaptation, where measures are planned and sequenced to create a more resilient and adaptive system. Sequencing and potentially bundling adaptation measures can be a cost-effective way to improve baseline resilience.[265]

Implementation of adaptation measures can be coordinated and sequenced for greater effect to create better resilience outcomes. For example, not all adaptation measures need to be put in place at once. They can be added over an extended timeframe with staged investment, as more information becomes available. This can also help with budgeting for measures that must be implemented now for high-risk vulnerable areas, and those measures that can be added later.

Further details on how to approach infrastructure planning under uncertainty are available in our methodology report. Sequencing the implementation of adaptation measures improves their effectiveness by maximising their impact, reducing the impacts of climate change and maximising a return on investment.

Figure 6 (below) sets out a proposed timeline for the Victorian Government to implement our recommendations.

Figure 6: Timeline for Victorian Government action (note: AAPs = adaptation action plans)



Glossary

Term	Definition
adaptation	Adaptation is adjustment within natural or human systems in response to actual or projected stimuli or their effects, which aims to moderate harm or exploit beneficial opportunities.
adaptation action plans	Victoria has 7 system-based adaptation action plans. The plans guide Victorian Government adaptation efforts in each sector. The 7 sectors are the built environment, education and training, health and human services, natural environment, primary production, transport, and water cycle systems.
adaptation measure	A specific action implemented to reduce the impacts of climate change.
adaptive capacity	The ability for infrastructure or a system to successfully adjust to, take advantage of or respond to the consequences from climate change impacts.
adaptive pathway approach	Sequences of interlinked and flexible adaptive actions and decision points, which can be implemented progressively over time depending on future dynamics and changes to climate change risks.
benefit-cost ratio	An indicator used to estimate the overall value-for-money of a project or proposal. A BCR greater (or less) than one means the net present value of all benefits exceed (or is smaller than) the net present value of costs.
business case	A business case is a document that establishes an investment need, defines its benefits, explores interventions, estimates costs and confirms a preferred solution is deliverable.
carbon	A naturally occurring gas, also a by-product of burning fossil fuels from fossil carbon deposits, such as oil, gas, and coal, of burning biomass, of land use changes, and of industrial processes (e.g. cement production). It is the principal anthropogenic greenhouse gas that affects the Earth's radiative balance.
critical asset	Critical assets (physical, data/information, intellectual, process, technology) are those that are essential for supporting the social and business needs of both the local and national economy.
cascading impacts	Occur when an extreme hazard generates a sequence of secondary events in natural and human systems that result in physical, natural, social or economic disruption, whereby the resulting impact is significantly larger than the initial impact.
compounding impacts	The combination of multiple drivers and/or hazards that contributes to societal and/or environmental risk.

Term	Definition
catastrophic event/s	Natural or man-made incident that causes extreme levels of damage, harm or disruption to the community.
climate change	A change in the state of the climate that persists for an extended period, typically decades or longer. Human-induced climate change is the result of a growing concentration of carbon and other greenhouse gases in the atmosphere
climate hazard	A phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.
climate projections	A simulated response of the climate system (including variables such as temperature, precipitation, wind, solar radiation, sea level) to a scenario of future emissions or concentrations of greenhouse gases and changes in land use, generally derived using climate models. Climate projections depend on an emission scenario, in turn based on assumptions concerning factors such as future socioeconomic and technological developments that may or may not be realised.
climate model	Simulation of current and future climate change projections using modelling techniques.
cost-benefit analysis	A structured method that quantifies in monetary terms as many of the costs and benefits of a proposal as far as possible, including items for which the market does not provide a satisfactory measure of economic value.
disaster	Situation where widespread human, material, economic or environmental losses have occurred which exceeded the ability of the affected organisation, community or society to respond and recover using its own resources.
discount rate	A percentage rate used to convert future costs and benefits into present values to allow costs and benefits occurring at different points of time to be compared.
direct costs	Quantifiable losses incurred as a result of an event that have a direct market value, including damage and downtime of the asset from climate related hazards.
embodied emissions	The type of greenhouse gas emissions associated with materials used in construction, maintenance and disposal of infrastructure. This includes the emissions from the extraction, manufacturing, transportation, installation, maintenance, renovation and disposal of the materials used in these processes.
exposure	The presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected by a hazard.
extreme weather event	An event that is rare at a particular place and time of year. The characteristics of what is called extreme weather may vary from place to place.
geospatial analysis	Visualisation and mapping of the exposure of vulnerable assets and operations in areas based on proximity to climate hazards.

Term	Definition
greenhouse gas emissions	The production of gaseous constituents of the atmosphere, both natural and human-made, that absorb and emit radiation at specific wavelengths on the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself, and clouds. This property causes the greenhouse effect.
hazard	The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.
indirect costs	Quantified flow-on consequences from downtime, including economic costs of disruption to freight and the community.
infrastructure life cycle	The process from the beginning of design through to the end of the asset's life, including planning, development, construction, use, and decommissioning.
intangible	Direct and indirect damage that cannot be easily quantified in monetary terms, such as impacts on biodiversity, nature and health.
maladaptation	Actions that may lead to increased risk of adverse climate-related outcomes, including generating more greenhouse gas emissions, increased or shifted vulnerability to climate change, more inequitable outcomes, or diminished welfare, now or in the future. Most often, maladaptation is an unintended consequence.
mitigation	Actions taken to reduce greenhouse gas emissions or increase the amounts of greenhouse gases removed from the atmosphere.
net zero emissions	A state where the amount of greenhouse gas emissions produced by human activities equals the emissions removed from the atmosphere.
overlays	An overlay is a planning instrument/tool that applies to land with special features such as flood or bushfire risk.
preventative measures	The use of predictive analysis to forecast asset failure and reduce the risk of failure by scheduling maintenance ahead of time based on historical data.
programmed drainage clearing	Clearing of surface and sub-surface drainage to reduce the extent and frequency of climate impacts.
recovery	The coordinated efforts and processes used to bring about the immediate, medium-term, and long-term holistic regeneration and enhancement of a community following an emergency.
resilience	The ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events. This involves the capacity of a system to continue providing services, when exposed to hazards or if a disruptive event occurs, in a timely and efficient manner, including by preserving and restoring its essential basic structures and functions.

Term	Definition
retrofit	Addition of new technologies or features to old assets.
return on investment	A measure of the efficiency of an investment, expressed as a percentage or ratio by subtracting the cost of the investment from the gain from the investment and then dividing this amount by the cost of the investment.
risk	Effect of uncertainty on objectives or system operation. Risk is often characterised by reference to the likelihood of potential events, consequences, or a combination of these and how they can affect the achievement of objectives or system operation. Risk is often expressed in terms of a combination of the consequences of an event or a change in circumstances, and the associated likelihood of occurrence.
risk assessment	Process of comparing the results of risk analysis against risk criteria to determine whether the level of risk is acceptable or tolerable. Process to comprehend the nature of risk and to determine the level of risk. Risk analysis provides the basis for risk evaluation and decisions about risk treatment.
robust	The strength or ability of elements, systems and other units of analysis to withstand a given level of stress or demand without suffering degradation or loss of function.
sensitivity	The degree to which a system is adversely or beneficially affected by hazard-related stimuli.
site-specific analysis	Analysis of local conditions and resource planning specific to an asset and its location.
vulnerability	The degree to which a system is susceptible to, or unable to cope with, adverse effects of hazards, including climate change, variability and extremes.

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