Managing uncertainty
Uncertain climate change-planning
Some uncertainty cannot be avoided, but can be dealt with by considering a range of climate scenarios and
understanding system sensitivities and ability to withstand change being resilience.
Consistent here is policy/decision making is a matter of a local, regional or company level, it serves most
effectively in the context of policy and public guidance which are consistent across tiers of government and election cycles.
This is an opportunity for clear and robust strategic planning including identifying long term gains or damages yet. Agreement
Supply level targets. Under the requirements of adaptation and carbon reduction, they may no longer be possible to meet the
public expectation of a secure uninterrupted supply without very large investment which would need to be met from
private and public funds. Public debate is required to understand the trade-offs and to reach a reasonably agreed position.

Decision-making, planning and managing
Adaptation is not a once-off issue, but needs to be integrated into core business. It can then operate as a lever to
incentivise transition from a fixed approach to a fully integrated, flexible and dynamic planning framework early
for infrastructure management. Decision-making for adaptation should incorporate simple criteria at each decision point.
Key questions include:
• What must be protected at all costs?
• What can be sacrificed?
• How can we facilitate consideration of infrastructure adaptation in land-use planning processes?
• What can we do to facilitate a transition phase?
• What can the engineering and business resilience and what is the cost, specification, timing and availability challenge?

Levers and tools
Some levers and tools to achieve effective and timely adaptation are:
• Risk management: mainstreaming adaptation into the wider management of operational, environmental economic and budget risks.
• Financial tool for decision-making: selecting tools such as cost benefit analysis, financial analysis and forward budgeting.
• Instruments such as service level agreements, leases, policies, building codes, standards and guidelines to ensure consistent frameworks for adaptation across the multiple levels of complex organisational structures.
• Innovation: new products and designs, thinking, connecting, cooperation to foster resilience: regulatory mechanisms need to provide opportunities for innovation (e.g. encouragement to go beyond building code minimum standards).
• Legislation and regulation to support infrastructure adaptation should be forward looking and should not constrain the ability to adapt.
• The planning process should incorporate adaptation, for example by setting thresholds and trigger points for decision-making about investments, for sea-level rise.

Communication requirements
Effective communication to align purpose of adaptation across multiple levels of government, service providers, customers and regulators is essential to establish a good business case for adaptation.

Policy implications
Investment and investment models
Investment models for infrastructure adaptation may include:
• Wait for failure and replace,
• Ongoing repair and incremental improvement,
• Significant transformation.
For some infrastructure types, run to failure is not an option (e.g. transport). Improved maintenance, planning and operational approaches may be less affordable than simply building new. However, once the decision to invest in new infrastructure is made, that is the point at which adaptation for future climate change should usually be incorporated, since retransporting to deal with change is expensive.

The role of insurance
Insurance can prompt or discourage adaptation. It can act as a quarantine adaptation management tool. Planning market
pressure on high risk locations is infrastructure. However following fires or damage, insurance can incentivise adaptation, as it does not encourage improvement of infrastructure, rather funding replacement of like with like.

Retirement
Following extreme events there is often a political inclination to rebuild - to get back to "normal" - yet it is an opportunity to build back better. Grouping mechanisms to encourage "building back better" are in place and approved before an event, including some thought given to funding models, may enable betterment and so improve resilience to climate change.

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References
• OECD 2011. Climate change risk to critical buildings and infrastructure. A supplement for the peer review of national adaptation assessment, Department of Climate Change and Energy Efficiency, Canberra.

Climate proofing Australia’s infrastructure
Infrastructure is a critical asset in Australia. It supports economic activities, provides services to communities, contributes to the quality of life and enhances our lives. Infrastructure is often long-lived, which poses a particular set of challenges with respect to climate change – infrastructure designed today may still be around in times climate-anticipated for fifty or more years in the future.

Key Points
• Agreement and support from multiple levels of government, service providers, customers and regulators to decide that it is prudent and timely to take action (e.g. to adapt), and what action to take.
• Understanding of when incremental actions are sufficient (for example, through upgrading maintenance) and when large-scale investment in new infrastructure is required.
• Exploration of new and funding models to build back better following natural hazards especially by having enabling mechanisms already in place.
• Long-term planning, beyond regulatory or election cycles, and which allows flexibility and innovation in materials, designs, and institutional arrangements.
• Managing uncertainty by considering a range of future scenarios, understanding where system sensitivities lie and seeking to enhance resilience.
• Educating the public to understand the trade-offs between security of supply and cost under the requirements for adaptation and carbon reduction imposed by climate change.

Approach
The policy guidance provided in this brief was developed at a workshop held in Sydney. The workshop was attended by policy makers and managers from within NSW State Government agencies, Geoscience Australia, Sydney Water, Sydney Water Services Association of Australia, Transgrid, Ausgrid, Sydney Airport, Sydney Ports, Optus, RailCorp, Infrastructure Sustainability Council of Australia, Institute of Public Works Engineering Australia, BlueScope Steel, Landlease Construction, private consultants, Ron Cox (University of New South Wales), Daryn McEvoy (RMIT University), Paul Bell (University of Queensland) and NCCARF staff.

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Climate change adaptation and disaster reduction: the need for better management systems for infrastructure, Policy Guidance Brief 7. NCCARF 2012.
**Future effects, impacts and issues**

A unique feature of infrastructure planning is the very long time horizon involved (see Fig 1). Given the uncertainties associated with climate change, it is logical to make the best use of current infrastructure. The potential for losses to existing infrastructure can be great. For example, the estimated costs of coastal erosion and tidal inundation in 2050 are positioned at $5.5 billion in 2030, and $12.7 billion in 2050 (DCCEE, 2011).

Planning and designing infrastructure will require consideration of potential future climate and operating conditions and projected to the end of the infrastructure design life. This may require ongoing reviews of operational and maintenance practices, designs, and materials. The potential to build flood-proof infrastructure is limited only by the start of the life of the climate may mean that the ongoing risk of existing infrastructure is completed, forcing water supply and sewer systems to change. Refurbishing to manage climate impacts is generally costly and is to be avoided if possible. The long life of the built or inefficient infrastructure may mean that any attempted change can be summarised as:

- the risk of financial losses to owners of adapted facilities (loss of revenue, damaged or inefficient assets);
- the risk of scarce financial losses to owners of re-engineered facilities;
- the risk of increased financial losses to owners of re-engineered facilities.

**Adaptation: what this means for the sector**

As shown in Table 1, planning and adapting for climate change is an iterative process and requires changes, adaptation, and climate change planning and assessment. Sydney Water fast-tracked improvements to infrastructure and water supply sources following severe drought in 2000. Table 1: Summary of sector risks, actions and issues in New South Wales organisations.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Key risks</th>
<th>Actions/Issues</th>
<th>Case studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>Storms, blackouts, heatwaves</td>
<td>Planning for future climate change is needed.</td>
<td>Sydney Water fast-tracked improvements to infrastructure and water supply sources following severe drought in 2000.</td>
</tr>
<tr>
<td>Water</td>
<td>Drought, water stress</td>
<td>Alternative supply sources for electricity and water are often proposed as solutions to increasing demand, as ways of managing risks, and hence avoid costly investment in seldom-used generating capacity is one example.</td>
<td>Sydney Water fast-tracked improvements to infrastructure and water supply sources following severe drought in 2000.</td>
</tr>
<tr>
<td>Public transport</td>
<td>Extreme temperatures, floods</td>
<td>Infrastructure can be a considerable burden on society and government.</td>
<td>Table 1: Summary of sector risks, actions and issues in New South Wales organisations.</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>Extreme storms, heat</td>
<td>Major climate-related damage to infrastructure can be a considerable burden on society and government.</td>
<td>Table 1: Summary of sector risks, actions and issues in New South Wales organisations.</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Dust storms, fire</td>
<td>Major climate-related damage to infrastructure can be a considerable burden on society and government.</td>
<td>Table 1: Summary of sector risks, actions and issues in New South Wales organisations.</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Extreme temperatures, floods</td>
<td>Major climate-related damage to infrastructure can be a considerable burden on society and government.</td>
<td>Table 1: Summary of sector risks, actions and issues in New South Wales organisations.</td>
</tr>
</tbody>
</table>

**Adaptation: what this means for managing the sector ... continued**

Utilities. Both drought and flooding mean water supply security, droughts limit water availability. Floods can directly impact infrastructure such as distribution and transmission lines as well as telecommunications infrastructure. High service demand (e.g. electricity during extremely hot weather) can stretch existing capacity to their limits and lead to service interruptions. These costs are high but so can the costs of not adapting. Actions are likely to be ‘low regrettability’, to avoid unnecessary investments in costly infrastructure. For example, if the demand for water is much higher than the demand for electricity, it makes sense to invest in water supply infrastructure first, even if it is cheaper to invest in electricity infrastructure. The decision to invest in water supply infrastructure first may be made in response to climate extremes to support major infrastructure investment (e.g. desalination plant). Innovation and augmentation. Planning for climate change can provide opportunities for innovation in products and services. For example, if water demand is much higher than the demand for electricity, it makes sense to invest in water supply infrastructure first, even if it is cheaper to invest in electricity infrastructure. The decision to invest in water supply infrastructure first may be made in response to climate extremes to support major infrastructure investment (e.g. desalination plant).
Future effects, impacts and issues

Adaptation: what this means for managing the sector... continued

Adaptation: what this means for managing the sector

Table 1: Summary of sector risks, actions and issues in New South Wales organisations.

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<tr>
<th>Sector</th>
<th>Risks</th>
<th>Actions</th>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>Drought, heat stress, storms, floods</td>
<td>Improved irrigation systems, new crop varieties</td>
<td>Decreased yields, increased costs, land degradation</td>
</tr>
<tr>
<td>Energy</td>
<td>Voltage instability, frequency instability</td>
<td>Load shedding, demand side management</td>
<td>System reliability, increased costs</td>
</tr>
<tr>
<td>Water</td>
<td>Water scarcity, water quality issues</td>
<td>Desalination, recycled water</td>
<td>Increased demand, infrastructure costs</td>
</tr>
<tr>
<td>Transport</td>
<td>Extreme weather events, sea level rise</td>
<td>Road and rail upgrades</td>
<td>Increased maintenance, safety concerns</td>
</tr>
<tr>
<td>Communications</td>
<td>Outages due to extreme weather</td>
<td>Battery backup systems, alternative power sources</td>
<td>Service disruptions, increased costs</td>
</tr>
</tbody>
</table>

Adaptation is crucial to managing the sector in the face of climate change. This involves identifying and prioritizing the most significant risks, developing and implementing strategies to address these risks, and monitoring and evaluating the effectiveness of these strategies over time. Key actions include:

1. **Risk Assessment and Prioritization**: Conducting a systematic risk assessment to identify and prioritize climate-related risks.
2. **Planning and Policy Development**: Developing sector-specific adaptation plans and policies that align with broader regional and state plans.
3. **Investment in Infrastructure**: Investing in resilient infrastructure that can withstand future climate impacts.
4. **Institutional and Sectoral Collaboration**: Engaging with stakeholders across sectors and government levels to coordinate efforts.
5. **Monitoring and Evaluation**: Regularly reviewing adaptation strategies to ensure they remain effective and responsive to evolving climate conditions.
6. **Adaptation Research and Innovation**: Fostering research and innovation to develop new adaptation technologies and approaches.

Ultimately, effective adaptation requires a multi-stakeholder approach, where governments, industries, and communities work together to prepare for and mitigate the impacts of climate change.
The climate context

The nation’s infrastructure serves communities, industries and businesses across the vast and geographically diverse continent of Australia. Infrastructure is a key component of the national economic base and everyday life, and planning must take account of changes to climate projected for many years in the future, bearing in mind that uncertainties in climate change projections are large.

Projected changes in Australian climate include (Horton, 2011):
• Annual average warming by 2050 (95% projection) of approximately 1°C across Australia, with warming of 1 to 1.2°C by 2100. This may result in changes to rainfall and temperature patterns.
• Drying in southern areas of Australia, especially in winter, and in southern and eastern areas in spring. Changes in annual rainfall are projected to be pronounced in parts of northern Australia remain highly uncertain.
• Intense rainfall events in most locations will become more extreme, driven by a warmer, wetter atmosphere. This may lead to a flood in a flood events (IPCC, 2007).
• Drying plus increased evaporation means soils will flatten due to over much of southern Australia. Significant rainfall events can create floods in these areas.
• The number of cyclones is not projected to increase, there is expected to be an increase in its intensity brighter seasons and an increase in the number of storms.
• Much of Australia’s infrastructure is located close to the coast, and is vulnerable to sea-level rise. Rising sea level will affect the rail and road and impede evacuation.

Current effects, impacts and issues

Infrastructures, whether publicly or privately funded, require a significant capital outlay and on-going maintenance costs. Wear and tear on infrastructure generally include an element of climate impacts – be it simple weathering (e.g. solar breakdown of paint, saltwater corrosion) or major damages or destruction during extreme events. The rate of observation will depend on design choices, construction processes, building materials, natural environment in which structures are built. Decisions about what and how to build infrastructure will be affected through several decades. Lifetime maintenance costs and operational costs are ongoing challenges for local authorities to manage development, and to provide associated infrastructure.

Coastal protection. Coasts are some of the most highly developed areas of Australia, and are exposed to storms, cyclones and extreme weather events. Coastal flooding and erosion have increased in recent decades and are expected to continue. Planning for climate change impacts is generally considered the most important aspect of coastal flood risk management, as policies and strategies aimed at reducing vulnerability to coastal flooding are essential.

Transport. Rail and road are vulnerable to flooding and sea-level rise. More than 90% of rail and road networks experienced major flooding. Rail and road networks are vulnerable to flooding, with the potential for loss of existing infrastructure. This may include: flooding of rail network in coastal areas; damage to road infrastructure; damage to rail infrastructure; damage to road infrastructure; damage to rail network; damage to rail network; damage to road infrastructure.

Utilities. Natural gas and electricity networks are vulnerable to extreme weather events. Damage to transport infrastructure can disrupt emergency supplies of food and goods as well as the evacuation process. Power cuts may occur during extreme weather events, leading to the potential for loss of data and the risk of loss of infrastructure.

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Cross-sectoral issues

Impacts on one infrastructure sector can have flow-on effects to another, for example, a loss of electricity can halt train operations, and damage rail track signals. The electricity sector is one that is closely interdependent with all other sectors. The energy sector has a central role in ensuring the reliable operation of other systems, and therefore their interdependence is critical for the reliable operation of the economy.

Drivers of change

Safety: Public and employee safety is an important consideration for all sectors, and can be increased through adaptation. On some construction projects, work hours are reduced to limit heat exposure, and workers are provided with shaded areas to take breaks. Health benefits can also be increased through improved ventilation, reduced exposure to chemicals, and improved access to recreation and leisure facilities. Adaptation can also be used to reduce the potential for loss of existing infrastructure. In the case of rail and road infrastructure, for example, this may include: upgrading existing infrastructure; developing new infrastructure; improving maintenance and repair; and closing of mobile phone networks to the general public. These are reserved for emergency services.

Future effects, impacts and issues

A unique feature of infrastructure planning is the very long time horizon involved (see Figure 1). Given the uncertainties associated with climate change projections, it is important to consider the time horizons of infrastructure planning and the potential for loss of existing infrastructure. The potential for loss of existing infrastructure can be significant and should be considered in infrastructure planning. The potential for loss of existing infrastructure can be significant and should be considered in infrastructure planning.

As shown in Table 1, planning and adapting for climate change can provide opportunities for innovation in products and services. The NCCARF Policy Guidance Brief (2013) identifies a range of adaptation strategies that can be used to reduce the potential for loss of existing infrastructure. These strategies include: improving infrastructure maintenance; improving infrastructure design; and reducing the potential for loss of existing infrastructure.

Adaptation: what this means for the sector...

Planning and designing infrastructure will require consideration of potential near-future and operating conditions projected to the end of the infrastructure design life. This may require consideration of the following:
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</thead>
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<tr>
<td>Agriculture</td>
<td>Drought, wind storms</td>
<td>Investment in crop and livestock production, improved irrigation systems</td>
<td>• Risk of financial losses to farmers; • Risk of increased financial losses to farmers; • Risk of increased financial losses to farmers;</td>
</tr>
<tr>
<td>Construction</td>
<td>Seismic activity, coastal erosion</td>
<td>Improved building codes, better materials, better design</td>
<td>• Planning and designing infrastructure should consider the potential for loss of existing infrastructure; • Planning and designing infrastructure should consider the potential for loss of existing infrastructure; • Planning and designing infrastructure should consider the potential for loss of existing infrastructure;</td>
</tr>
<tr>
<td>Energy</td>
<td>Extreme temperatures</td>
<td>Improved insulation, improved cooling systems</td>
<td>• Risk of financial losses to investors; • Risk of increased financial losses to investors; • Risk of increased financial losses to investors;</td>
</tr>
<tr>
<td>Health</td>
<td>Extreme weather events</td>
<td>Improved emergency response systems, improved evacuation systems</td>
<td>• Planning and designing infrastructure should consider the potential for loss of existing infrastructure; • Planning and designing infrastructure should consider the potential for loss of existing infrastructure; • Planning and designing infrastructure should consider the potential for loss of existing infrastructure;</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Coastal surge, sea-level rise</td>
<td>Improved infrastructure design, better materials</td>
<td>• Planning and designing infrastructure should consider the potential for loss of existing infrastructure; • Planning and designing infrastructure should consider the potential for loss of existing infrastructure; • Planning and designing infrastructure should consider the potential for loss of existing infrastructure;</td>
</tr>
<tr>
<td>Public safety, wind storms</td>
<td>Improved building codes, better design</td>
<td>• Planning and designing infrastructure should consider the potential for loss of existing infrastructure; • Planning and designing infrastructure should consider the potential for loss of existing infrastructure; • Planning and designing infrastructure should consider the potential for loss of existing infrastructure;</td>
<td></td>
</tr>
<tr>
<td>Rail and road</td>
<td>Flooding, heat damage (e.g. rail buckling, road cracking, bridge washout)</td>
<td>Improved infrastructure design, better materials</td>
<td>• Planning and designing infrastructure should consider the potential for loss of existing infrastructure; • Planning and designing infrastructure should consider the potential for loss of existing infrastructure; • Planning and designing infrastructure should consider the potential for loss of existing infrastructure;</td>
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<td>Telecommunications</td>
<td>Extreme temperatures</td>
<td>Improved cooling systems, improved design</td>
<td>• Planning and designing infrastructure should consider the potential for loss of existing infrastructure; • Planning and designing infrastructure should consider the potential for loss of existing infrastructure; • Planning and designing infrastructure should consider the potential for loss of existing infrastructure;</td>
</tr>
<tr>
<td>Water</td>
<td>Drought, water scarcity</td>
<td>Improved water management systems, improved storage systems</td>
<td>• Planning and designing infrastructure should consider the potential for loss of existing infrastructure; • Planning and designing infrastructure should consider the potential for loss of existing infrastructure; • Planning and designing infrastructure should consider the potential for loss of existing infrastructure;</td>
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Approach

The role of insurance

Insurance can prompt or discourage adaptation. It can act as a climate-adaptation management tool by placing market pressure on high-risk locations to reduce climate-related risks. However, following losses or damages, insurers can deepen adaptation, as it does not encourage improvement of infrastructure, rather funding replacement of like with like.

Reference

Key Points

Infrastructure is often long-lived, and what is designed today must withstand changes in climate fifty or more years in the future. To ensure design, building, financing and maintenance of infrastructure are all adaptable to future climate change requires:

• Agreement and support from multiple levels of government, service providers, customers and regulators to decide what is prudent and timely to take action (i.e. to adapt), and what action to take.
• Understanding of when incremental actions are sufficient (for example, through upgrading maintenance) and when large-scale investment in new infrastructure is required.
• Experience on how best to choose and build models to build back better following natural hazards, especially by having mechanisms already in place.
• Long-term planning, beyond regulatory or election cycles, and which allows flexibility and innovation in materials, designs, and institutional arrangements.
• Managing uncertainty by considering a range of future scenarios, understanding why system semantics keep evolving to enhance resilience.
• Educating the public to understand the trade-offs between security of supply and cost under the requirements for adaptation and carbon reduction imposed by climate change.

National Climate Change Adaptation Research Facility

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Why climate change?

The unprecedented climate change that has occurred over the past few decades is affecting the way we live, work, travel, and the way we grow our food and generate our energy. Climate change is a global crisis, which poses a severe threat to all our societies and economies. The impacts of climate change are already being felt around the world, and they will be amplified in the future, unless we act now.

What do we need to do?

Managing uncertainty

Uncertain climate change places new and unique challenges on society.

• What will be the impacts or effects of climate change?
• How will we adapt?
• How will our infrastructure be affected by climate change?

To address these questions, we need to develop robust, evidence-based decision-making frameworks that can be applied in a range of contexts, including policy development, investment, and management. This requires integrating climate change adaptation into existing decision-making processes, and developing new decision-making frameworks that can effectively incorporate climate change information and decision-making processes.

References

IPCC 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation A Special Report of Working Group II of the Intergovernmental Panel on Climate Change. (www.ipcc.ch) and IPCC-AR5-WSIP.

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Approach

Climate proofing infrastructure

Infrastructure has a critical role in Australia. It supports economic activities, provides services to communities, contributes to productivity and wellbeing, and enhances our lives. Infrastructure is often long-lived, which poses a particular set of challenges with respect to climate change – infrastructure designed thirty to fifty years ago may not be able to adapt to the changes in climate anticipated for fifty or more years in the future.

Climate proofing Australia’s infrastructure

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• Long-term planning, beyond regulatory or election cycles, and which allows flexibility and innovation in materials, designs, and institutional arrangements.
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Climate change impacts on infrastructure: The past decade has seen us be caught off guard by climate change impacts, which are occurring more rapidly than expected. Many critical infrastructure sectors are unprepared for the impacts of climate change and are not equipped to adapt. The impacts of climate change are changing the way we build and operate infrastructure: infrastructure is sometimes obsolete before it is designed to. As climate change impacts increase, we need to adapt our infrastructure to cope, which is expensive. This risk can be reduced by ensuring that infrastructure is designed to be resilient to climate change and to incorporate climate change adaptation into planning and design at the earliest opportunity.

Approach

The Policy Guidance Brief 6 is concerned with the role of infrastructure management and its role in ensuring that the planning and management of infrastructure is adaptable to climate change. There is a need to ensure that infrastructure can adapt to climate change impacts and that the system is resilient to these impacts. The brief highlights the need for collaboration and engagement with stakeholders, to ensure that infrastructure is designed to be resilient to climate change.

Key Points

- Infrastructure is often long-lived, and what is designed today must withstand changes in climate fifty or more years in the future. To ensure design, building, financing and maintenance of infrastructure are all adapting to climate change requires:
  - Agreement and support from multiple levels of government, service providers, customers and regulators to decide that it is prudent and timely to take action (ie. to adapt), and what action to take.
  - Understanding of when incremental actions are sufficient (for example, through upgrading maintenance), and when large-scale investment in new infrastructure is required.
  - Engagement of infrastructure and building models to build back better following natural hazards, especially by having enabling mechanisms already in place.
  - Long-term planning, beyond regulatory or election cycles, and which allows flexibility and innovation in materials, designs, and institutional arrangements.
  - Managing uncertainty by considering a range of future scenarios, understanding where system sensitivities lie and working to enhance resilience.
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